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PARLIAMENT LIBRARY BUILDING

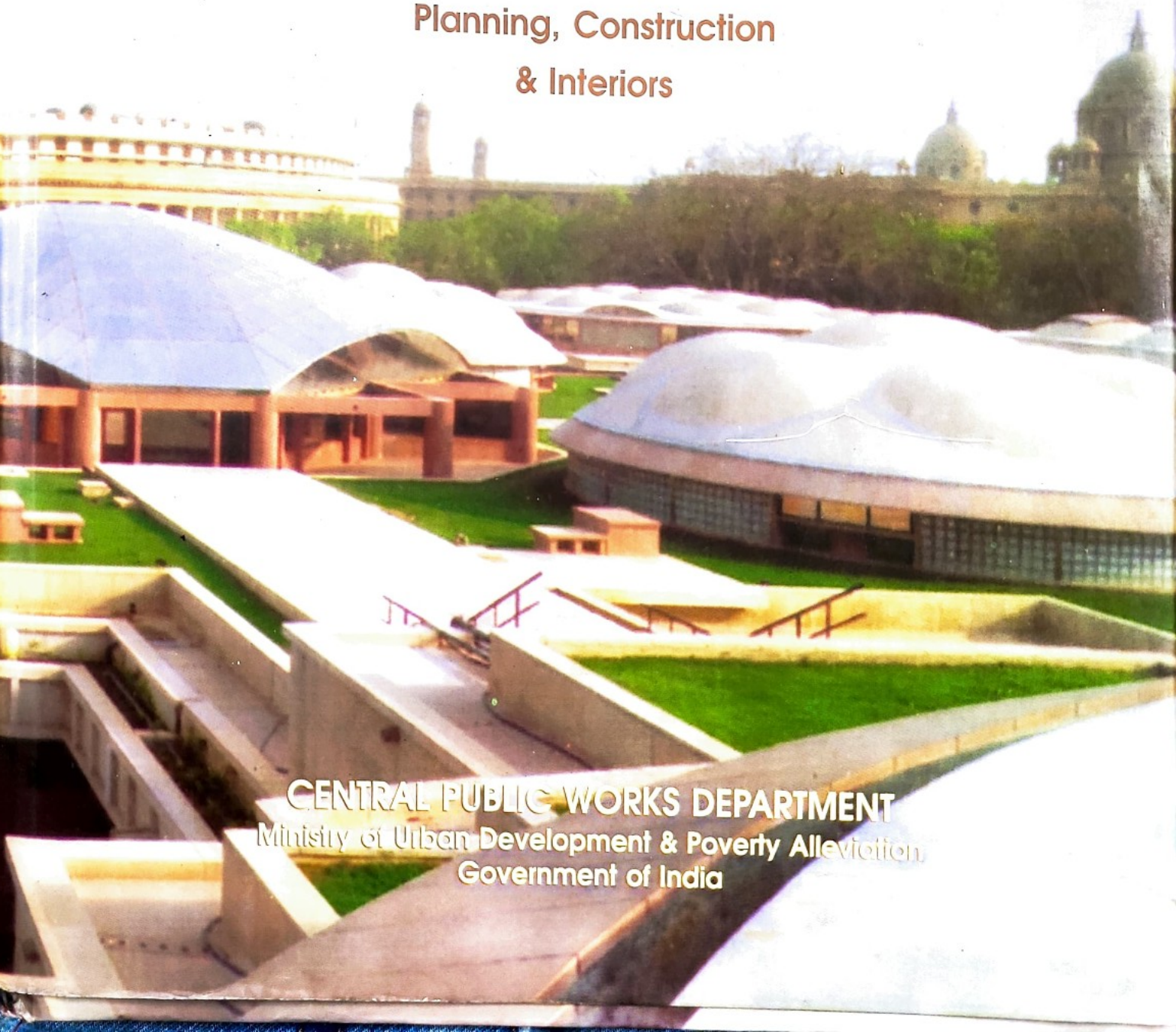
A

DOCUMENTATION

Covering

Planning, Construction

& Interiors



CENTRAL PUBLIC WORKS DEPARTMENT
Ministry of Urban Development & Poverty Alleviation
Government of India



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FOREWORD

The Parliament Library Project is of special significance to CPWD in many ways. It is after a very long time that CPWD got the opportunity to build a mammoth project of this size and grandeur. The Project has helped showcase CPWD's capabilities in adopting innovative and modern techniques in structural design, execution and E&M services.

I have been closely associated with the Project ever since its inception as Chief Engineer (Electrical) till February, 2001 and even thereafter. It has given me immense satisfaction to see our plans and schemes for the building & services taking concrete shape, culminating in the inauguration of the building on May 7, 2002 by the Hon'ble President of India.

I am happy to see the Documentation of the planning, construction & interiors of the Parliament Library Project brought out in the form of a book. If there is one aspect of the working of CPWD which requires improvement, it is in the matter of Presentation. We should make it a habit to record and document (both videographically and in a narrative form) the stages of work as and when the construction progress. I exhort all engineers and architects of CPWD to make Documentation a mandatory activity in all large projects handled by them.

This compilation covers the activities relating to the Civil Engineering part of the work. A companion volume covering Electrical, Electronic & Mechanical services in the Project has already been distributed. Put together these two volumes give a detailed account of the planning, design and construction of the entire building.

This Documentation will help in disseminating information on innovative and uncommon construction techniques to the Engineers & Architects of CPWD. It has been a commendable effort for which the Team deserves appreciation.

J. N. Bhavani Prasad
Director General (Works),
Central Public Works Department

New Delhi
September 23, 2003



PREFACE

It is a matter of great pleasure to me to see this documentation on the construction of Parliament Library Building being brought out. A complementary volume on the provision of Electrical, Electronic & Mechanical services for this building has already been released. These two volumes provide a vivid insight into the process of construction of this complex structure. This documentation is in addition to a video graphic documentation which was released in September, 2002.

It is not everyday that CPWD gets an opportunity to construct monumental buildings of this kind. Therefore, it is imperative to have the experiences of the Team in planning & erecting this building recorded in as much detail as possible. I am happy to see that the chapters cover the entire gamut of planning & construction – starting from the selection of site right up to Interior Decoration & Landscaping. A brief chapter on the maintenance of the building is also thoughtfully added.

The Document describes in great detail, *inter alia*, the work on foundation, domes and the finishing items of superstructure. It is heartening to see that an attempt at applying scientific techniques of Project Management has been made.

The potential of CPWD to produce outstanding works has never been in doubt. Almost all units spread over the country have at one time or the other produced magnificent works in their respective areas of operation. The construction of the Parliament Library Building might attract more attention because of its size and stature, but it essentially under scores the age-old values of CPWD - dedication, quality consciousness and expertise in construction. This documentation, when it reaches the hands of our engineer- officers should serve as a reaffirmation of CPWD's potential.

I congratulate the Project Team of PLP, in having brought out this useful documentation.

(B. Majumdar)
Additional Director General (S&P)
Central Public Works Department

New Delhi
September 20, 2003



REMINISCENCES

CPWD has been in the fore-front of Nation building for close to 150 years now. The new Parliament Library Building is modular, utilitarian and centrally air-conditioned with provision for all the facilities of a modern Library. Construction of this prestigious building by CPWD is yet another feather in its Cap.

It was my proud privilege to be the first Chief Engineer & Project Manager of this Project from November, 1993 to December, 1996 during which time after the commencement of work in April, 1994, the Foundation work was completed and we made good headway in the planning of the Superstructure and its award. It was a unique experience to be involved in the execution of "rock anchored diaphragm wall and raft system of foundation with curtain grouting" which was the first of its kind in the country.

The foundation, about 4 metre below water table, involved 2 lakh cubic metre of excavation and required extensive water proofing treatment. Many innovative methods, both manual and mechanical, including use of Krupp Hydraulic Hammer and Hydraulic Rock Splitter, were adopted for the excavation of about 1 lakh cubic metre of rock, use of explosives being totally prohibited.

It was a matter of immense satisfaction when the Project Team was awarded the ISO –9002 certification for Quality System in Construction Services in September, 1996. Indeed it was for the first time that such a certificate was issued by BIS to a Civil Engineering Organization in the Country. This was another "first" for CPWD. It goes to the credit of the Project Team that the Manuals and various Documents required to establish, implement and maintain the Quality System under ISO – 9002 were all prepared in-house without involving any external consultant.

Again from mid 2001, I was associated with the Project as Additional Director General, when it was in its crucial phases of finishing. The assembling and erection of Stainless Steel and Carbon Steel structure for Domes of varying size and shape, is again a testimony that CPWD is second to none in planning and execution of innovative and complex structural systems. It is also gratifying that the BIS

extended the ISO 9002 certification to the Project Team which is an acknowledgement that CPWD continued to implement the certified Quality System till the completion of the Project.

Consistent with the uniqueness of the Project, the Team has now brought out a narrative documentation of the Project as a whole. The fruits of first hand experience of constructing such a unique structure would be lost to posterity if such documentation is not done. The document covers important planning and constructional aspects and highlights technical details not commonly encountered. This is an excellent effort and the Team deserves all praise for bringing out this useful document.

Erection of another land mark in Lutyens' Delhi in the form of Parliament Library Building is the outcome of the best efforts put in by each and every member of the Project Team, Architect and Structural Engineers and close coordination amongst various agencies. I most heartily thank and congratulate each one of them and wish them all the best in their future endeavours too.

New Delhi
September 20, 2003

(Jag Mohan Lal)
Former Additional Director General
Central Public Works Department

ACKNOWLEDGEMENT

Now that this document is ready, looking back. I feel that the Project was easier done than said ! The task of putting down in writing the efforts of thousands of workers toiling for nearly 8 years to complete this building, was indeed stupendous. But with their characteristic unflagging energy & enthusiasm the PLP team has done it again - this time in black & white (and colour too !).

Shri A.K. Garg, Superintending Engineer has lead from the front as usual, ably assisted by his colleague Shri R.K.Soni, Supeintending Engineer and his team-in particular S/Shri R.K. Shami, Jitendra Kumar & Sanjay Gupta, Executive Engineers, S/Shri O.N. Awasthi, Madan Pal, R.K. Rastogi, S.P. Bajpai & Hari Om Sharma, Assistant Engineers, S/Shri S.P. Jain, B.C. Kandpal & Sharan Singh, Junior Engineers, Shri Rajesh Kumar, Draughtsman and Shri Sudarshan Lal Wadhwa, Stenographer.

The efforts of S/Shri Madan Pal & R.K. Rastogi, Assistant Engineers and Shri S.P. Jain, Junior Engineer needs special mention for their commendable work in preparation of sketches, designing & printing of this book. Shri L.R. Raturi has magic in his fingers and wore out his key board in composing this manuscript. I gratefully acknowledge the efforts of all these officers & staff.

The valuable suggestions given by Shri J.N.Bhavani Prasad, DG(W), Shri B. Majumdar, ADG, Shri Krishan Kumar, DG(Retired) and Shri Jag Mohan Lal, ADG (Retired) has helped in improving the document. If the reader finds the document informative and interesting the credit goes to Shri A.K. Garg, Shri R.K. Soni and all other officers & staff who have helped in compiling this document.

K. Srinivasan
Chief Engineer & Project Manager
Parliament Library Project
Central Public Works Department

New Delhi
September 23, 2003

"Cheshire Puss," she began, rather timidly,.....
"Would you tell me, please, which way I ought to go from here?"

"That depends a good deal on where you want to get to," said the Cat.

"I don't much care where....." said Alice.

"Then it doesn't matter which way you go," said the Cat.

".....so long as I get *somewhere,"* Alice added as an explanation.

"Oh, you're sure to do that," said the Cat, "if you only walk long enough."

From – Alice in Wonderland

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PARLIAMENT LIBRARY BUILDING – Why & How

1.0 BACKGROUND

To run the largest democracy of the world efficiently, the Parliamentarians need to deliberate, discuss and take decisions on myriad vital issues for which they must have access to truthful, non-partisan, authoritative and full information. Till the year 1921 there was no separate Library as such for members of the Indian Legislature. Only a small collection of publications comprising mainly Departmental reports, proceedings of Legislatures, statues, etc. used to be maintained without any proper classification. Books and other important publications, when required by members, were obtained on loan from the Libraries of the then Legislative Department and the Imperial Secretariat. Inadequacies inherent in such an arrangement came to be realized over the years and a small Library was, for the first time, established in 1921 in the then Central Legislative Assembly. This Library continued to serve members on a very modest scale for a number of years.

It was only after the country achieved Independence in 1947 and the Constituent Assembly commenced the work of drafting a new Constitution for free India that the demands on the Library started multiplying. Too much dependence of members on governmental sources of information for policy-making as well as evaluation of policy, or even for critical appraisal of any governmental activity, was felt to be rather unsatisfactory. An independent and comprehensive Library service was, therefore, envisioned not merely as a repository of books, legislative debates and parliamentary papers, but for providing an up-to-date and objective store-house of knowledge on which members could draw upon.

The year 1950, when India became a Sovereign, Democratic Republic, saw the beginning of a systematic expansion of Parliament Library's collections, both quantitatively and qualitatively. With the current information explosion and the steadily growing collection of publications, the library was experiencing a serious shortage of stacking space to accommodate the expanding information service and the latest library management techniques. For want of adequate space the publications were being stored in different buildings like the Parliament House including its corridors, Parliament House Annexe, 36 Gurudwara Rakab Ganj Road, Vittal Bhai Patel House and 23, Mahadev Road buildings. Obviously, this arrangement was inconvenient, cumbersome and was not conducive to the modernization of the Library. Therefore the need for a centralized and modern Parliament Library Building was felt.

2.0 SITE SELECTION

2.1 Proposal No. 1 – At Plot No. 114

The proposal for construction of the new Parliament Library building envisaged locating it on Plot No.114 between the existing Parliament House Annexe Building and the Parliament Street for which requisition was received on August 21, 1971. The building was designed as nine storeyed structure including two basements with total plinth area

of 12281sqm. The A/A & E/S for the project was accorded for Rs.1,71,48,195/- by the Lok Sabha Secretariat on August 30, 1972. However, due to a ban on new construction at that time, the building work could not be started. Subsequently due to the special nature and importance of the scheme, Prime Minister's Approval for the construction of library building was communicated on September 26, 1974 with the condition that the plans should be approved by the Delhi Urban Arts Commission (DUAC).

2.2 Proposal No. 2 – At Plot No. 115

During a subsequent review, however, the Hon'ble Speaker Lok Sabha desired that the library building should be located on Plot No.115, next to the Parliament House in the same campus so that it is conveniently approachable from the Parliament House. The building planned was a four storeyed structure (Two basements + Two storeys above ground) with total plinth area of 19827 sqm. The cost of the proposed library building was estimated at Rs. 4,71,28,147/- and preliminary estimate was sent to the Lok Sabha Secretariat in August, 1977.

In the Zonal plan of the area, Plot No.115 was earmarked as "OPEN AND GREEN". The proposal for change of land-use from "Green" to "Government Offices" was therefore put up to the Government. The ministry approached DUAC on August 5, 1977 and approval of DUAC was conveyed on August 23, 1978, but Town & Country Planning Organisation (TCPO) & Delhi Development Authority (DDA) did not agree for change of land use. Subsequently DUAC Chairman along with Members also visited the Plot No.115 on March 13, 1980 and they felt that Plot No.115 be kept as "OPEN AND GREEN" as proposed in Zonal Plan. The specialized Advisory Group for Central Vista and Central Secretariat Complex in its meeting held on July 4, 1980 also opined that Plot No.115, should be kept as "OPEN & GREEN". However, General Purposes Committee of the Parliament at its meeting held on December 22, 1980, recommended that Parliament Library Building should be constructed on Plot No. 115. The design of Parliament Library Building on Plot No. 115 at conceptual stage for 2½ storey above ground and 1½ storey below ground was approved subsequently by DUAC in June 1981.

Since the accommodation provided did not meet the requirements of Parliament Library, the Lok Sabha Secretariat desired to construct a 7 storeyed building which was rejected by DUAC at conceptual stage. DDA also rejected change of land use from "green" to "government offices".

2.3 Proposal No. 3 – At Plot No. 114

The proposal came under review again when the Hon'ble Vice President of India visited plot No. 114 on August 27, 1983 and suggested to have the Library Building on Plot No. 114 instead of Plot No. 115.

A specialised group of Central Vista & Central Secretariat Complex Committee, during meetings on November 11, 1983 and November 25, 1983 also felt that it is not advisable to construct a competing structure close to the Parliament House and it was decided to locate the Parliament Library building on Plot No.114. The General Purpose

Committee in a meeting on March 9, 1984 agreed that the Parliament Library Building may be constructed on Plot No. 114 with a provision of suitable motorable sub-way connecting the proposed building with the Parliament House.

The conceptual drawings for Library Building on Plot No. 114 were submitted to DUAC on May 22, 1984. The plans & models were discussed with DUAC on March 16, 1985 and DUAC suggested that total height of proposed building may be restricted to 85 feet (25.5m). Library Committee also approved the proposal and named the building as "SANSADIYA GYANPEETH". Models of the building were prepared and shown to the then Hon'ble Speaker and Works & Housing Minister on May 14, 1985 and one of them was tentatively approved for submission to DUAC with modifications. It was suggested that since the requirements of Lok Sabha Secretariat are very huge (approximately 30000sqm) a portion of the building shall have to be taken higher than the existing building (may be upto 130 feet) instead of 85 feet for which relaxation in height should be given by DUAC.

The building was proposed to be with two basements plus eight floors for the main wing and fourteen floors for the stack wing with plinth area of 36,570sqm. The A/A & E/S was communicated by Lok Sabha Secretariat on July 29, 1987 for an amount of Rs.26.05 crores. Foundation stone of the proposed building was laid by Shri Rajiv Gandhi, Hon'ble Prime Minister on August 15, 1987 at Plot No.114.



Foundation Stone being laid by Hon'ble Prime Minister, Shri Rajiv Gandhi

The modified conceptual drawings were sent to DUAC vide letter dated December 7, 1987 for construction of Parliament Library Building at Plot No. 114 and were approved by DUAC vide letter dated January 15, 1988, with some modifications.

2.4 Proposal No. 4 (and final)– At Plot No. 115

A Monitoring Committee headed by Secretary, MOUD was set up later on to go into the various formalities. The Committee held its meetings starting from October 1987 to July 1988. Meanwhile, new guidelines on Building By-laws came into force restricting ground coverage to 25%, as against 30% allowed previously. This necessitated the move for relaxation of guideline so as to accommodate the building with plinth area as planned.

At this stage, the Project came under the scrutiny of the highest Executive of the country viz. the Hon'ble Prime Minister himself. A meeting was held under the Chairmanship of Hon'ble Prime Minister of India on August 31, 1988. The model & drawings of the Parliament Library Building for construction of building on plot No.114 were discussed. New restrictions imposed regarding land use were also discussed. Hon'ble Prime Minister observed that the Parliament Library, besides being functional, should be a monumental building like the Parliament House. All the three buildings in the Parliament Estate should be viewed as a whole and appropriate landscaping done in the entire Complex with the help of experts in the area. There could be a happy blend of the old and new architecture as was done at the Louvre Museum, Paris. The following decisions were taken as per minutes issued on September 2, 1988.

a) The entire Parliament Complex including the Parliament House, Parliament House Annexe, Plot No. 118 and 115 should be treated as one campus enclosed by one boundary wall going around.

b) The Parliament Library Building be constructed on Plot No.115 between the Parliament House and Parliament House Annexe , instead of Plot No.114 as planned.

c) As the very first step, the portion of the Talkatora Road intervening Parliament House and Parliament House Annexe be closed and the area integrated in the landscape of Parliament Complex.

d) Some eminent Delhi based architects about 6 or so may be selected and invited to prepare the new model for the Parliament Library Building to come up on Plot No. 115 , on a competitive basis.

2.5 Project Impementation

Thus, the stage was set for the work to commence in right earnest. The notification to be published in the Gazette of India for change of land use was issued by MOUD on March 30, 1989. Plot No.115 at Talkatora Road measuring 9.86 acres was allotted for Parliament Library Building by MOUD and L&DO on June 10, 1993. The approval of Hon'ble Lt. Governor of Delhi was accorded for cutting/removal of 43 trees from Plot



Land before start of work – Plot No. 115



Bhoomi Poojan by Shri Shivraj V.Patil, Hon'ble Speaker

No.115 for construction of Parliament Library Building on August 12, 1993. Architectural Consultants and agencies for executing the work were appointed in quick time. Bhoomi Pujan for Construction of Parliament Library Building was done on April 17, 1994 by Shri Shivraj V. Patil, Hon'ble Speaker, Lok Sabha.

The efforts of all these very Important Personages and the various agencies involved in conceiving, planning and executing this mammoth Project, happily culminated on May 7, 2002 in the inauguration of the Building by the Hon'ble President of India Shri K.R. Narayanan in the presence of Hon'ble Vice President Shri Krishan Kant, Hon'ble Prime Minister Shri Atal Bihari Vajpayee, Shri P.M. Sayeed, Hon'ble Dy. Speaker, Lok Sabha (Discharging the functions of Speaker), Hon'ble Leader of Opposition Smt. Sonia Gandhi, Shri Pramod Mahajan, Hon'ble Minister of Parliamentary Affairs & Shri Ananth Kumar, Hon'ble Minister of Urban Development & Poverty Alleviation.

The following pages report how exactly this was achieved.



Lighting of Lamp for Inauguration of Building by Shri K.R. Narayanan, Hon'ble President of India

CONSULTANTS AND PROJECT TEAM

1.0 CONSULTANT ARCHITECT FOR THE BUILDING

1.1 Panel of Consultant Architects

As per the decision taken by the Hon'ble Prime Minister on August 31, 1988 for selection of an eminent Delhi based Architect as Consultant for Parliament Library Building, the name of six Architects were proposed by the Director General (Works), CPWD vide U.O. Note dated September 7,1988 for limited Architectural competition for the Parliament Library Building. This shortlist was readily available because the same set of Architects were earlier selected for designing the permanent residence of Hon'ble Prime Minister in 1985.

The approval to the names was accorded by Hon'ble Minister of Urban Development on September 22,1988. The letter seeking consent for participation in the competition for the Library building was sent to the Consultants on September 24, 1988. Architects M/s Kanvinde Rai & Chowdhury and Shri Satish Gujral opted out of the competition and names of M/s Satnam Namita & Associates, M/s Kabil Associates and M/s CP Kukreja & Associates Pvt. Ltd. were added to the list. Following seven Delhi based Architects were finally selected for the Architectural competition.

a) M/s Kabil Associates

b) M/s C.P. Kukreja & Associates Private Limited

c) M/s Sharat Das & Associates Private Limited

d) M/s Kothari & Associats

e) M/s Satnam Namita & Associates

f) M/s Raj Rewal Associates

g) M/s Ram Sharma & Associates

1.2 Board of Assessors

It was decided that the entries received in the competition will be assessed by a Board of Assessors with Hon'ble Speaker, Lok Sabha as the Chairman.The Board of Assessors for assessing the entries received through the architectural competition was constituted by Ministry of Urban Development on March 23, 1989.

1.3 Assessment of Entries

A brief indicating the conditions & instructions, Project information and also functional requirements to be incorporated in the conceptual design was sent to all Architects participating on January 16, 1989. Queries raised by various consultants upto January 31, 1989 were replied on February 10, 1989. The entries from all seven consultants were received on September 11, 1989.

The Board of Assessors during a meeting on February 2, 1990 selected entry 'F' as first best entry & 'G' as second best entry as per minutes issued on March 9, 1990. The first best entry 'F' was of M/s Raj Rewal Associates & second best entry 'G' was of M/s Ram Sharma & Associates. The Hon'ble Speaker, Lok Sabha approved the selection of M/s Raj Rewal Associates as Architect Consultant for the Sansadiya Gyanpeeth which was communicated by Joint Secretary, Lok Sabha Secretariat on May 14, 1990.

1.4 Draft Agreement

The Secretary General, Lok Sabha Secretariat during meeting on May 17, 1990 decided that draft agreement for entering into contract with M/s Raj Rewal Associates should be prepared. The draft was prepared and sent on July 9, 1990 for approval of the Lok Sabha Secretariat. The draft agreement was vetted by Min. of Law & Justice and was received back through Director (W&S) from Lok Sabha Secretariat on July 23, 1990 with some observations. These observations were attended to and a modified draft agreement was sent to Lok Sabha Secretariat on August 16, 1990.

The request for constitution of a Committee to decide upon the scope of work & negotiating the fee was sent to Additional Secretary, Lok Sabha Secretariat by Chief Engineer (NDZ-I) on July 30, 1990. Hon'ble Speaker held a meeting on November 15, 1991 to consider immediate steps towards construction of Parliament Library Building and for constitution of High Powered Monitoring Committee and decided as below.

a) Hon'ble Minister of Urban Development would act as Chairperson of a High Powered Committee which may be named as the High Powered Monitoring Committee;

b) Constitution of Negotiating Team for finalising the terms of contract with M/s Raj Rewal Associates would be decided by the High Powered Monitoring Committee.

1.5 High Powered Monitoring Committee

High Powered Monitoring Committee was set up by Ministry of Urban Development on November 25, 1991. Smt. Sheila Kaul, Minister of Urban Development being chairperson of the Committee.

1.6 Negotiation Committee

The negotiation committee was set up by MOUD on November 25, 1991. Secretary, M/o Urban Development being Chairman of the Committee.

1.7 Approval of Consultant Architect

The draft for agreement to be drawn with Consultant Architect was decided by negotiation committee on January 13, 1992 during its third meeting. Based on recommendations of negotiation committee, High Powered Monitoring Committee during meeting on April 2, 1992 approved the terms and conditions of contract and fee to be paid to Consultant Architect subject to concurrence by Hon'ble Finance Minister and Minister of State for Parliamentary Affairs and Law & Justice (since they could not be present during the meeting). The approval for signing the agreement with

Consultant Architect was conveyed by M/o Urban Development on July 6, 1992 and agreement was signed on July 10, 1992 between Executive Engineer , Construction Division No. VI and Consultant Architect.

1.8 Fee Payable

As per terms of the agreement, the Architect was to be paid a fee at the rate of three percent (3%) on the accepted tendered cost of the civil works including structural works and landscape works plus any other items of works additionally entrusted to him like fixtures, library stacks and interior of all public areas (Subsequently the Architect was indeed assigned additional work of planning the interiors and furniture for the building).

2.0 STRUCTURAL DESIGN CONSULTANT FOR DOMES

The structural system adopted for construction of various Domes for Parliament Library Building is very intricate & have been used for the first time in India. Hence it was felt necessary that proof checking by a world class firm who had done such unique structures in various parts of the world was required. The CPWD officers visited London & Paris and held discussions with reputed structural consultants and visited recent constructions done in steel in London & Paris. The team identified following structural consultants.

a) M/s Antony Hunt Associates Ltd. at London.

b) M/s Ove Arup & Partners at London.

c) M/s RFR at Paris

d) M/s Group Arcora at Paris

e) M/s Syntec Ingenieric at Paris

A set of architectural & structural drawings were supplied to the consultants. The sequence of development, analysis techniques, Preliminary design as well as the scope of work expected from the consultants were also explained to them. The team gave their recommendations on. February 27, 1998 that from the consultants with whom discussions were held the first three i.e.M/s Antony Hunt Associates , M/s Ove Arup & Partners & M/s RFR seemed to possess the best expertise. In addition, all the three firms have Engineer at senior level who could communicate in English fluently, hence it was proposed that further interaction might be carried out from these three firms.

The proposal was then sent to Ministry on March 20, 1998, Ministry finally approved the proposal to engage the foreign consultant on November 19, 1998. Notice Inviting Offers for professional services in the design of Domes was sent to these three firms on January 21, 1999. All the three firms quoted and M/s RFR, Paris quoted the lowest rate. The offer of M/s RFR was approved by Director General (Works) and acceptance communicated to M/s RFR, Paris on June 5, 1999.

3.0 CONSULTANT FOR KITCHEN EQUIPMENTS

Parliament Library Building has provision of Kitchen & Kitchenettes with Canteen facility for Staff & VIPs. The kitchen/canteen equipments & layout needed to be designed by a specialist in the field. The Lok Sabha Secretariat on July 10, 1996 approved the appointment of Indian Tourism Development Corporation (ITDC) as Consultant to design Kitchen-related items. After detailed discussions with ITDC & Lok Sabha Secretariat the scope of the technical consultancy services in the matter of kitchen management for Parliament Library Building was identified and the offer given by ITDC on July 16, 1997 was approved by Chief Engineer and Project Manager on August 16, 1997. The total fee payable was Rs. 13.5 lacs.

4.0 PROJECT TEAM

The proposal for sanction of Project Team headed by Additional Director General for pre-construction stage for a period of six months and for construction stage for a period of 30 months was sent by Director General (Works) to Additional Secretary (W) on June 8, 1990 with target for completion of building within 30 months. High Powered Monitoring Committee during first meeting on November 26, 1991 decided that proposal for creation of Project Team may be scrutinized first by Sub-committee consisting of Secretary (Expenditure) or his nominee, Additional Secretary (Works), MOUD and Director General (Works), CPWD before decision is taken.

High Powered Monitoring Committee during meeting on April 2, 1992 as per recommendation of sub-committee agreed for sanction of 45 posts of Project Team for pre-construction stage subject to consent of Hon'ble Finance Minister and Minister of State for Parliamentary Affairs and Law & Justice (since they could not be present during the meeting).

However, keeping in view the need for achieving economy, MOUD considered the matter and proposed that 29 posts which are to be filled by promotion may be sanctioned and balance 16 posts (requiring direct recruitment) may be provided by the CPWD from within the overall sanctioned strength. Thus a Project Team with 29 posts for planning/ construction was sanctioned by MOUD on September 15, 1993. Balance 16 posts were proposed to be provided from existing strength of CPWD.

However, depending on the actual requirement arising from time to time, additional posts were inducted into the Team (and a few posts deducted too). Thus, in addition to 29 posts as above, 5 posts were created for Parliament Library Project after cadre review from cadre strength; 2 posts sanctioned for Parliament Library Project i.e. Senior architect & Architect were diverted to other units; and 43 posts from other units were diverted to Parliament Library Project subsequently by Director General (Works), making a total strength of 75 posts. The organizational Chart of the Project Team is given as per Fig. 2.1.

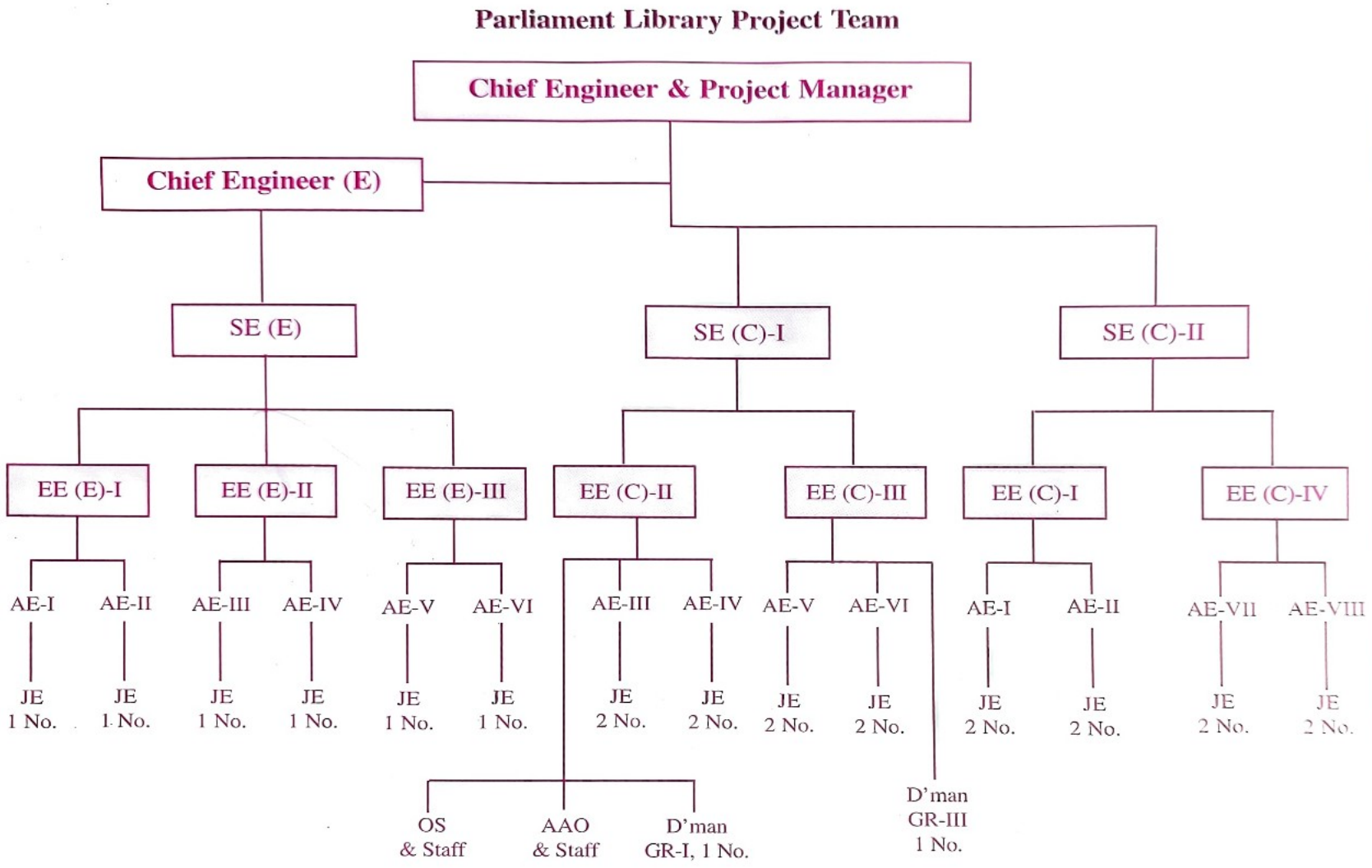


Fig 2.1 : Organisational Chart



Project Team , CPWD (May,2002)

BUILDING PLANS

1.0 PLANS – COMPETITION STAGE

At the competition stage the building was conceived by Architect with three basements and two floors above ground. The areas in the building were demarcated for serving different functions and so the building was divided into the following blocks named after the functional uses to which these pertain :

a) Library Block

b) BPST (Bureau of Parliamentary Studies & Training) Block

c) VIP Block

d) Auditorium Block.

e) Museum Block.

f) Services Block (housing services like A/C Plant room, Sub-station, Canteen etc.)

g) Hall of National Achievement.

h) MP's Reading Block.

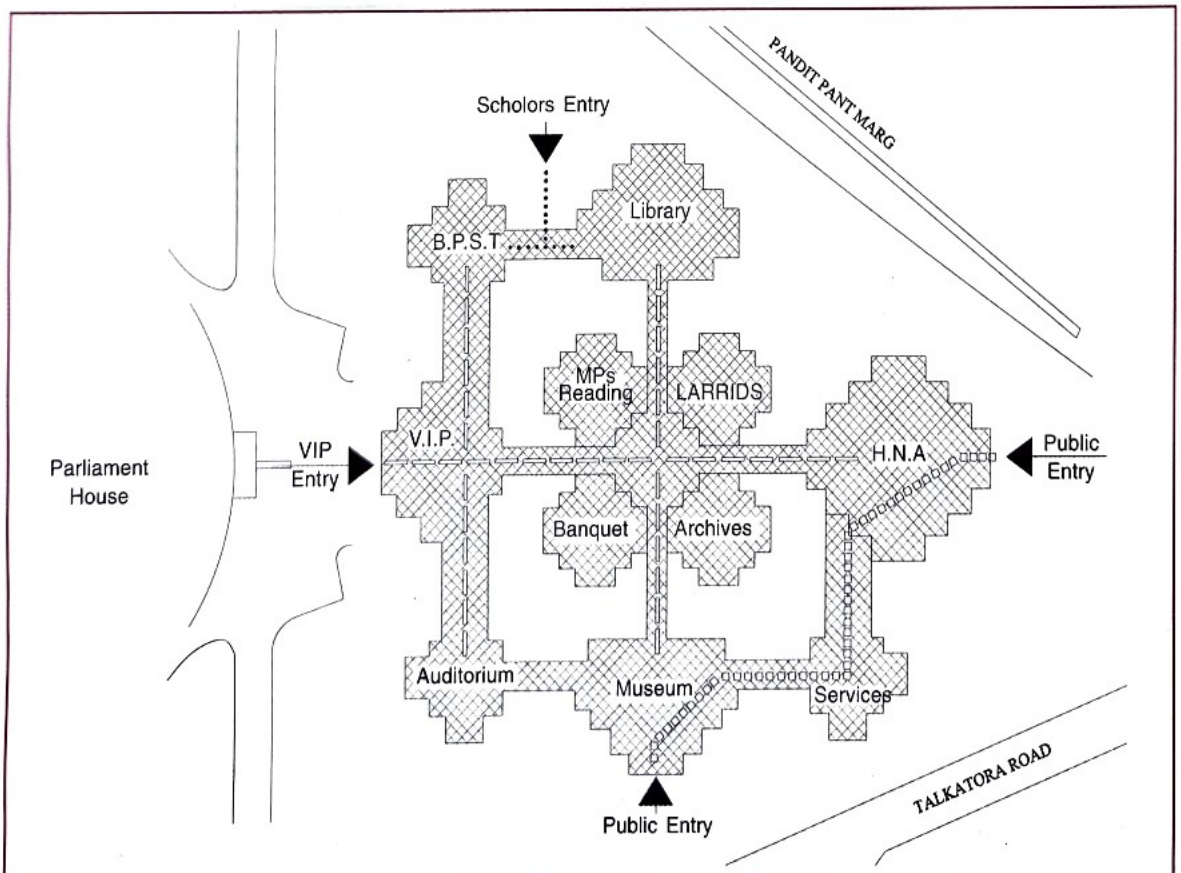


Fig. 3.1 Functional Zones Demarcation – Competition Stage

i) LARRDIS (Library Administration, Research, Reference, Documentation & Information Services).

j) Archives Block

k) Banquet & Dining Block.

l) Parking

2.0 PLANS- REVIEW BY VVIP

The following suggestions were made during various meetings of Library Committee & VVIPs starting from June 1990 to August 1992 keeping functional requirements in view.

a) The capacity of Auditorium was first increased from 200 to 500 and subsequently it was felt that Auditorium with a seating capacity of 500 will be inadequate and Hon'ble Prime Minister suggested that it should have a seating capacity of 1100 persons.

b) The main gate of the Library Building facing Prime Minister's Gate of the Parliament House should either be shifted or earmarked as an exclusive VVIP Gate.

c) As far as possible, the new building should not have sharp corners and should be round in shape in order to maintain harmony with existing Parliament House Building.

d) The roof of the central structure should be circular in shape instead of the angular design and unbreakable transparent glass should be used to allow natural light.

e) Auditorium must have a permanent screen and a well equipped projection room for screening of films.

f) Requirement of security should be met by suitably designing the building.

g) As the building proposed is to have basements, proper care for preventing dampness has to be taken.

h) The building should have all the modern facilities like micro filming, reprographic services, documentation & Press clipping service, Computer Centre, and also modern Satellite communication link with major libraries of the World.

i) There is no separate entry for VIPs, who are to occupy the dais in the Auditorium, hence a separate entry should be provided for VVIP's.

j) That no space should be obliterated by filling up with earth etc., and every space which can possibly be made available should be constructed.

k) It was decided that since proper maintenance of carpets is a difficult proposition, the Architect should consider, if some other kind of flooring could be provided, e.g. marble, Kota Stone, tiles etc.

l) The possibility of providing sliding doors and windows should be explored instead of traditional openable doors and windows keeping in view the climatic conditions in Delhi, where one expects a lot of dust.

m) The library building would have the latest facilities for storage and information retrieval systems. It was decided that help of National Informatics Centre would be obtained. For allied facilities like direct linkage of Parliament Library Building with the Libraries all over the world (and particularly to the UN Library) provision of main frame computer system with possible terminals at convenient points should be made available.

n) The facilities of Parliament Library should be made available to the researchers only through terminal in Parliament House Annexe. It will, however, not be possible to allow entry of general public to the Library.

o) The area marked for Museum should be converted into Computer/Electronic Room for storage of Audio/Video Cassettes for documentation/retrieval system.

3.0 PLANS APPROVAL – LOK SABHA SECRETARIAT

The modified preliminary Architectural Drawings were submitted by Architect on September 8, 1992. These drawings incorporated suggestions thrown up in the various meetings to the extent possible.

In the proposed architectural plan only the Central Core Block (with usable floor area of 2600sqm) was provided in the third basement, However, there were technical as well as practical problems in constructing this small area in the third basement. The Architect was therefore persuaded to give up the idea of having a third basement.

The Consulting Architect was otherwise able to accommodate the usable area provided in third basement at the upper floors. The revised drawings with following modifications were sent to Lok Sabha Secretariat on January 28, 1993.

a) The area requirement as seen in totality was accommodated by the Consulting Architect even without providing 3rd basement. Hence 3rd basement was deleted.

b) In view of increased area of Auditorium, Hall of National Achievements was omitted.

c) Keeping in view the area requirement of audio-video Library, the area meant for Museum was reduced.

The Lok Sabha Secretariat vide letter dated February 1, 1993 informed that drawings seem to be broadly in order and may be submitted to NDMC for further necessary action. Shri Shivraj V. Patil, Hon'ble Speaker, Lok Sabha during a meeting on February 17, 1993 agreed that CPWD may go ahead with the finalisation of plans with provision for two basements only. The drawings as finally approved by Lok Sabha Secretariat had the following provisions.

i. Library Block

ii. BPST (Bureau of Parliamentary Studies & Training) Block.

iii. VIP Block.

iv. Audio-Visual (AV) Block

v. Audio-Visual Museum (AVM) Block.

vi. Services Block (housing services like A/C Plant Room, Sub-station, Canteen etc.)

vii. Auditorium Block with seating capacity of approximately 1100 persons (800 persons at ground floor and 300 persons at Balcony).

viii. MP's Reading Block.

ix. LARRDIS (Library Administration, Research, Reference, Documentation & Information Services) in two blocks.

x. Banquet Hall &Committee Rooms Block.

xi. Parking in three levels.

4.0 CONSTRUCTION PLANS APPROVAL-LOCAL BODIES

Construction Plans were submitted to NDMC for approval vide scheme No.1538 dated February 24, 1993 and were rejected by NDMC vide letter dated April 7, 1993. Secretary, Urban Development called a meeting on May 7, 1993 of representatives from Ministry, DUAC, CPWD, DDA, NDMC, Land & Development Office and Consulting Architect to discuss the matter connected with approval of plans by various local bodies. Most of the issues were cleared in the meeting and it was decided as per minutes issued vide letter dated May 18, 1993 that necessary approval would be coneyed by all concerned.

4.1 Approval from Central Vista Committee

Plans were sent to Central Vista Committee by NDMC on April 21, 1993. The plans were approved with some observations by specialized Advisory Group for Central Vista and Central Secretariat Complex during meeting held on May 12, 1993.

4.2 Approval of Delhi Fire Service

Delhi Fire Service gave the approval with certain conditions vide letter dated June 4, 1993.

4.3 Approval of Delhi Urban Arts Commission

The plans were deemed to be approved by Delhi Urban Arts Commission as per minutes issued vide letter dated May 18, 1993 reproduced below:

"Regarding approval of DUAC it was mentioned by the Chairman that as the proposal is based on the architectural competition with which DUAC was also

associated, it could be assumed that the plans have the approval of the commission."

4.4 Approval of New Delhi Municipal Corporation

The building plans were approved by NDMC on July 13, 1993 subject to compliance of following observations within 60 days.

a) Receipt of approval from D.D.A. regarding proposed ground coverage and extended basement.

b) Corrections in plans w.r.t. area chart .

c) Strict adherance to the observations of Central Vista Committee given on May 12, 1993.

4.5 Approval of Delhi Development Authority

The approval for relaxation of various norms as below was received from DDA on August 13, 1993.

a) Permissible ground coverage from 25% to 34%

b) Setback for basements to 3m, in place of 9m towards Talkatora Road.

c) Having 3 basements instead of 1 and built up area in basement (other than used for parking and services) is to be counted in FAR. Though relaxation was received for three basements, main building with two basements and underground parking in three levels was constructed.

4.6 Final Approval by NDMC

The final approval of plans was received from NDMC vide letter dated September 2, 1993.

4.7 Revised approvals

The plans were again submitted for revalidation vide scheme No.3046 dated June 11, 1999 and approved vide order dated August 9, 1999 as communicated vide letter dated January 3, 2000 with validity upto August 8, 2002.

5.0 COMPLETION PLANS & COMPLETION CERTIFICATE- LOCAL BODIES

The completion plans were submitted to NDMC on April 24, 2002. The provisional completion certificate was issued by NDMC on May 24, 2002 subject to compliance of some observations.

5.1 Approval of Chief Engineer (E) NDMC

Chief Engineer (Elect), NDMC has issued "No Objection Certificate" for issue of completion certificate by NDMC on July 15, 2002.

5.2 Approval of Delhi Urban Art Commission

The completion plans were forwarded by NDMC to DUAC. The proposal was

considered by DUAC during meeting on July 22, 2002 and commission decided to make a site visit to the complex. The site was visited by members of the commission on July 25, 2002 and the proposal was again considered by the commission during meeting on August 6, 2002 and following decision was communicated as per letter dated August 28, 2002 of DUAC.

"Taking note of the overall position in the matter, the Commission decided that it has 'no objection' to the issuance of completion certificate by NDMC provided the proposal is as per applicable norms regulations bye-laws and master plan etc. Further NDMC/Architect/Promoters should ensure to submit a copy of the completion drawings as well as the set of drawings sanctioned by NDMC for records of the Commission."

5.3 Approval of Delhi Fire Service

No objection certificate has been issued by Chief Fire Officer, Delhi Fire Service vide letter dated October 11, 2002.

5.4 Final Approval by NDMC

After compliance of observations the request for issue of completion certificate was sent to NDMC vide letter dated October 19, 2002 & completion certificate was issued vide letter no. C/6157-58 /CA/BP dated February 17, 2003.

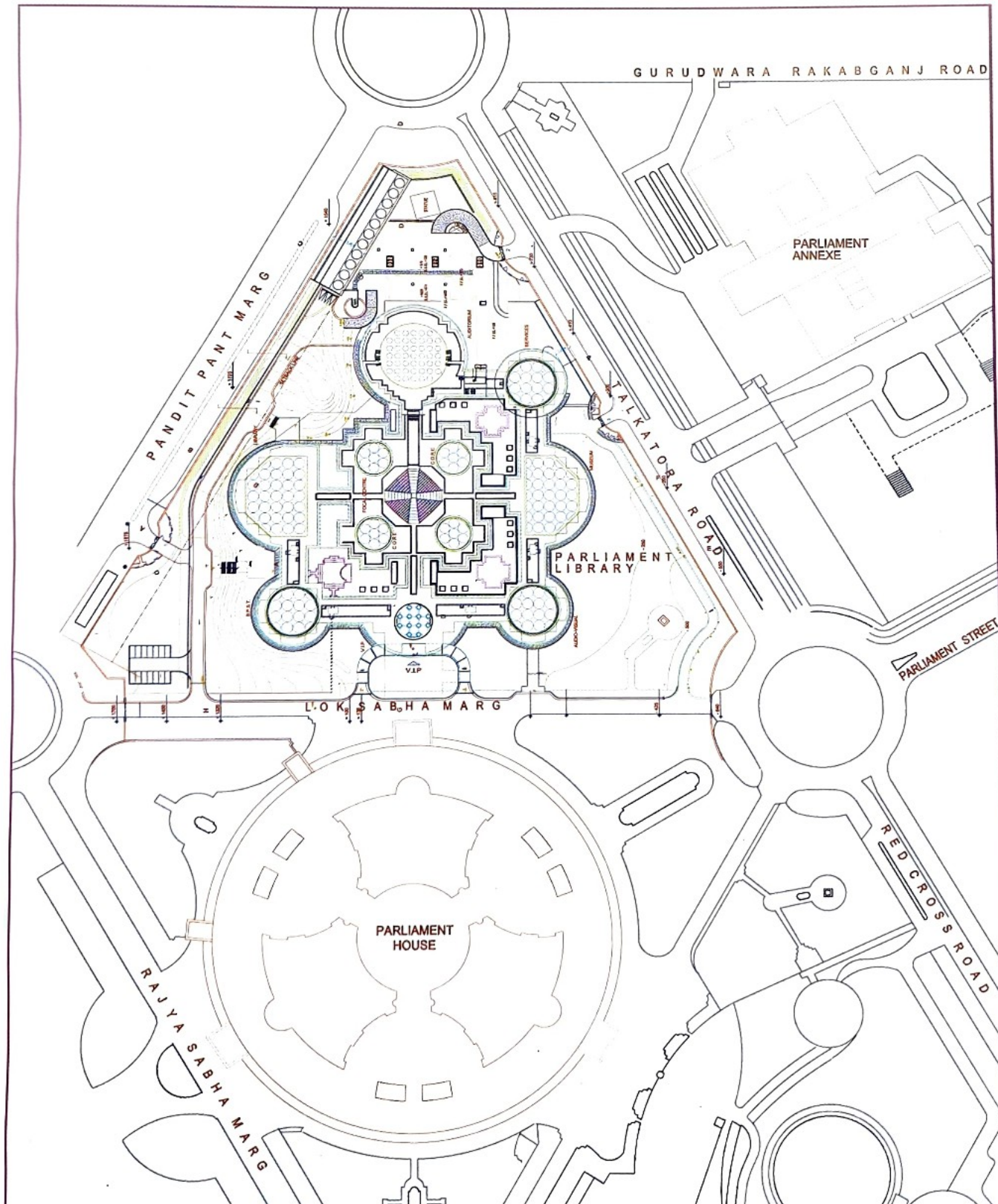


Figure 3.2 : Layout Plan

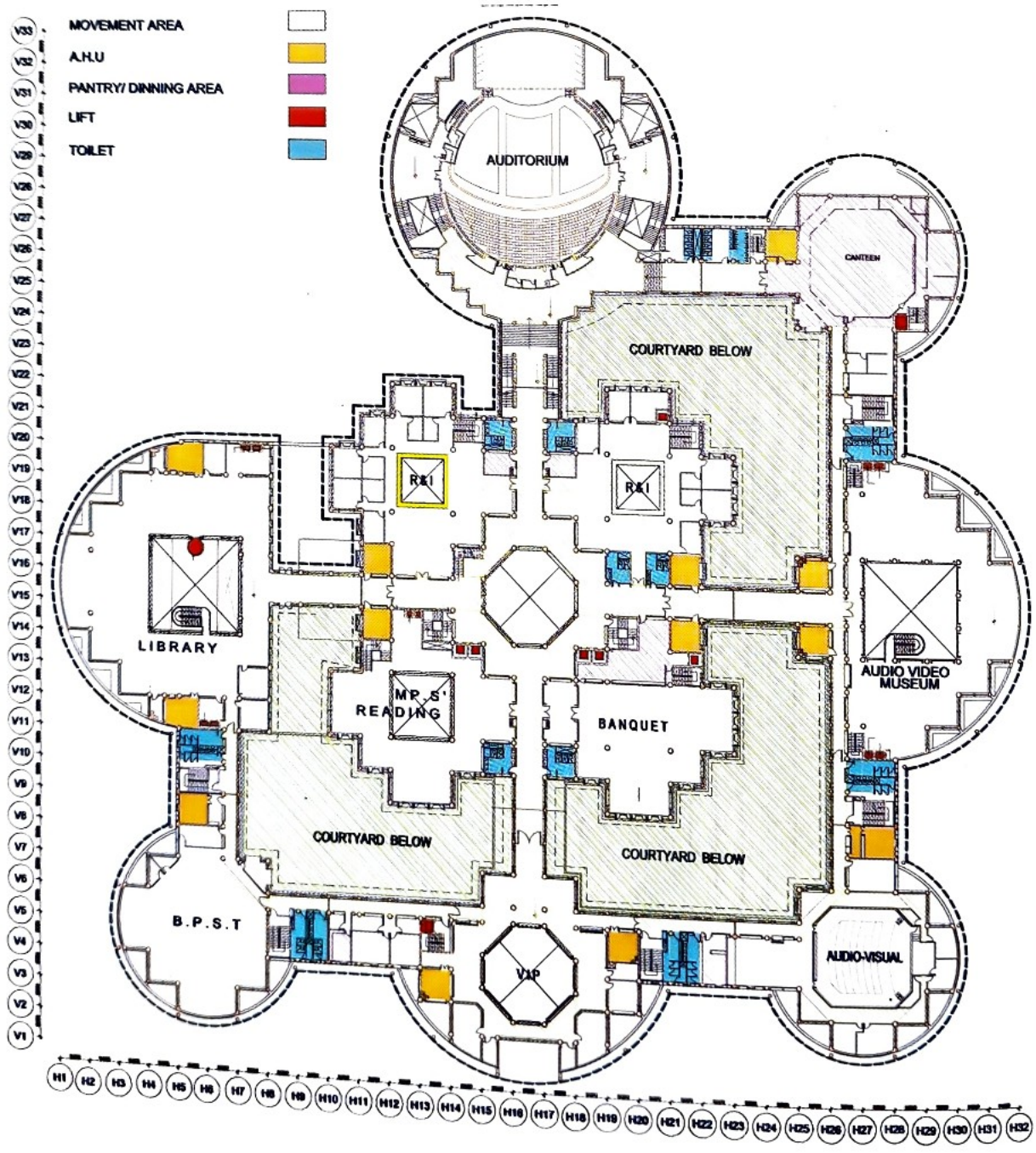


Figure 3.3 : First Floor- Plan

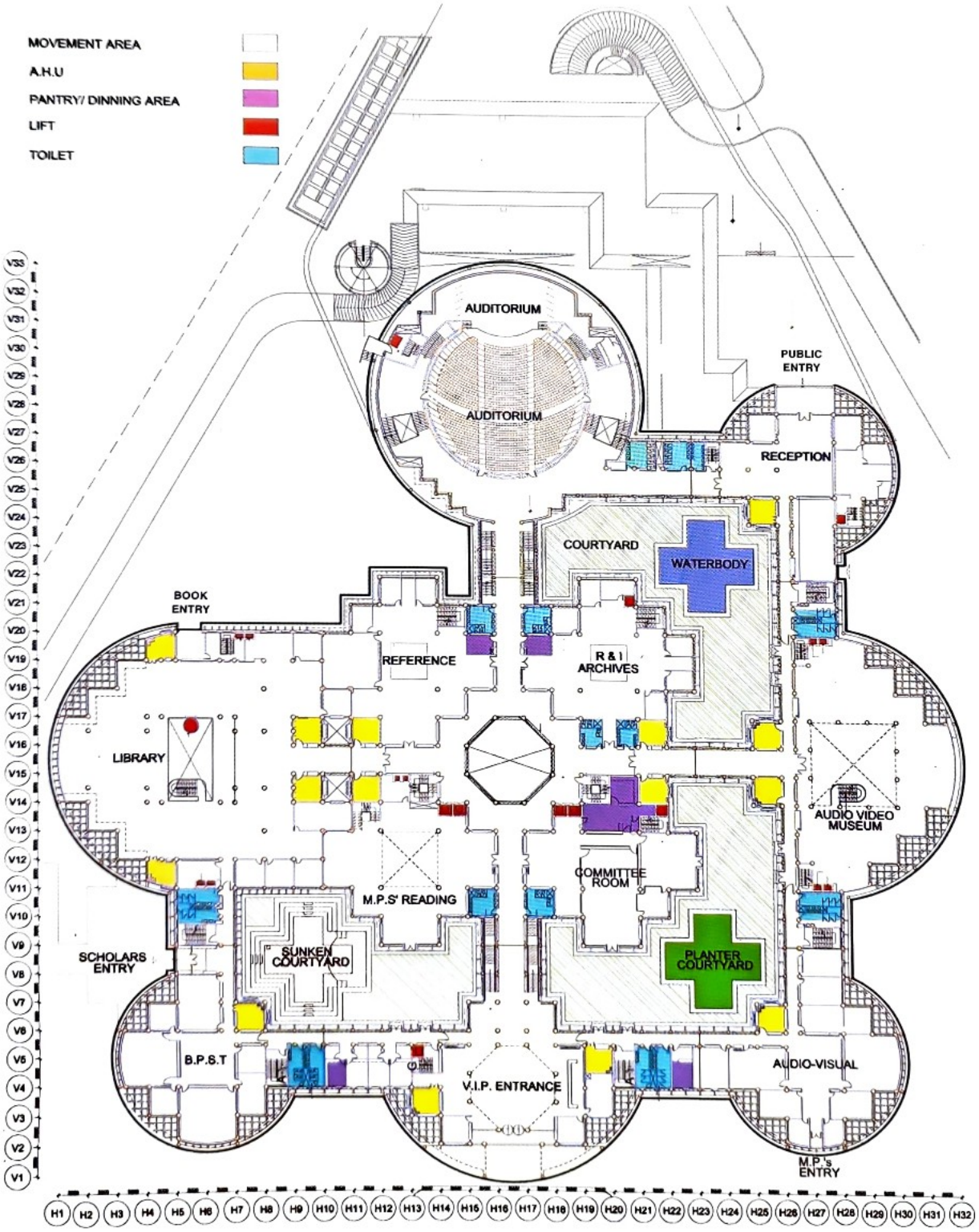


Figure 3.4 : Ground Floor – Plan

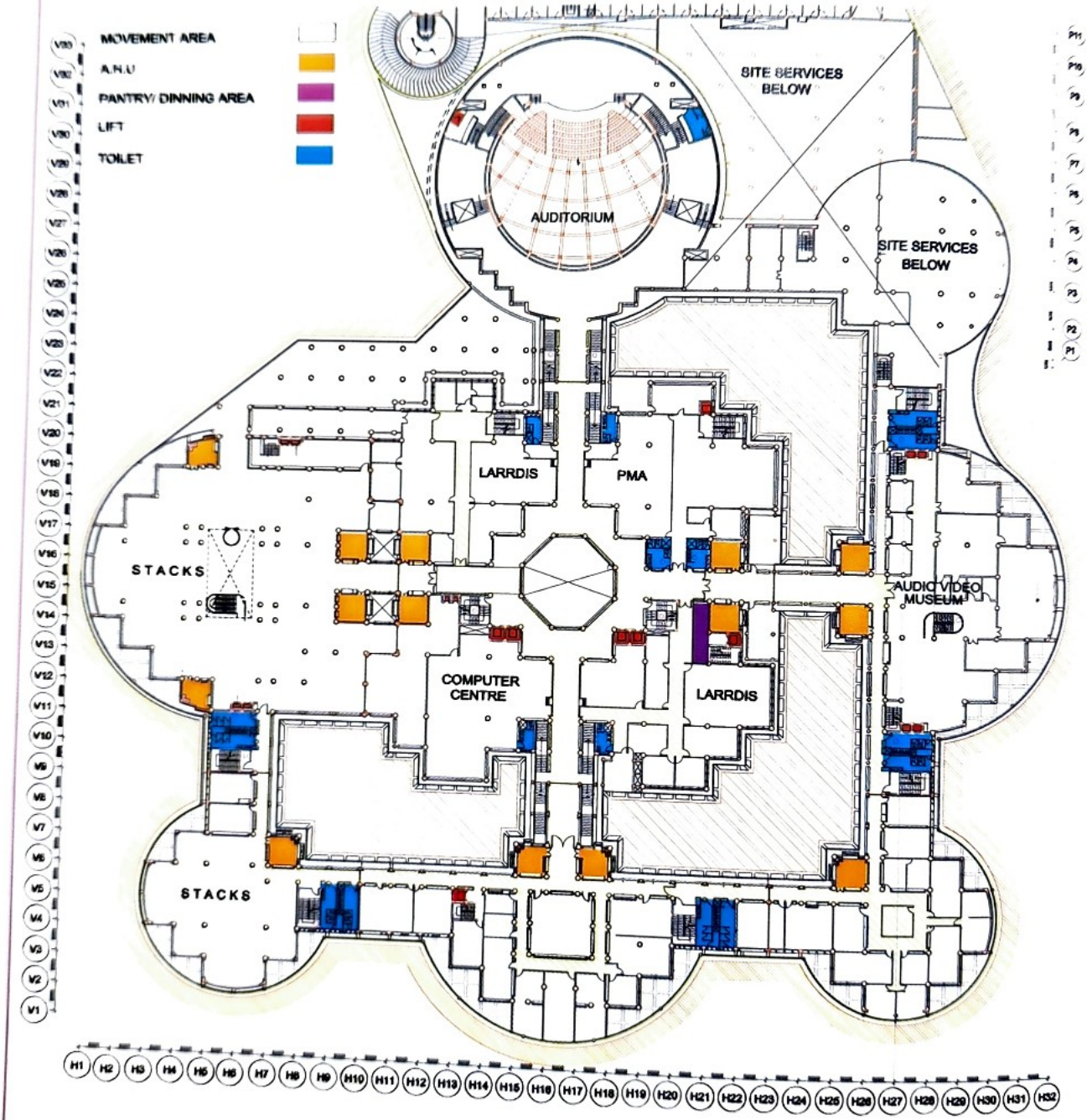


Figure 3.5 : First Basement – Plan

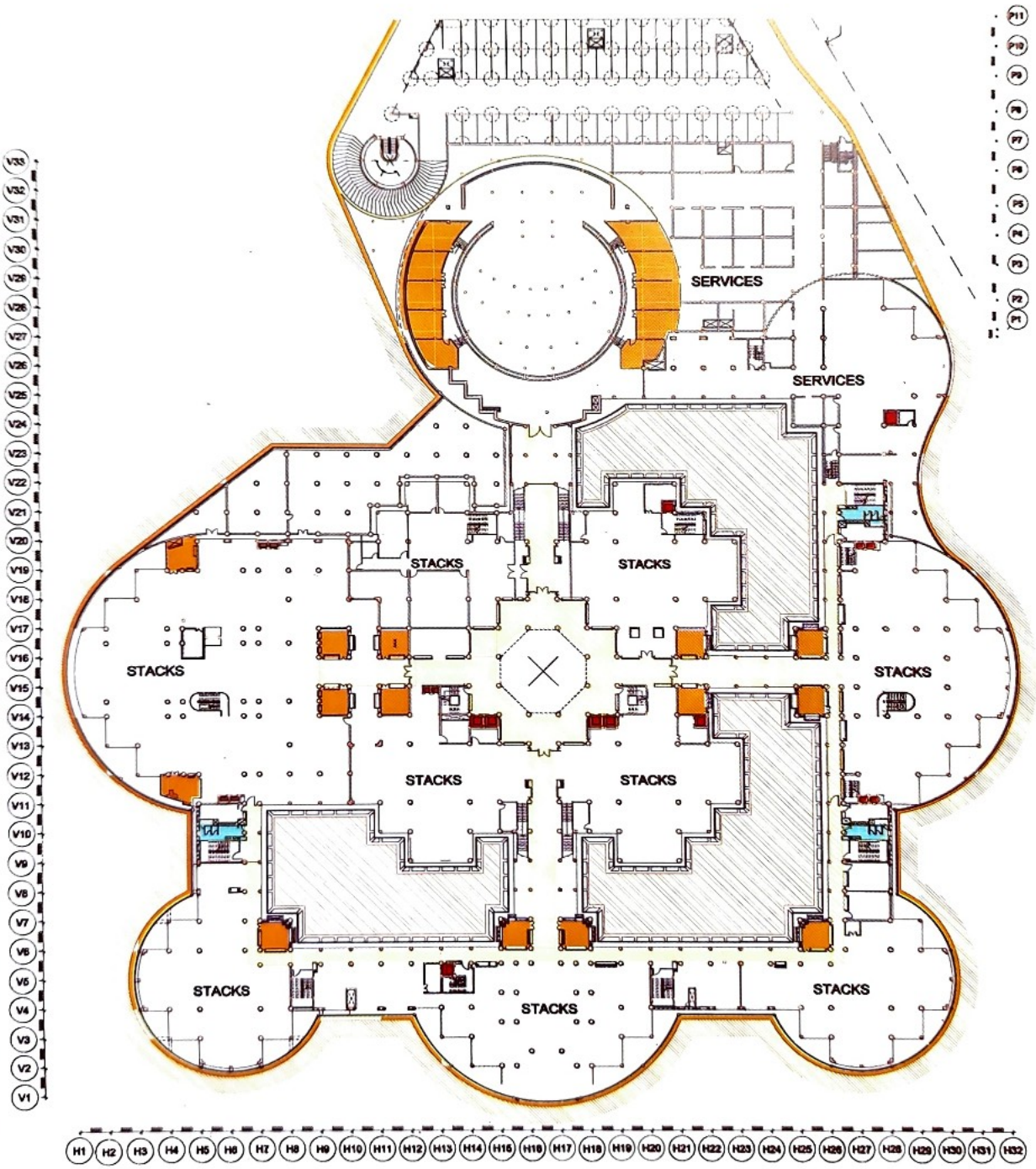


Figure 3.6 : Second Basement – Plan

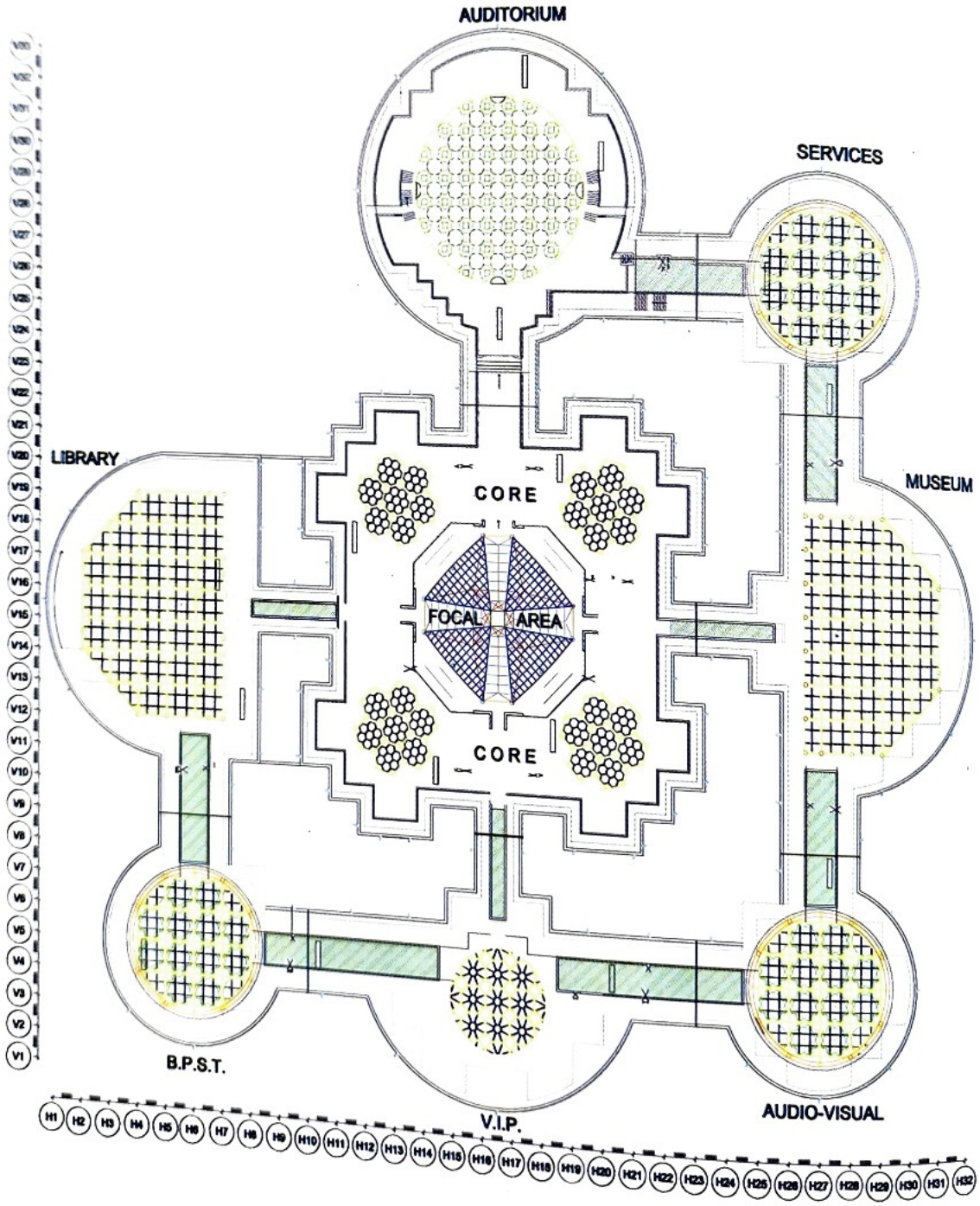


Figure 3.7 : Terrace -Plan

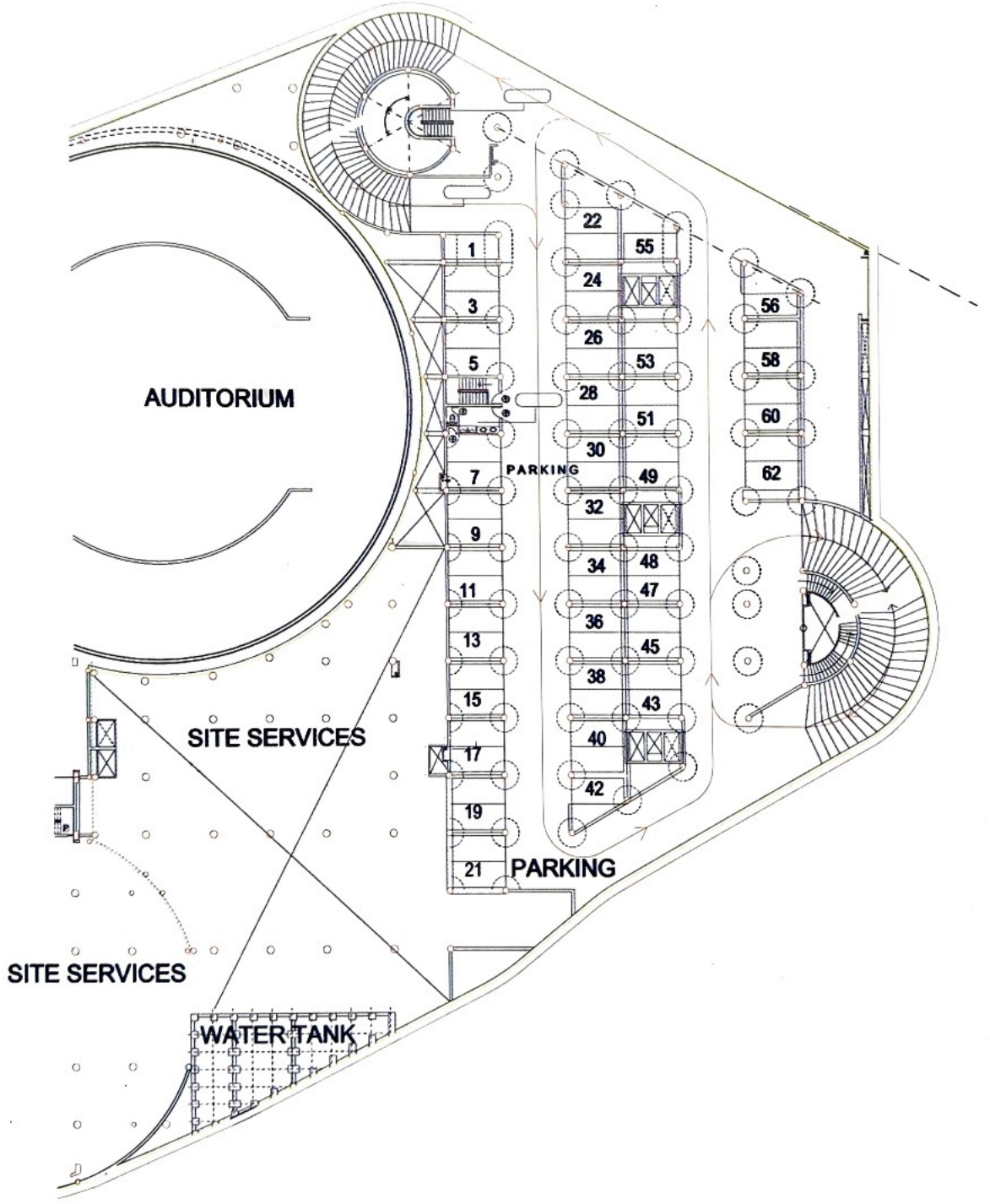


Figure 3.8 : Typical Parking Plan – First & Second Level

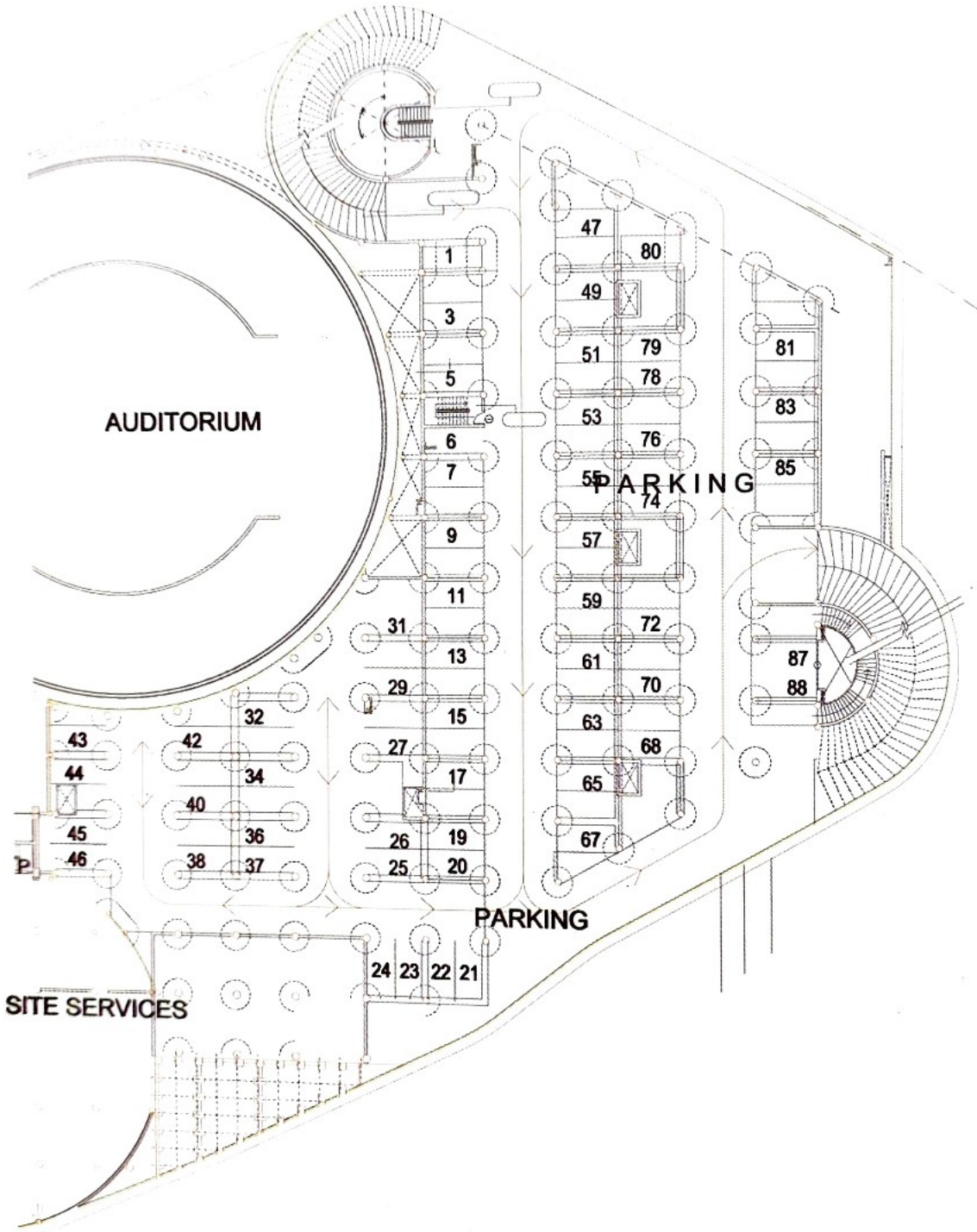


Figure 3.9 : Parking – Third Level

ARCHITECTURAL CONCEPT

1.0 DESIGN CONCEPT

The central function of the complex is the Parliament Library, a house of knowledge, symbolically a place of enlightenment. The design concept with its connotations of an inward looking building shows a specific preference for subtle spatial enclosures rather than forms of grandeur. The building has been designed with an aim to achieve a low key architectural expression signifying sagacity, even spiritual elegance rather than to compete with the power of the Parliament House. The analogy of a relationship between a Guru and the King may not be far fetched while comparing the Parliament Library Building with the Parliament House.

Both visually and symbolically the central hall of the existing Parliament denoting people's power, consensus and democracy, is linked to the core of the new complex, symbolising knowledge, on a central axis, through a sequence of spaces culminating in a new auditorium of 1067 persons capacity. The building has been conceived as a formal structure within the Indian Tradition, but built in a contemporary idiom to capture the essence without mimicking past historical styles.

2.0 URBAN CONTEXT

Lutyen's and Baker's plan for New Delhi follows largely "Beaux Arts", central-line-axis planning criteria. It is based on classical western ideals of symmetry and balanced composition. The Parliament House Building by Baker, circular in Plan, has three axes

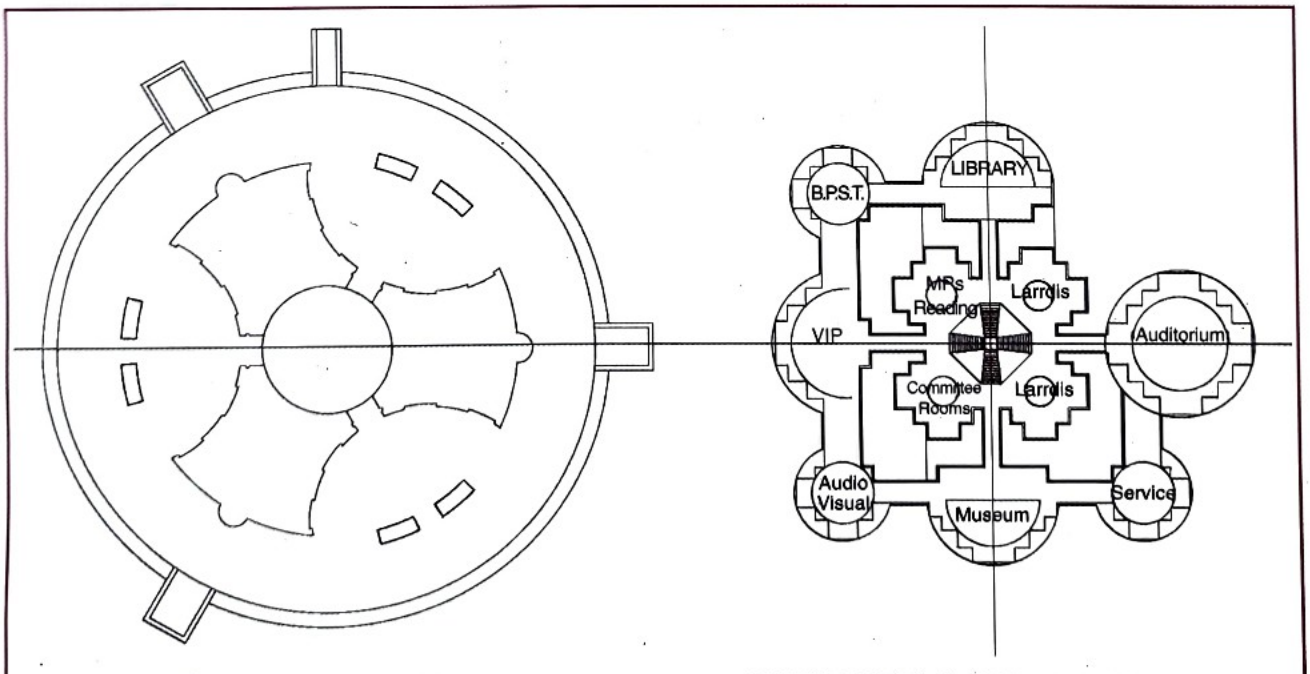


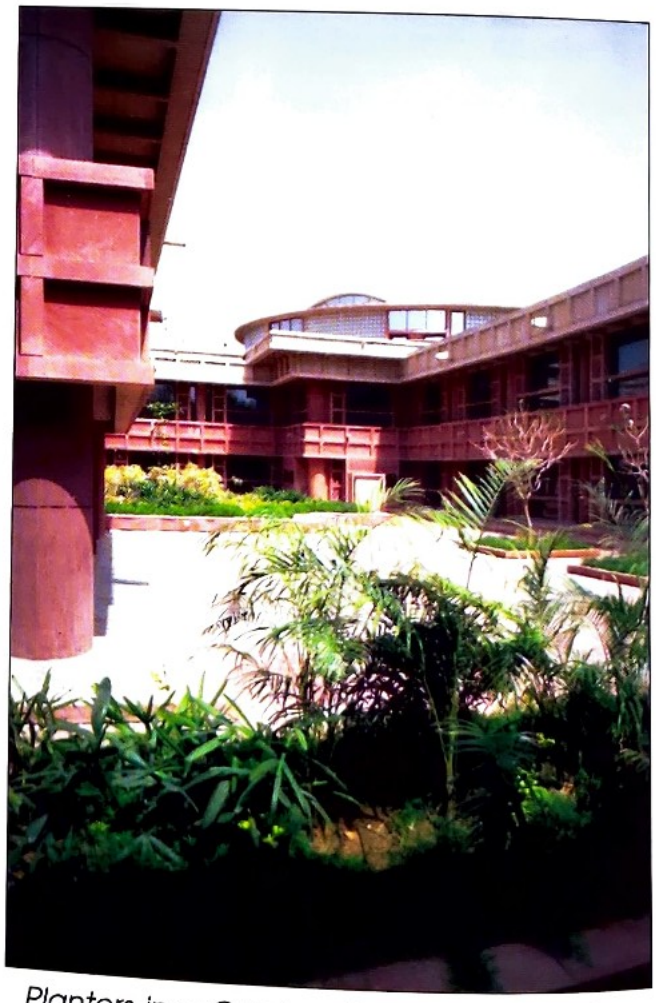
Fig 4.1 : Central Axis of Parliament House and Library Building

meeting in the central dome. One of these axes has been taken as an axis of Library building layout plan, with VIP Entry on one end (near PM's Gate) & Auditorium on the other end, focal area being the central point. A perpendicular axis through the focal centre aligns the Library Hall and the Museum.

Baker's circular plan has echoes of the Mandala diagrams. The library building in the form of a square, symmetrical yantra on a triangular plot with the planning ideals from the temple at Raunakpur, Taj Mahal and Datia only complements the circular Parliament House. Indeed, a satellite circle in relationship to the existing structure of Parliament was considered but rejected since a similar form would detract from the old and would show lack of confidence in the present generation's ability to make a creative statement. The design thus complements but does not imitate the Parliament House. The height of the building has been restricted to the podium level of Parliament House in deference to the Urban context of the site. Only architectural features of glazed crystalline forms or "domes" protrude above the podium level, here again keeping the height of domes as low as possible, and in any case well below the roof of the Parliament House.

3.0 URBAN FORM AND LANDSCAPE ELEMENTS

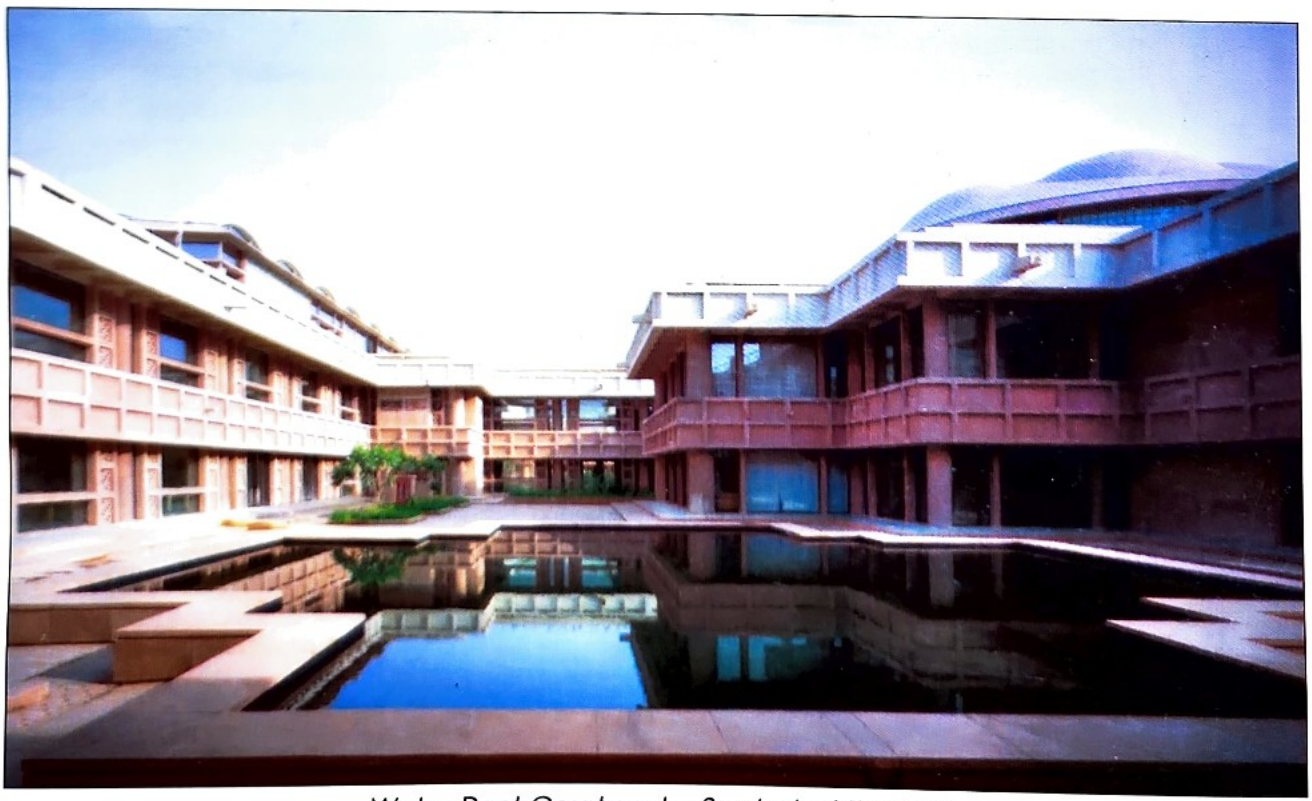
There are three courtyards symmetrically placed around the central built form, which not only serve as functional extensions to the adjoining areas of the Library building but also symbolize certain basic tenets of the Constitution of India. Thus, the first courtyard is built adjoining the MPs reading room & BPST committee room which has an atmosphere of tranquility around a "sunken court" with a small amphitheater which is symbolic of LIBERTY of thought and expression. The second courtyard having a big tree symbolizes, Social, Economic and Political JUSTICE and is surrounded by the Committee Rooms, Banquet Hall etc. The third courtyard is surrounded by the Museum and Auditorium and its space can be utilized for out door exhibitions around a water pool which represents EQUALITY of status and opportunity.



Planters in a Courtyard – Symbol of Justice



Sunken Courtyard – Symbol of Liberty of Thought & Expression



Water-Pool Courtyard – Symbol of Equality

Another reason which has influenced the inward looking urban form is an attempt to create a sensitive relationship with the existing trees on the site. The layout plan defers to a magnificent cluster of trees and allows them to interrupt what would have otherwise been a geometrical plan of square Yantra. Most of the trees on the Parliament end and periphery have been kept intact. The shrubs and turfed grass have been provided on the terrace for developing a terrace garden which is visible from Parliament House Corridor. The external lawn areas have been developed in harmony with Parliament House Complex.

4.0 ZONES DEMARCATION AND MOVEMENT AREA :

4.1 The complex is divided into three zones for easy accessibility and utility for VIPs, Scholars and general public. This zoning ensures privacy and security for the VIPs and segregates the Scholars area of BPST from public activity areas of the Museum and the Auditorium. All specific functions of the building have been clearly defined and instead of creating one omnibus space, separate inter connected blocks have been made for each main function of the complex. The functional relationship of various areas is discussed as below.

a) VIP entrance hall is just opposite to gate No.5 of the Parliament House Building and gives immediate access to the central core of the Library Building complex. This central area housing library activities , is covered with a fully glazed stainless steel dome and around it are located MPs reading room, LARRDIS, Banquet Hall and Archives. Further radiating from this space are the main arteries to Library, Museum and Auditorium. There is a separate entry for MPs from Audio-Visual Block and functional areas are easily approachable by MPs through this entry. MPs reading room adjoins the Library & LARRDIS block at the ground level and provides easy access for VIPs for reference and other facilities.

b) BPST is a self contained unit and is approachable directly from the VIP reception and also has a separate entry for scholars from Pt. Pant Marg. It is directly connected to the Library reading room for easy access by visiting scholars and administrators.

c) The Museum, Auditorium & Canteen can be independently approached by the general public from yet another entrance at Service Block and these are further inter-related to other areas by peripheral and arterial corridors.

4.2 The public spaces and administrative areas have been located generally at ground and first Floor, whereas basements have been utilized for stacking of books, storage and infrastructural service requirements.

4.3 Books and periodicals which are to be moved into the building in bulk consignments have a separate book entry between Library & LARRDIS.

4.4 Kitchen material is received through a separate entry from gate No. 3.

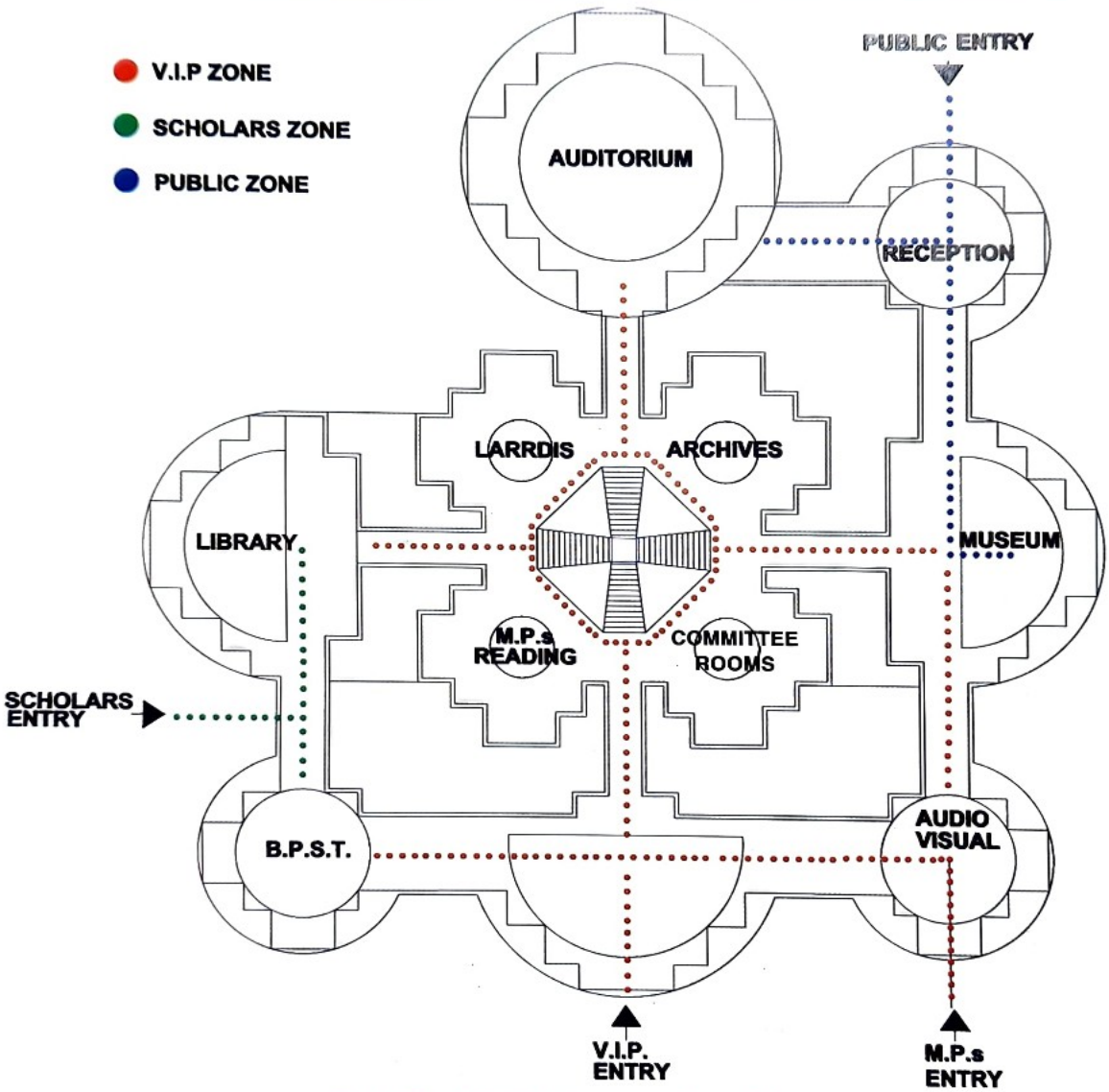


Fig 4.2 : Zones Demarcation Plan

5.0 ARCHITECTURAL EXPRESSION & MATERIALS

Red sand stone cladding has been provided on the external surface of the library building to match the adjoining Parliament House. Internally however, the Library Building is finished with a variety of materials or combination of materials - be it the floors or the walls or the ceilings. The terrace is covered with twelve domes of various shapes and sizes, some of which are opaque and some partly opaque & partly glazed. The central focal dome is fully glazed to provide diffused light into the basement levels. The crystalline forms of glass & steel present an attractive feature during the day and night. Light wells with glass block panels have been provided along the building periphery & periphery of the courtyards to provide diffused light in the basements.

Stainless steel and carbon steel frame work for the domes is exposed (not covered by false ceiling) when viewed from within the building, which accentuates the feeling of openness in the mind of the viewer beneath the dome. This feeling is further strengthened by the glass-block glazing all along the periphery of the domes.

6.0 FURNITURE & FURNISHING

The Furniture & Furnishing has been designed according to requirements of various functional areas as per general specifications given below:

a) The mobile closed stacks have been provided to increase the storage capacity. These are made from powder coated CRCA sheets mounted on rails with manually operated opening/closing system.

b) The open stacks for storage of books etc. are made of stainless steel or powder coated steel hollow frames. The shelves are made of either exterior grade commercial block board finished with Burma teak ply veneering and Burma teak bull nosed beading or powder coated CRCA sheets.

c) Study carrels, workstations, officers table, reading tables, Banquet tables, Conference Room/Committee Room tables are in general made of Burma teak wood/exterior grade commercial block board with Burma teak veneering with stainless steel structural system.

d) Sofas provided are single/two/three seater with frame work of stainless steel with cushions and foam backing and soft leather upholstery.

e) Chairs for Banquet Hall and Canteen are made of Burma teak wood and are upholstered with fine quality soft leather over foam cushions. The chairs for other locations like Committee Rooms, Auditorium, common areas and offices are upholstered with fine quality fabric with support system made of powder coated steel legs/prongs with or without castors.

f) Counters are provided in the library, Reception and at other entry points with working top of exterior grade commercial block board with Burma teak ply veneering with Burma teak bull nosing/beading. The counter top and the facia are provided with granite.

g) The use of carpet has been kept to the minimum and synthetic carpet has been provided only in Auditorium, Computer Training Room & Video Conferencing Room of Computer Center.

h) Vertical blinds with manual operating device have been provided.

SALIENT FEATURES

1.0 ADMINISTRATIVE APPROVAL & EXPENDITURE SANCTION

The project has been sanctioned in four parts as per details given below:

a)	Building work	(Original)	:	Rs.88.41 Crore	August, 1993
		(Revised)	:	Rs.141.31 Crore	June, 1999
b)	Additional facilities (Special Electrical & Mechanical Services)	(Original)	:	Rs. 8.79 Crore	August, 1996
		(Revised)	:	Rs.15.04 Crore	June, 1999
c)	Interior Decoration, Storage System, Furniture & Furnishing		:	Rs.35.56 Crore	June, 1999

2.0 GROUND COVERAGE & PLINTH AREA

a)	Plot area	:	39916 sqm
b)	Ground coverage (Permissible)	:	25% Relaxed to 34% by DDA vide letter dated August 13, 1993
c)	Ground coverage (Achieved)	:	34%
d)	FAR achieved	:	66%
e)	Plinth Area		

Main Building :

First Floor	:	9950.84 sqm
Ground Floor	:	13379.55 sqm
First Basement	:	11384.41 sqm
Second Basement	:	15725.61 sqm
Total Main Building		**50440.41 sqm**

Parking :

First Level	:	2878.18 sqm
Second Level	:	3103.18 sqm
Third Level	:	4037.71 sqm
Total Parking	:	**10019.07 sqm**

The parking is available for 212 Cars.

Total Area	:	**60459.48 sqm**	Say **60460 sqm**

3.0 FLOORWISE DISTRIBUTION OF ACCOMMODATION :

Block	Second Basement	First Basement	Ground Floor	First Floor
Library	Mobile closed stacks for Library	Open stacks for Library & Library staff	Reading area & Library staff	Open stacks, reading area & Library staff
BPST	Mobile closed stacks for Library	Open stacks for Debates & Gazettes & BPST staff	Committee/ Lecture/ Conference Hall & BPST Staff	Conference/ Lecture Hall & BPST staff
VIP	Mobile closed stacks for Library	Micro Filming Unit & Computer Room	VIP Lounge, MP's Querry Room & other offices	VIP Foyer & Hon'ble Speaker's Room
AV	Mobile closed stacks for Library	Micro Filming unit, Press & public relation	Press Public Relation Unit, Snack Bar	Multi media Auditorium, PPR Unit
AVM	Mobile closed stacks for AV	Audio Visual unit & Door-Darshan	Museum	Museum & Audio-Visual
Services	-	Plant Room & Sub Station	Reception Public entry, Kitchen store	Canteen
Auditorium	AHUs	Electrical services	Auditorium	Auditorium
Core-H	Mobile closed stacks for Library	Computer center	MP's Reading room	MP's Reading room
Core-I	Conservation Laboratory & Mobile closed stacks	Acquisition & processing staff of Library	Reference, Administration & Documentation offices, committee room	Library and computer staff
Core-J	Mobile closed stacks for Parliamentary Museum and Archives	Museum & Archives staff	Research & Information unit staff	Research & information unit staff
Core-K	Mobile closed stacks for Press Clippings	Press clipping staff	Committee rooms E & F	Banquet Hall

4.0 WATER SUPPLY

4.1 Underground Water Storage Tanks

a)	Fire tank	:	1.0 lac ltrs
b)	Drinking water tank	:	1.5 lac ltrs
c)	Air-conditioning water tank	:	4.5 lac ltrs

4.2 Overhead Water Storage Tanks

In all ten numbers of overhead water tanks with total capacity of 76,518 ltrs. have been provided on terrace.

5.0 AUDITORIUM /COMMITTEE/CONFERENCE/ LECTURE HALLS

a)	AUDITORIUM	:	Seating capacity of 1067 persons i.e. 260 in balcony & 807 at Ground Floor
b)	BPST Commitee Room, Ground Floor	:	26 Seats
c)	BPST Conference/Lecture Room, GF	:	39 Seats
d)	BPST Conference/Lecture Room, GF	:	43 seats
e)	BPST Conference /Lecture Room, FF	:	190 seats (150+40)
f)	Core-I Committee Room, GF	:	24 seats
g)	Core-K Committee Room, GF	:	24 seats
h)	Core-K Committee Room, GF	:	64 seats
i)	Audio Visual PPR, GF	:	75 seats (64+11)
j)	Audio Visual PPR, FF	:	140 seats (131 + 9)
k)	Audio Visual Museum, FB	:	35 seats

6.0 FURNITURE

a)	Mobile closed stacks	:	8100 nos (Single face) with total stack length of 53400m
b)	Open stacks	:	493 MD2 (double unit) & 163 MD1 (single unit) with 15420 running metre total stack length.
c)	Work Stations	:	416 nos
d)	Study Carrels	:	262 nos
e)	Proposed Storage of books	:	30 lac Volumes

7.0 CONTRACT DETAILS

Sl. No.	Name of Work	Name of Agency	Cost of Work (Rupees)
A	**Foundation System**		
1	Foundation System	M/s Cemindia Co. Ltd.	266685193
2.	Foundation System (Supplementary Agreement)	M/s Trafalgar House Construction India Ltd.	841608
3.	Shifting of storm water drains	M/s Sunil Kumar Goel	453629
	Add: DC & Contingencies etc.		37895478
	Total		**305875908**
B	**Superstructure**		
1	Superstructure	M/s Larsen &Toubro Ltd.	529592799
2	Aluminium doors & windows.	M/s Mahavir Aluminium Ltd.	11240609
3	Wooden Fire check doors.	M/s Larsen &Toubro Ltd.	10686544
4	Auditorium Stage works	M/s Mannu Lal & Sons	10318885
5	White sand stone jali 30 mm thick	M/s Ralhan Construction Co.	6527430
6	Cross Combed Cedar wood false ceiling panels.	M/s Bharat Furnishers & Interior Decorators	5324976
7	Accoustical sliding & folding partition on auditorium stage.	M/s Consolidated Services	3452800
8	White sand stone jali 32 mm thick	M/s Ralhan Construction Co.	3436702
9	Stainless Steel door hardwares	M/s Soft Sensations	1922651
10	Stainless Steel Box type door closer & dead bolts.	M/s Soft Sensations	1836604
11	Fire Resistant Blanket on steel trusses in Auditorium.	M/s Agni Safety India	977218
12	Sand stone grating over drains & White sand stone slab 30 mm thick	M/s Nishant Builders	1144015
13	Portable fire extinguishers.	M/s Great Sales Corporation	883048
14	Sand stone jali 50 mm thick	M/s Ralhan Construction Co.	877173
15	Fire barriers	M/s Global Fire Protection Co.	808130
16	Stainless Steel Pull handles, flush bolts and door stoppers.	M/s Soft Sensations	657252
17	Stainless Steel door hardwares	M/s d-line India Pvt.Ltd.	299620
18	Stainless Steel Box type door closer & dead bolts.	M/s d-line India Pvt. Ltd.	110700
19	Cross Combed Cedar wood false ceiling panels.	M/s Royal Furnishers	561330
	Add: DC & Contingencies etc.		83525822
	Total		**674184308**

C	**Domes**		
1	**Domes & Ancillary Works**	M/s Larsen & Toubro Ltd.	174778138
2	Stainless Steel Wire Ropes & end Connectors	M/s Well Worth Ropes Pvt.Ltd.	343653
	Add: DC & contingencies etc.		24764211
	Total		**199886002**
D	**External Works including Horticulture & Boundary Wall**		
1	Boundary wall and gates etc.	M/s Nishant Builders	13219688
2	Horticulture Works Phase-II - External Areas.	M/s Garden View Landscape Pvt. Ltd.	5690654
3	Horticulture Works Phase-I - Terrace & Courtyard.	M/s Garden View Landscape Pvt. Ltd.	2325000
4	Sprinkler & Drip Irrigation System for Horticulture	M/s Surge System India Pvt.Ltd.	669410
5	Boring of Tubewells	M/s B & R Tubewells Drilling Corporation	480647
6	Cooling Tower Pit	Shri Dinesh Jain	463328
	Add: DC & Contingencies etc.		3231071
	Total		**26079798**
E	**Furniture & Kitchen Equipment**		
1	Mobile Closed stacks.	M/s Godrej & Boyce Mfg. Co. Ltd.	85961774
2	Study Carrels & Work Stations	M/s Godrej & Boyce Mfg. Co. Ltd.	33865463
3	Office Banquet Hall Furniture & Sofa.	M/s Mukherjee Associates	29300895
4	Committee Room Furniture	M/s Mukherjee Associates	14796275
5	Open Stacks for Library Type 'B'	M/s Modern Decorators	14675701
6	Open Stacks for Library Type 'C'	M/s Exquisite Decors Pvt. Ltd.	11422736
7	Open Stacks for Library Type 'A'	M/s Exquisite Decors Pvt. Ltd.	11199122
8	Auditorium Chairs	M/s Godrej & Boyce Mfg. Co. Ltd.	9365653
9	Kitchen Equipments	M/s Continental Equipment India Pvt. Ltd.	7853390
10	Glass Blocks in Light wells	M/s Overseas Connexion Ltd.	7461836
11	Office Chairs	M/s Featherlite Products (P) Ltd.	6989798
12	Kitchen Equipments - Walk in Cold Rooms/ Deep Freezers.	M/s Continental Equipment India Pvt.Ltd.	4422717
13	Office Chairs	M/s Godrej & Boyce Mfg. Co. Ltd.	3605910
14	Signages & Boards.	M/s Royal Signages	824970
	Add: DC & Contingencies etc.		34185666
	Total		**275931906**

8.0 COST

The total plinth area is 60,460 sqm and cost per sqm for various components works out as below:

Sl. No.	Sub Head	Cost in Crores of Rupees	Cost per Sqm (Rs.)	Percentage of Total Cost
1.	Foundation System	30.59 Crore	5060	15.14
2.	Superstructure	67.42 Crore	11151	33.38
3.	Domes	19.99 Crore	3306	9.90
4.	External i/c Hort. & Boundary wall	2.61 Crore	432	1.29
5.	Furniture & Kitchen Equipment.	27.59 Crore	4563	13.66
6.	Electrical	53.80 Crore	8898	26.63
	Total	**202.00 Crore**	**33410**	**100.00**

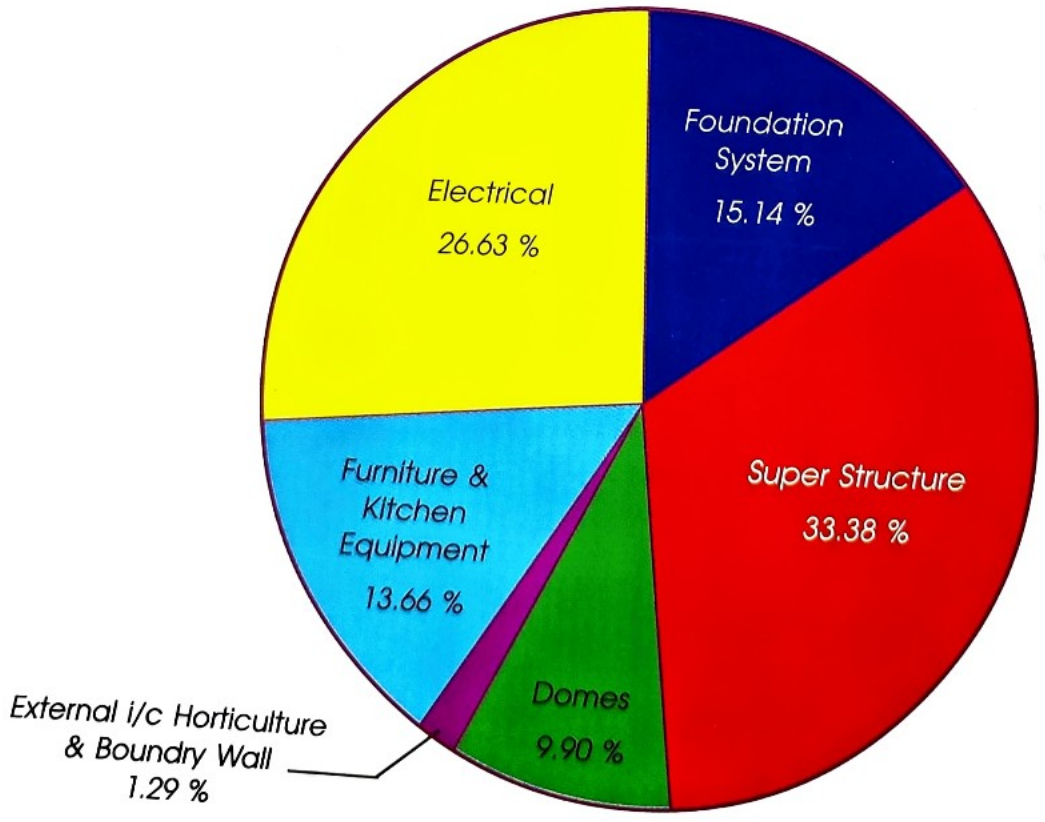


Fig 5.1 : Cost of Project (Pie Diagram)

PREQUALIFICATION

1.0 FOUNDATION SYSTEM

1.1 Prequalification

Initially, a pre-qualification notice for the Building work was published in various leading newspapers for inviting offers from reputed Civil Engineering Contractors for the entire civil engineering work of this project, including foundations. In the meanwhile the soil investigation report from the Geo-technical Consultant was received and it was realized that special foundation techniques would have to be employed for this building.

After considerable deliberations and discussions with experts in the field within and outside CPWD, it was decided to adopt construction of Diaphragm wall with inclined rock anchors. It was also decided to hold down the raft foundation with vertical rock anchors to take care of uplift pressure. This involved execution of very specialised items for which it was considered necessary to shortlist firms experienced in such foundation system. Shortlisting of contractors for the entire building including foundations, was therefore given up.

It was also decided that short-listing of specialised water proofing firms would be done simultaneously. The main Contractor for the foundation system was expected to enter into a sub contract with one of the short-listed specialised firms for water proofing. The intention was to hold only the main contractor responsible for both the foundation work as well as work of water proofing treatment.

Accordingly, press notice was issued in various leading Newspapers in Delhi, Chennai, Mumbai & Calcutta for short-listing of a) Specialised firms in constructing foundation system and b) specialized firms in water proofing, the following pre-requisites were specified for short-listing.

a) The Building is to have two basements and the foundation system involves about one lac cum of rock excavation (without blasting), water proofing of 7000 sqm. area, rock anchored RCC diaphragm wall and base raft, curtain grouting, alongwith ancillary works. Specialized firms experienced in works of similar nature who had successfully completed at least 3 such works with two or more basements under high-water-table conditions each costing not less than 5 crores during the last 5 years having necessary equipments for completing the work within a period of 12 months were eligible for prequalification.

b) Specialized firms for water proofing of the basement & diaphragm wall having at least 12 years experience in quality water proofing work and having executed satisfactorily 3 works costing not less than Rs. 30 lacs each were eligible for prequalification.

After going into the bio-data, technical competence, financial soundness and

capability of various firms to undertake such work in terms of criteria laid down for pre-qualification M/s Skanska Cementation India Ltd. (Formerly M/s Cem India Co. Ltd. and later M/s Trafalgar House Construction India Ltd.), M/s Asia Foundation Construction Ltd. (AFCONS) and M/s Larsen & Toubro Ltd. for the main Foundation work and M/s Structural Water Proofing Company, M/s Lik Proof Pvt. Ltd. and M/s Overseas Water Proofing Corporation for the water proofing work of the foundation system were short-listed with the approval of Director General (Works).

1.2 Prebid Conference

Tender documents were issued to the prequalified firms and a prebid conference was conducted to modify technical conditions, wherever required, and to avoid conditional tenders as they pose many problems in financial evaluation of conditions for proper comparison. Some of the salient suggestions made by the firms & accepted by the department during prebid conference were as under:

a) For working out the theoretical consumption of cement in the diaphragm wall excess consumption upto 10% of theoretical quantity as per the item 4.2 of schedule read with Para 5.17 of additional specifications was permitted.

b) The free & fixed length of rock anchors were modified. The minimum free length for the vertical rock anchors was kept 5m and minimum fixed length was also kept 5m against original free length of 3m & fixed length of 5m. For the inclined rock anchors the free length of 8m and fixed length of 5m was provided against minimum free length of 3m and fixed length of 5m as originally provided. An item of additional payment for the free length in inclined rock anchor beyond 8m was provided.

c) The provision for mobilisation advance not exceeding Rs. One crore in two instalments, was made.

d) The provision for Secured Advance not exceeding Rs. 10 lacs for Plant & Machinery was made for the machinery brought to site by the contractor in one instalment within one month of bringing such plant & machinery. No such advance was to be given in respect of machinery which contractor already possesses.

Thus, after having discussed threadbare the contract condition, construction methodology and site constraints, and after having modified the NIT to accommodate the mutually acceptable deviations, it was expected that the difficulties in operating the contract would now be minimized, if not totally eliminated. As a result of the prebid conference suitable amendments were annexed with the NIT and the prequalified firms were asked to quote accordingly. The tenders were received on January 12, 1994 and lowest tender of M/s Cemindia Co. Ltd.was approved on March 3, 1994.

2.0 SUPERSTRUCTURE

2.1 Prequalification

Prequalification notice was published in leading national newspapers in the last

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2.0 SUPERSTRUCTURE

2.1 Prequalification

Prequalification notice was published in leading national newspapers in the last

week of September, 1994 and first week of October, 1994 giving brief of work and eligibility conditions in Prequalification notice as below:

a) Estimated cost of work is approximately Rs. Thirty Crores with plinth area of about 58,000sqm. including parking. Main library building is a four storeyed structure with two storeys below and two above ground while the adjacent parking is a three level basement structure. Work involves construction of large span RCC framed structure with waffle slab, marble flooring of different combinations including Granite, extensive fine chiselled stone work cladding in wall and circular columns, stone trellis, carving in stone, aluminium doors/windows, stainless steel/mild steel tubular domes upto 30m span with glass bricks/ferrocement as infill materials and other civil work required for internal electrification & lifts etc. Work also requires a very high degree of co-ordination on part of civil contractor on account of high quality water supply and sanitary installation, high technology support services, latest facilities for storage and retrieval information system, satellite connection, latest technology in fire fighting with alarm system, central air-conditioning etc. Work is to be completed in twenty seven months.

Main building contractor will engage specialised firm experienced in internal water supply and sanitary installations from one of the selected specialised firms through this short listing. Department also reserves right of getting entire work including Internal water supply and sanitary installations done through the main contractor only. The responsibility for the total work will rest with the main contractor.

Foundation work which includes construction of raft with vertical rock anchors, diaphragm wall with inclined rock anchors, RCC protective wall, water proofing of basements, column dowels etc. is already in progress.

b) Contractors having experience in quality work of non-residential buildings, involving above type of work only can apply for prequalification. Applicant should have completed satisfactorily at least three such works of minimum value of Rs. Fifteen Crores (civil work only) each, at present cost level (based on cost index of CPWD) during last fifteen years. One of these three works should be a centrally air-conditioned building having a minimum plinth area of 20,000sqm. Annual turnover of the firm should not be less than Rs. Fifteen crores during last five years.

c) Quality of water supply & sanitary installation in the proposed building is to be of a very high order. Specialised firms should have been in this field for at least ten years. The firm should have completed satisfactorily at least three such works of water supply & sanitary installations each costing not less than Rs.Forty lacs at the present cost level (based on cost index approved by CPWD) during last five years.

In response to the above, 23 applications for superstructure work and five applications for internal water supply & sanitary installations were received. After preliminary scrutiny of the applications, eight firms for superstructure work and four firms for water supply & sanitary installations were selected for detailed scrutiny.

The works done by the eight selected firms for the superstructure work were inspected by the Committee constituted by Director General (Works) and only three firms were found to meet the criteria as laid down. In an attempt to broaden the list, it was decided to contact some more leading firms. The criteria laid down in earlier press notice were also relaxed for this purpose to the following requirements:

a) The area of the centrally airconditioned building should be 15000sqm instead of 20000sqm.

b) The average annual turn over of the firm in last 3 years should not be less than Rs.7.5 crores instead of Rs.15 crores in each of last five years.

The following seven firms for the main building work and four for water supply & sanitary installations fulfilled the modified criteria.

a) *Main Building work:*

i. M/s Shahpoorji Pallonji & Co. Ltd.

ii. M/s Tarapore & Company

iii. M/s Larsen & Toubro Ltd.

iv. M/s Tirath Ram Ahuja Ltd.

v. M/s Ahluwalia Contract (India) Ltd.

vi. M/s Prakash Constn. & Engg. Co. & Chawla Interbild Constn. Co. Ltd.

vii. M/s B.E.Billemoria & Co. Pvt. Ltd.

b) *Water Supply & Sanitary Installation Work:*

i. M/s Northern Sanitation Works (Pvt.) Ltd.

ii. M/s D.S.Gupta Contracts Pvt. Ltd.

iii. M/s S.Sony & Co.

iv. M/s D.S.A. Engineers.

The Director General (Works) based on recommendations of the Committee approved all the above seven firms for superstructure work and four firms for water supply & sanitary installation works. The firm executing the work of superstructure was obliged to engage one or more firms for water supply & sanitary installations work from these four approved firms which were specified in contract for superstructure.

2.2 Pre-bid Conference

The tender documents were issued to all prequalified agencies except M/s BE Billimoria & Co. Pvt. Ltd., who had expressed their inability to tender for the work. The prebid conference was held on September 20, 1995 & again on October 20, 1995. Some of the salient modification made in the tender documents after deliberations with

the agencies are as under:

a) Trunking for cables is to be provided at places in the flooring and suitable openings have to be provided for junction boxes in the stone slabs of the flooring for which nothing extra would be paid.

b) Theoretical quantity of stainless steel planks for false ceiling, flats for cramps & tubes for railing shall be taken as quantity actually required and measured plus 5% for wastage due to cutting etc., over the theoretical quantities of such stainless steel materials no variation shall be allowed (originally no provision was made in NIT for wastage & variation for these stainless steel items stipulated).

c) The stone veneer work of 50mm thick in circular columns with circular stones in four equal pieces in plan & of height not exceeding 1250mm will be used (originally there was no provision for number & size of stone pieces)

After issuing the addendum as per the modifications suggested & agreed, the agencies were requested to submit their tenders on November 8, 1995. The tenders after scrutiny were sent to Central Works Board for acceptance on December 30, 1995 with recommendations for negotiation with lowest tenderer M/s Larsen & Toubro Ltd. The Central Works Board however decided to re-invite the tender on April 26, 1996. The tenders from the same qualified agencies were again received on May 30, 1996. Only three agencies participated in the tender. M/s Larsen & Toubro Ltd. was the lowest tenderer. The work was awarded to M/s Larsen & Toubro Ltd. on July 19, 1996.

3.0 DOMES & ANCILLARY WORKS

3.1 Prequalification

As the work of Domes with complex geometry was being executed for the first time in India, to get an idea as to the expertise available in the country for this work, a Press Notice was issued on March 12, 1997. The agencies were asked to submit details of works satisfactorily completed involving stainless steel / mild steel trusses, ferro cement work, stone cladding, glass bricks/ structural glazing, sealing of joints and water proofing. Twenty three firms responded to this notice. Only three firms i.e. M/s EPIL Ltd.; M/s Mukund Ltd and M/s Larsen & Toubro Ltd. (ECC Construction Group) appeared close to the criteria laid down.

In view of the lukewarm response, it was decided to call Global Tenders for this work. Further to collect requisite data of various firms both Indian & Foreign who were keen to participate in the execution of work, a global enquiry was made through press notice on May 1, 1998 which was published in various Indian Newspapers and was also sent to various Indian Missions abroad and Foreign Embassies in India. On the basis of global enquiry, in addition to twenty five Indian firms, response was received from four foreign firms.

On the basis of details submitted by the firms (Indian/ Foreign) a global prequalification notice was issued on August 22, 1998 in leading Indian newspapers.

The prequalification notice was also sent on August 29, 1998 to Foreign Embassies/High Commissions of France, Japan, China, Singapore, Australia, South Korea, USA, Britain, Netherlands, Germany & Italy at New Delhi. In addition to Foreign Embassies at New Delhi, the prequalification notice was also sent on August 28, 1998 to various Indian Missions located in these countries.

As per the global prequalificaton notice, following criteria was adopted for prequalification of agencies for construction of Domes:

a) The firms/contractors having extensive experience in high quality work involving fabrication, handling and erection of heavy tubular structure both stainless steel as well as high-strength carbon steel at heights, backed with design facilities were invited to apply for prequalification. Applicants were required to have necessary facilities for preparing detailed shop drawings.

b) Prequalification was open to firms having joint ventures between foreign and Indian companies. Details of such joint ventures were also to be given alongwith applications.

c) The applicants should have satisfactorily completed at least three works involving welding, fabrication and erection of structures in carbon steel and or stainless steel weighing atleast 100MT each in a work of gross minimum value of Rs.3.00 crore (0.75 million US $) each or two similar works of gross minimum value of Rs. 4.5 crore (1.125 million US $) each during last 5 years. The applicants should also have had experience of at least three works of welding, fabrication and erection of stainless steel each at least 15 MT by weight during this period.

d) The firms/ sub contractors intended to be associated with main firm for structural glazing and water proofing should have satisfactorily completed at least three works each of magnitude given against each item, in last five years.

i.	Structural glazing	2000sqm
ii.	Waterproofing	5000sqm

The firms who want to do the structural glazing and water proofing works themselves should meet the criteria given in para (d) above. The intending firms / contractors who do not meet the criteria given in para (d) above should give a list of firms/ sub contractors intended to be associated for structural glazing and water proofing with their credentials for consideration of the department. These firms / sub contractors should have requisite experience in each item as mentioned in para (d). However, the responsibility of the total work will rest with the main firm.

e) Independent offers were also invited from the firms/ contractors specialised in structural glazing and water proofing meeting the criterion for each item given in para (d) above.

f) Average annual turnover of the applicant under para(c) should not be less than

Rs. 5.00 Crores (1.25 million US $) during last three years i.e. total turnover of Rs. 15 crores (3.75 million US $) during last three years.

In response to the global prequalification notice, 11(eleven) firms including one from Japan and one from China had applied for prequalification.

A committee consisting of Chief Engineer and Project Manager, Parliament Library Project, Chief Engineer (CDO), Chief Engineer (CSQ) and Superintending Engineer (Civil), Parliament Library Project was constituted to inspect the works of intending firms/ contractors. On the basis of scrutiny of details submitted by the applicants, five firms were shortlisted for inspection of work.

After inspection of works of these five agencies the committee recommended the names of three firms for prequalification. The following three firms were approved by Additional Director General (S&P) on March 12, 1999 for construction of Domes & Ancillary Works.

i. M/s Ahluwalia Contracts (India) Ltd.

ii. M/s Larsen & Toubro Ltd.

iii. M/s Dodsal Limited.

3.2 Pre-bid Conference

Two-bid system was adopted for award of work. The tender documents were issued in three volumes i.e. Volume I containing General Conditions, Particular Specifications and Additional Conditions, Volume –II containing drawings and Volume III containing Price Bid. The two volumes I & II were submitted by the contractors in sealed cover as technical bid and Volume–III i.e. schedule of quantities &. price bid was submitted in a separate sealed cover.

The technical bids were opened and first pre-commercial bid meeting for the work was held on December 19, 1999 in which all the three prequalified firms participated. On the basis of observations of the three agencies and the discussions with M/s RFR (Structural Consultant), Corrigendum No. 1 alongwith supplementary drawings was issued. Following main provisions/ modification were included in the corrigendum No.1

a) Sub para 5.3.1.1 was modified to allow tenderers to use carbon steel tubes of grades other than Yst 310 of IS:1161-1979 also meeting the specifications laid down in IS:1161-1979 and having carbon content not more than 0.25%

b) Mechanical properties of stainless steel castings were added.

c) Size of glass blocks for wall lining and glass block precast panels were changed from 300mm x 300mm x 80mm to 190mm x 190mm x 80mm.

d) Provision of pan mixer supplemented by weigh batchers of high precision was made for HPFRC (High Performance Fibre Reinforced Concrete).

e) Detailed specification for focal dome was added.

Second meeting was held on January 11, 2000 in which M/s Dodsal Limited absented. On the basis of discussions with two agencies following amendments were made.

i. Provision of advance payment @ 75% of assessed value on steel tubes, plates, castings, rods & end connectors brought at contractor's workshops was made against bank guarantee.

ii. The requirement of yield strength of stainless steel tubes & plates were changed from 300N/sqmm to 200N/sqmm.

After issue of corrigendum No. II, the revised specifications for high performance fibre reinforced concrete (HP-FRC) were received from Structural Engineering Research Centre (SERC) on January 21, 2000. The third corrigendum containing revised specifications for HP-FRC and revised price bid schedule was issued on January 24, 2000.

Revised Technical & Price bids of both the contractors were received on January 25, 2000. After approval of technical bid, the price bids were opened on January 25, 2000 at 1.30 PM. The work was awarded to lowest tenderer M/s Larsen & Toubro Ltd. (ECC Construction Group) on February 22, 2000.

4.0 ALUMINIUM DOORS & WINDOWS

4.1 Prequalification

The prequalification Notice was published in leading newspapers of Delhi, Chennai, Mumbai, Calcutta and Bangalore with following prequalification criteria:

a) Firms having line of fabrication of aluminium doors and windows since (at least) last three years, equipped with automatic cutting machine with pneumatic clamping and fabrication machines like End milling, Crimping, Pneumatic press, Powder coating/anodising with chambers/series of dipping tanks for length upto 6m and R&D facilities, inhouse quality assurance and control facilities for providing and fixing powder coated/anodised Aluminium doors and windows with hermetically sealed double glazing with either in-house modern facilities of fabrication, desiccating and sealing or through specialised agency having similar facilities for glazing. The responsibility of total work was of the main agency.

b) The estimated cost of work was Rs. 100 lacs. The firms/contractors were to submit proof of having satisfactorily completed at least one single work of fabrication and erection of Aluminium doors/windows/curtain wall with single/double glazing etc. for a minimum value of Rs. 50 lacs or two such works of Rs. 40 lacs each during last three years at the present cost level (based on Cost Index of CPWD for building work).

In response to the above prequalification notice, 18 firms had applied for

prequalification. A Committee was constituted with Chief Engineer (PLP) as Chairman and Chief Engineer (CSQ), Director (P&WA), Superintending Engineer (PLP) and Executive Engineer (PLP) as member to visit the factories and their works. The committee visited the eight firms and after inspection, following four firms were approved for prequalification.

i. M/s Alkarma

ii. M/s Mahavir Aluminium Ltd.

iii. M/s ECIE Private Ltd.

iv. M/s Aluminite Architectural Pvt. Ltd.

4.2 Pre-bid Conference

Prebid conference was held on February 27, 1999 and all the agencies except M/s ECIE Pvt. Ltd., attended the conference. Two addendums were issued on March 8, 1999 and March 12, 1999. The tenders were received and opened on March 15, 1999. The work was awarded to the lowest tenderer M/s Mahavir Aluminium Ltd. on May 24, 1999.

5.0 STONE JALIS

Prequalification was also considered necessary for supply of stone jalis for false ceiling and wall lining and prequalification notice was published in leading newspapers. In response to prequalification notice, 8 firms applied for consideration. After scrutiny of the applications, inspection of their works & examining samples of jalis submitted by the agencies, the following five firms were prequalified for the purpose.

a) M/S Nishant Builders

b) M/S Stone Crafts.

c) M/S ABC Merchandising Co. Pvt. Ltd.

d) M/S Ralhan Constn. Co.

e) M/S Shel International

The work was ultimately awarded to lowest tenderer M/s Ralhan Construction Co.

6.0 AUDITORIUM STAGE & OTHER WORKS

Prequalification of contractors was also done for the work of Auditorium stage. Twelve firms applied for consideration. After detailed scrutiny only four firms were approved for the job by the Additional Director General (S&P) as below.

i. M/s Nishant Builders

ii. M/s Larsen & Toubro Ltd.

iii. M/s Décor India Pvt. Ltd.

iv. M/s Mannu Lal & Sons.

The work was ultimately awarded to M/s Mannu Lal & Sons.

7.0 BUILT-IN PREQUALIFICATION

There were some other specialized works as below for which prequalification criteria were built into the NITs.

a) Fire check doors

b) Supply of stainless steel door hardware

c) Supply of cross combed cedar panels

d) Fire barrier above lintel level

e) Motorized sliding & folding partition in auditorium.

FOUNDATION SYSTEM

1.0 INTRODUCTION

The Parliament Library Building consists of two basements and two floors above ground. The contiguous underground Car Parking area has three levels. The Main building is divided into 8 blocks i.e. Library, BPST (Bureau of Parliamentary Studies & Training), VIP, Audio-Visual, Core, Museum, Services and Auditorium. These blocks are separated by expansion joints. The shape of the structure envisages a number of curved areas and three internal courtyards. Above the roof level, the structure has twelve domes of special geometry. The founding level is generally rocky and the ground water level is high, which is expected to rise to the ground level on some occasions. In addition, the proximity to the existing Parliament House also puts certain constraints on normal practices of construction.

2.0 SOIL INVESTIGATION

Initially, the soil investigation of the area was carried out by electrical resistivity method. According to this study, there appeared to be no rock available upto 15m to 20m depth. However, the subsequent investigations done by the Central Designs Organisation of CPWD, through 12 bore holes indicated that rock is indeed available at depths varying from 3m to 14m below the ground level in the entire area. Since these two methods gave widely divergent results, it was decided to carry out a detailed soil investigation.

2.1 Selection of Agency

The geo-technical investigation was decided to be awarded to a firm after evaluating its technical capability. The NIQ was issued in press which indicated submission of sealed quotations in two parts; viz. Part-I for the technical bid and Part-II for the financial bid. Both the bids were received on the same day. Financial bids were opened only after finding that the following 4 firms met the required technical criteria.

a) M/s Cemindia Co. Ltd.

b) M/s Asia Foundation and Construction Ltd. (AFCONS)

c) M/s Simplex Concrete Piles (India) Ltd.

d) M/s Soil Rock and Foundation Engineering.

The work was awarded to the lowest bidder M/s Soil Rock and Foundation Engineering in March, 1993.

2.2 Detailed Investigation

The detailed investigation confirmed the presence of rock varying from 1.2m to 13.5m below the existing ground level. The top soil is made up of filled up materials. The underlying soil is sandy silt to silty sand. The type of rock varies from quartzite to sand stone. At a few locations prevalence of micaceous strata was observed. The recovery

of rocks was also varying in various bore holes indicating highly weathered and fractured rock of soft to medium strength. The ground water table was observed at 4m below the ground level. During rains, the same came upto 2m below the ground level.

The report goes on to add that the water level may rise and is likely to come up to ground level on some occasions. The report estimated an allowable bearing pressure of 45 tonnes per sqm over the rock surface at founding level. This was much more than the actual requirements. The report indicated that soil layer can be drained effectively with a well-point dewatering system and rocky layer can be drained by additional sumps/small wells. The results of chemical analysis of soil samples indicated that no special treatment is needed for RCC construction work as per requirements of IS: 456-1978. The report also suggested construction of grout curtain adjacent to proposed excavation from Parliament House side and monitoring of any uplift or settlement by installing gauges around Parliament House Building.

3.0 TYPE OF FOUNDATION

The two options available for construction of basements were :

a) Open excavation with extensive dewatering using well point system;

b) Excavation after construction of anchored diaphragm walls and curtain grouting along the periphery.

Because of the high water table, the amount of dewatering required would have been huge. Hence it was not advisable to resort to the first method. In addition, such dewatering would have brought down the ground water table under the existing Parliament House drastically. It was feared that the presence of large fissures in the founding rock would lead to removal of interstitial material due to the high velocities generated during the draw down. This could lead to differential settlements which could affect the Parliament House Building structure. In addition, the first method of open excavation would also entail much wider excavation beyond the pit for which space was not available due to close proximity to the surrounding roads and Parliament House Building. Hence, it was decided to adopt the second method of anchored diaphragm wall and raft foundation.

4.0 FOUNDATION SYSTEM

The foundation system consists of following elements :

a) Diaphragm wall

b) Inclined and Vertical Rock Anchors

c) Raft

d) Water Proofing

e) Retaining wall

f) Protective Wall

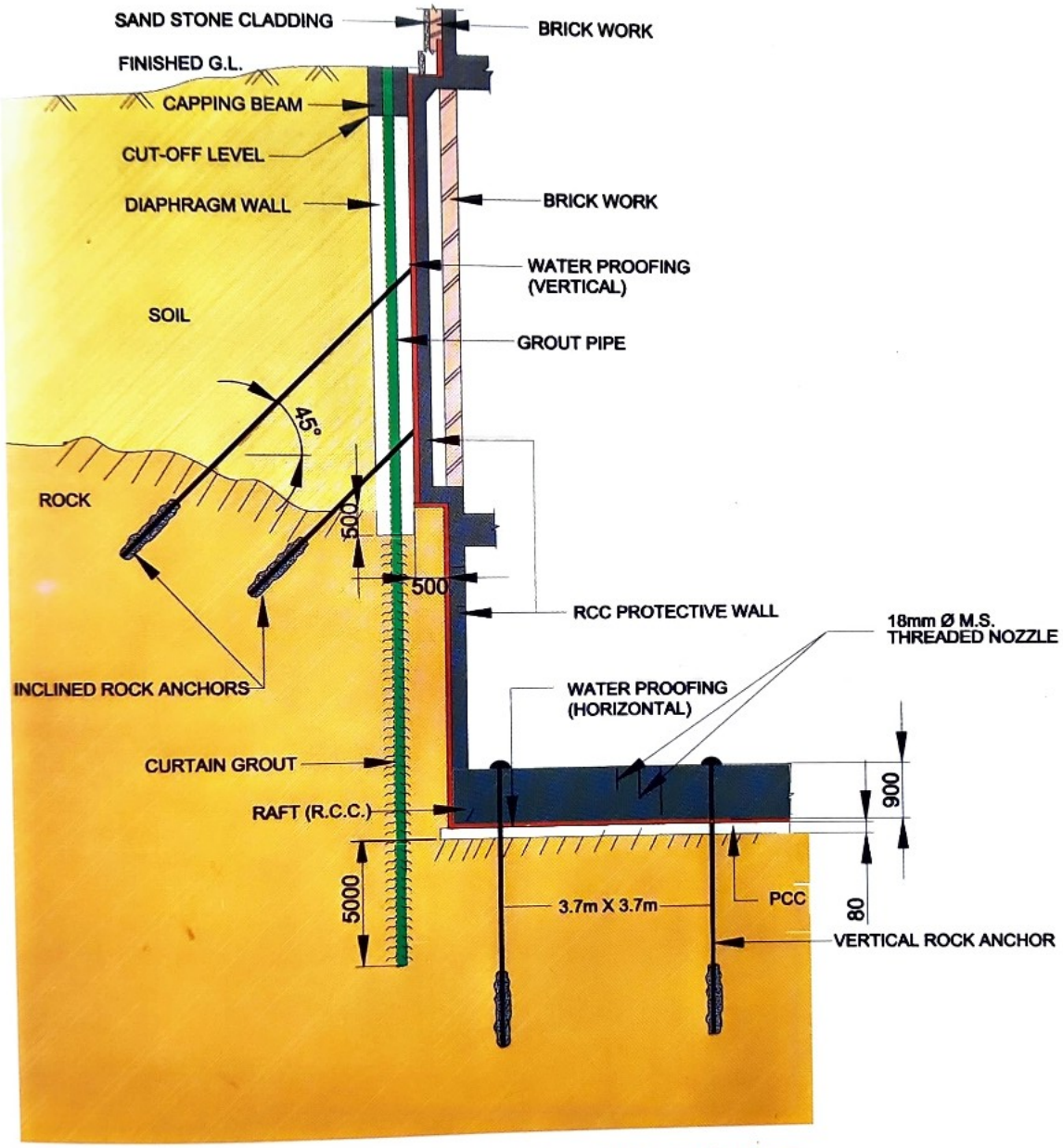


Fig 7.1 : Typical Foundation System

5.0 DIAPHRAGM WALLS

5.1 Brief Description

Diaphragm walls are panel walls in lengths of 5m having a thickness of 600mm with depths varying depending upon the availability of rock surface. The bottom of the walls are embedded 500mm into the rock. Wherever the rock level was located above the raft level, a 500mm wide ledge was also provided so that base of Diaphragm wall was not disturbed while excavation was going on. Inclined rock anchors are provided on to the diaphragm walls for stability during excavation.

5.2 Structural Analysis

The diaphragm wall is essentially treated as a rigid element. The static equilibrium is obtained by equating total horizontal pressure on the walls to the horizontal component of the pull in the anchors. The vertical loads due to self weight of diaphragm wall and vertical components of anchors are checked against allowable bearing capacity of rock. Two inclined rock anchors of 60t capacity have been provided at each level for every 5m panel. The number of levels vary from one to three depending upon the depth of the wall.

5.3 Structural Design

The bending moments and shear forces in the diaphragm wall in both directions were worked out and steel was provided accordingly. The minimum steel provided is limited to 0.2%. Concrete mix provided is 1:1½:3. The design is generally carried out as per IS:9556-1980. Other International Standards as well as sound engineering practices available from standard literature were used for analysis, design and detailing of these walls.

5.4 Trenching for Diaphragm Wall

The process of constructing the diaphragm wall begins with the construction of RCC guide walls (which were to be dismantled after completion of the diaphragm wall). This guide wall helps in keeping the grab in right alignment. The guide wall is laid out in panels of 5m length closely hugging the building line major part of which is in curvature.

Trenching for diaphragm wall is done with the help of rope-grab 4.30m in height and 1.83m in width. The total weight of this grab is nearly 3.5t and is operated by a crane. The capacity of TATA-320 crane used was 20t with boom length of 18m working in a plane at angle from 45^0 degrees to 75^0 with horizontal. Trenching operations with the grab go on till rock level is achieved.

The grab is then replaced by a chisel of required shape, size and weight to carry on further trenching in rock. For this purpose, elliptical chisel of 2t weight and



Guide Wall for Diaphragm Wall

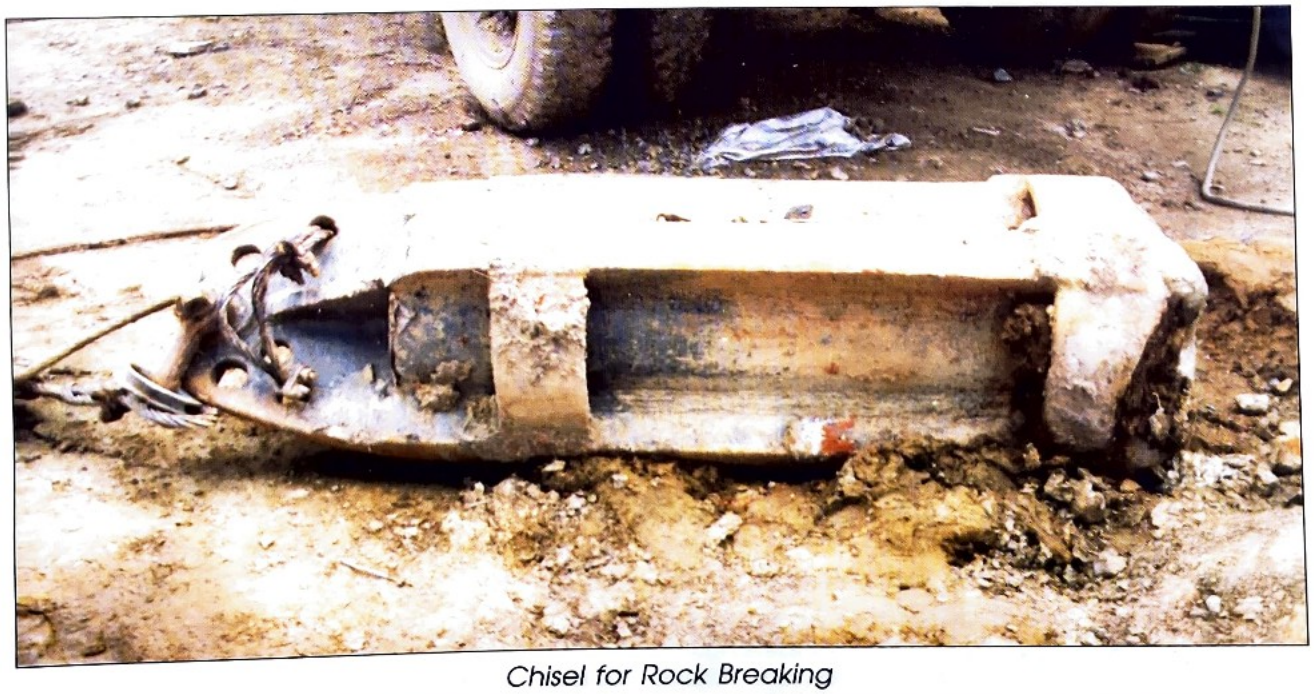
circular levelling chisel of 60cm diameter and 2.27t weight have been used. The samples of excavated rock help in deciding the founding level of the diaphragm wall since the diaphragm wall has to be embedded minimum 50cm into the rock.

More often than not, the rock stratum within a 5m panel length was found to be sloping. In such a situation the 50cm depth was taken from lowest point of the sloping rock.

During the entire operation of trench excavation, as also during the subsequent stage of construction of the diaphragm wall, the trench was kept filled with sodium-based bentonite slurry of 5% concentration (Fig 7.2) which has the property of stabilising the vertical sides of the trench and preventing them from collapsing. The bentonite was brought from Bhawnagar, Gujarat.



Grab for Trenching



Chisel for Rock Breaking

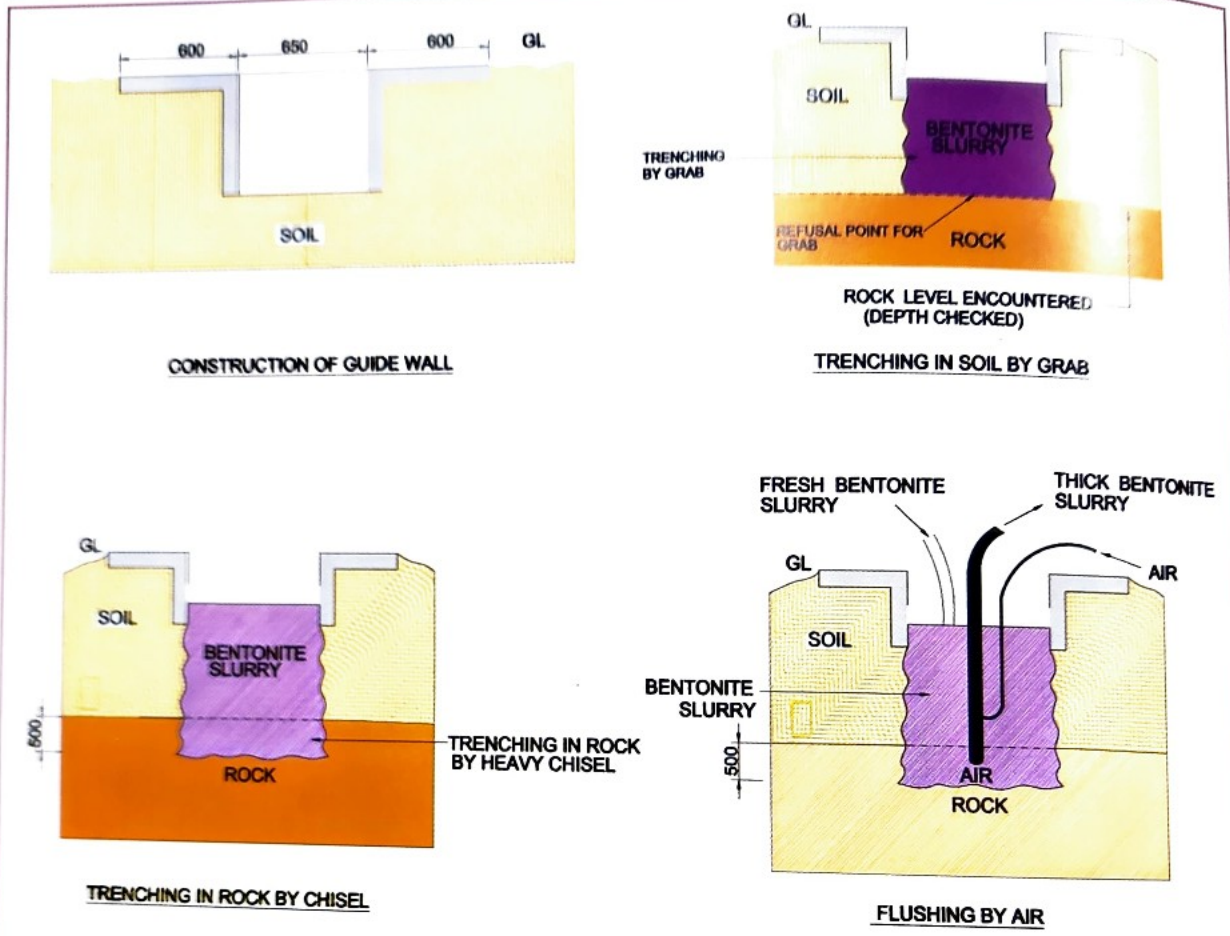


Fig 7.2 : Guide Wall & Trenching

5.5 Construction of RCC Diaphragm Wall

After the trench excavation work, the reinforcement cage for the diaphragm wall was lowered. The height of the cage was determined by the depth of the trench panel which in turn means the depth at which rock was found plus another 50cm for embedding the cage. Two gaps were left in the cage for inserting Tremie pipes used for underwater concreting of diaphragm wall. Trumpet pipes at the anchor locations i.e. 1.75m, 4.25m & 6.50m below the cut off level were left at the time of preparation of cage with necessary top pocket to accommodate the bearing and stressing plates of anchorage system. Length of the trumpet pipe was 50cm having 4.8mm thickness and 15cm internal diameter.

In each reinforcement cage 3 G.I. pipes, 65mm in diameter were placed vertically for the curtain grouting operation. Special reinforcement in the form of U bars, M bars, V bars, chairs, horizontal and vertical trimmer bars, end hooks for lifting, etc. were also provided. A mesh of 12mm diameter tor steel reinforcement was provided around the trumpet pipe on soil side of the cage to bear the shear stresses.

Before taking the reinforcement cage to the excavated trench panel, limited

welding of cross-members was done for imparting rigidity so that it retains its shape during its handling and subsequent concreting operations. Before placing the reinforcement cage in the trench, the trench was flushed properly to clean its bottom and to remove thicker slurry which might have been formed there over a period due to the settlement of Bentonite and intermingling of the slurry with the clay.

Finally, the reinforcement cage for the panel was lowered in the trench with the help of a crane. The Tremie pipes 20cm internal diameter & 6mm thickness were prepared in required lengths by connecting several pieces, threaded at ends and were inserted in the two slots meant for them in the cage. A hopper of 1.5m diameter was fixed with top to receive the concrete mix.



Tremie Pipe Being Lowered



Reinforcement Cage - Diaphragm Wall

A weigh batching plant having a capacity of 15 - 20cum/hour was used at the site for preparing the concrete mix. Apart from the screw driven cement pump four bins each having a capacity of 80cum for various ingredients were made for fulfilling material requirement of batching plant.

To restrict the water-cement ratio to 0.50 and achieve slump of 100-180mm required for diaphragm wall concreting, nearly 125ml of approved plasticizer was added to each bag of cement.

The concrete mix prepared at the batching plant was carried by tippers and unloaded into the hopper of tremie, the



Hopper for Concreting of Diaphragm Wall

opening of which was initially kept plugged with a plate and removed later so that the concrete mix goes down with force to completely push out the bentonite slurry present in the tremie pipe. This was necessary because the slurry should not be allowed to mix with the concrete. This was one of the reasons why the far end of the tremie pipe was always kept embedded in the concrete mix till the end, though the tremie pipe was gradually pulled upward as the filling level of the concrete in the trench started rising with more concrete mix going down. Gradual pulling out of the tremie pipe during concreting creates surges which facilitate flow of concrete and compaction. The diaphragm wall panels were tied with each other by a continuous capping beam above the cut off level.

Concreting of a panel was done in one operation in order to achieve a



Batching Plant

continuous surface without any joint. Diaphragm wall was constructed in panels using successive-panel method; i.e. a panel was cast by the side of another completed panel so as to form a good joint and continuous leak proof diaphragm wall.

The joint between two successive panels was made by using stop-end pipe of inner diameter 58.5cm of thickness one cm. Thus, before the reinforcement cage for a succeeding panel was lowered, the circular stop-end pipe of the preceding panel was gradually pulled out by deploying hydraulic jacks after the concrete had partially hardened leaving a semi-circular key in the preceding panel which was occupied by the male end of the succeeding panel to form a perfect joint.

At some places special bent panels of length smaller than 5m (4.3m and 4.14m) were cast to follow the circular shape of the building. At bent panels three tremie pipes were used instead of the usual two pipes. The third pipe was used to ensure proper flow of concrete at the joints. Also in some cases to avoid criss-crossing and fouling of anchors, sharp corners in diaphragm wall were avoided by straightening the alignment for casting the diaphragm wall.

Thus a total of 84 panels of diaphragm walls in 410m of periphery having total area of 2900Sqm were completed in less than four months. These panels were anchored by 360 inclined rock anchors.

6.0 ROCK ANCHORS

6.1 History

Ground anchors are in use by Civil Engineers for the past 50 years. In India, the application has been limited to works related to dams and stability of slopes. However, in a few buildings in Mumbai, anchors have been used in the past.

6.2 Types of Rock Anchors

Rock anchors have been used for the stability of the Diaphragm walls as well as against the uplift forces on the raft due to high water table. Two types of rock anchors namely "Inclined Rock Anchors & Vertical Rock Anchors" have been provided in the foundation system.

6.3 Design of Anchors

The design involves determination of fixed and free lengths of anchors. Anchors also need to be designed for required capacity. The analysis, design and testing



Inclined Test Anchor

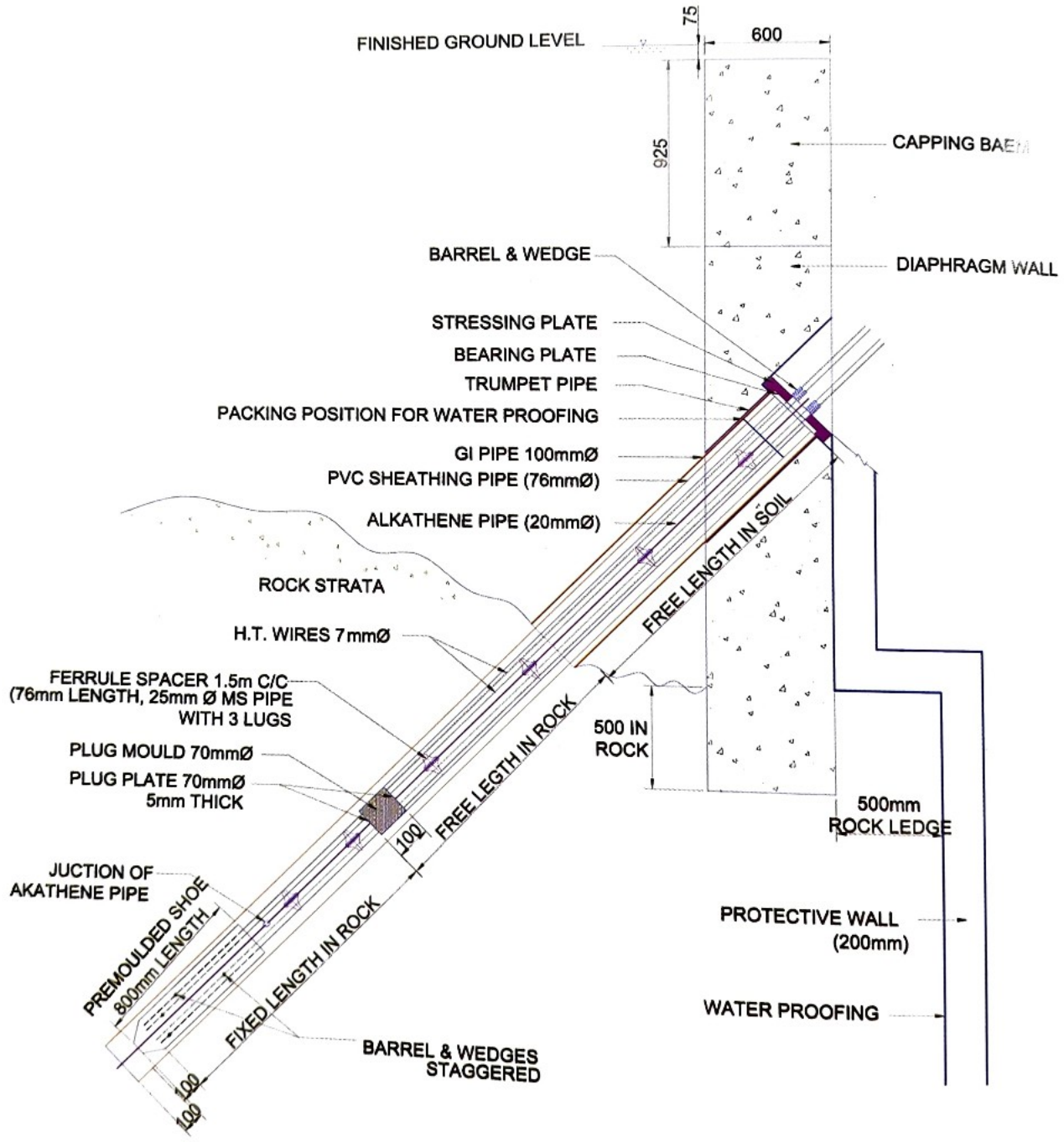


Fig 7.3 : Schematic Diagram of Inclined Rock Anchor

of the anchors were based on sound engineering practices available through Indian and other international codes of practice. British Standard code requires a minimum of 5m each for fixed and free lengths. It also limits the working stress in wires to 0.7 times of ultimate tensile strength. In this project a fixed length of 5m was used whereas free length of 5m for 60t inclined anchors and 8m free length for 110t vertical anchors was used.

6.4 Inclined Rock Anchors

The total length of an anchor was divided into free and fixed lengths. Fixed length portion of each anchor was necessarily embedded in rock. Some part of free length depending upon design, was also embedded in rock and the rest of the free length remained in soil. B class mild steel trumpet pipe of 150mm diameter and 4.8mm thickness painted with steel primer was placed at 45^0 to horizontal in the reinforcement cage of Diaphragm wall with necessary top niche to accommodate the anchorage bearing and stressing plates. Trumpet pipe was extended to the outer face of reinforcement cage of diaphragm wall.

a) *Preparation of Anchor Hole :* Anchor holes were drilled upto required depth with 5" diameter drilling bit in soil portion and 4" dia bit in rock portion with the help of Halco rigs. The drilling rods were 2m in length which could be assembled upto desired length. In soil portion G.I. pipe of 100mm diameter was installed to support the sides of the holes. The annular space between G.I. Pipe and the trumpet pipe was filled with cement concrete having 10mm and down stone aggregate admixed with water proofing compound.

   The required water proofing of the drilled hole was done by repeated cement grouting, washing, re-drilling, and re-grouting and so on. Re-drilling of the grouted hole was done while the grout was still green. After re-drilling, the hole was thoroughly washed with water and or with compressed air to remove loose materials. The hole was tested for water intake by fixing a rubber plug at the top of hole. The hole is considered adequately water proofed, if the water loss is less than 3 lugeons. The water test is conducted at a normalised test pressure of 0.5Kg/sqcm or less. If the lugeon value is more than 3, the process of grouting, re-drilling, re-grouting, washing and water test is repeated till required lugeon value is attained.

b) *Preparation of Anchor Assembly :* The cable anchors of 7mm diameter High Tensile (HT) wires conforming to IS: 1785 Part-I were prepared in a separate anchor yard and 18nos of wires were used for 60t capacity inclined rock Anchors.

   For protection against corrosion, free length of anchors were cleaned with sand blasting/sand papering. Primer coat of Berger Epilux 4 was applied, when the primer coat was sufficiently dry a coat of epoxy based paint Berger Epilux 4 was applied. Testing of primer and epoxy based paint was done as per IS: 14209 and IS: 12994 respectively.

   Fixed length was treated with sand blasting followed by de-greasing with acetone.

Three coats of epoxy, formulated by Araldite GY 257, Hardener HY 840 and Hardener HY 960 in 100, 45 and 5 parts by weight respectively were applied. While the third coat was still tacky, quartz sand was sprinkled to enhance the bonding.



Epoxy Painting of HT Wires

The HT wires were grouped together into a circular cable with ferrule spacers at 1.5m centre to centre. This ferrule spacer consists of 25mm M.S. pipe, 76mm long with 3 lugs. At the junction of fixed and free length a plug is formed by two circular M.S. end plates of 70mm diameter and 5mm thickness with 18 holes for high tensile wires & one hole for alkathene pipe. The wires are passed through these plates. The spacing between the two plug plates is kept 100mm which is filled with cement grout of 0.4 water cement ratio. A PVC sheathing of 76mm diameter and 2mm thickness is placed over the free length of the cable, starting from the plug level. A pre-moulded shoe, of 76mm diameter and 800mm long is cast using cement grout of 0.4 water cement ratio at the tip of the cable anchor assembly. A 20mm dia alkathene pipe to fill cement grout is provided to run through the cable assembly starting from outer end to the other end i.e. upto the shoe.

c) *Homing of Cable :* The cable assembly was gradually lowered into the hole which was properly washed and filled with water upto the top of trumpet pipe. Water was injected into the hole through the central alkathene pipe during homing process and continued till the grouting of fixed length is started. Fixed length of anchor was grouted with cement grout of 0.4 water cement ratio through the central alkathene pipe until the grout comes to the top of hole through annular space between the sheathing pipe and the G.I. pipe. The alkathene pipe was gradually withdrawn upwards during the process of grouting. The free length of the anchor was washed with water till clear water appears on top of hole and alkathene pipe was taken out of the hole.

d) *Prestressing/Tensioning the Wires :* Mild steel bearing plate 6mm thick was embedded with cement sand mortar at right angles to the axis of the hole in the anchor head niche. Mild steel stressing plate 50mm thick was placed over the bearing plate and the cable wires were passed through the holes of the stressing plate. A minimum period of 21 days was allowed to elapse after homing including

grouting of fixed length before stressing of wires was taken up. Thereafter, each wire was stressed using single wire stressing jack to design load + 10% of design load and released to zero. This cycle was repeated 2-3 times to neutralise the effect of "Permanent set". Barrel & wedge of "Killick Nixon" make was placed around each wire over the stressing plate.

After neutralising the effect of Permanent set wires were tensioned to design load + 10% + 5mm extension so as to neutralise wedge slip and were then locked with barrel and wedges. To monitor the loss of prestress, the residual stress was checked after 24 hours of stressing by pulling wires using the jack and reading the corresponding readings. The residual stresses in some anchors were checked after 7 days and 30 days also to monitor the loss of prestress. One anchor was even checked after one and half years and the prestress was found satisfactory. If the residual stress was more than the capacity of the anchors the projected lengths of the wires above barrel and wedges were cut.

e) *Final Grouting of Cable Hole :* Within 14 days of tensioning, the free length of anchor was cement grouted using hand injection pump with water cement ratio of 0.5. After cleaning of stressing plates, barrel and wedges thoroughly, epoxy paint was applied to the anchorage system. Finally the anchor head was cast concluding the process of installation of Inclined rock anchors.

f) *Testing of Anchors :* To ascertain capacity of anchors, 4 inclined anchors and 8 vertical anchors were tested at site at different locations with different free and fixed lengths. The bore log samples were also collected, help of which was taken in finalising the design of the anchors.

6.5 Vertical Rock Anchors

The process of preparation of anchor hole, anchor assembly, homing of cable, prestressing / tensioning the wires and final grouting of cable hole for vertical rock anchors is same as in the case of inclined rock anchors except the following.

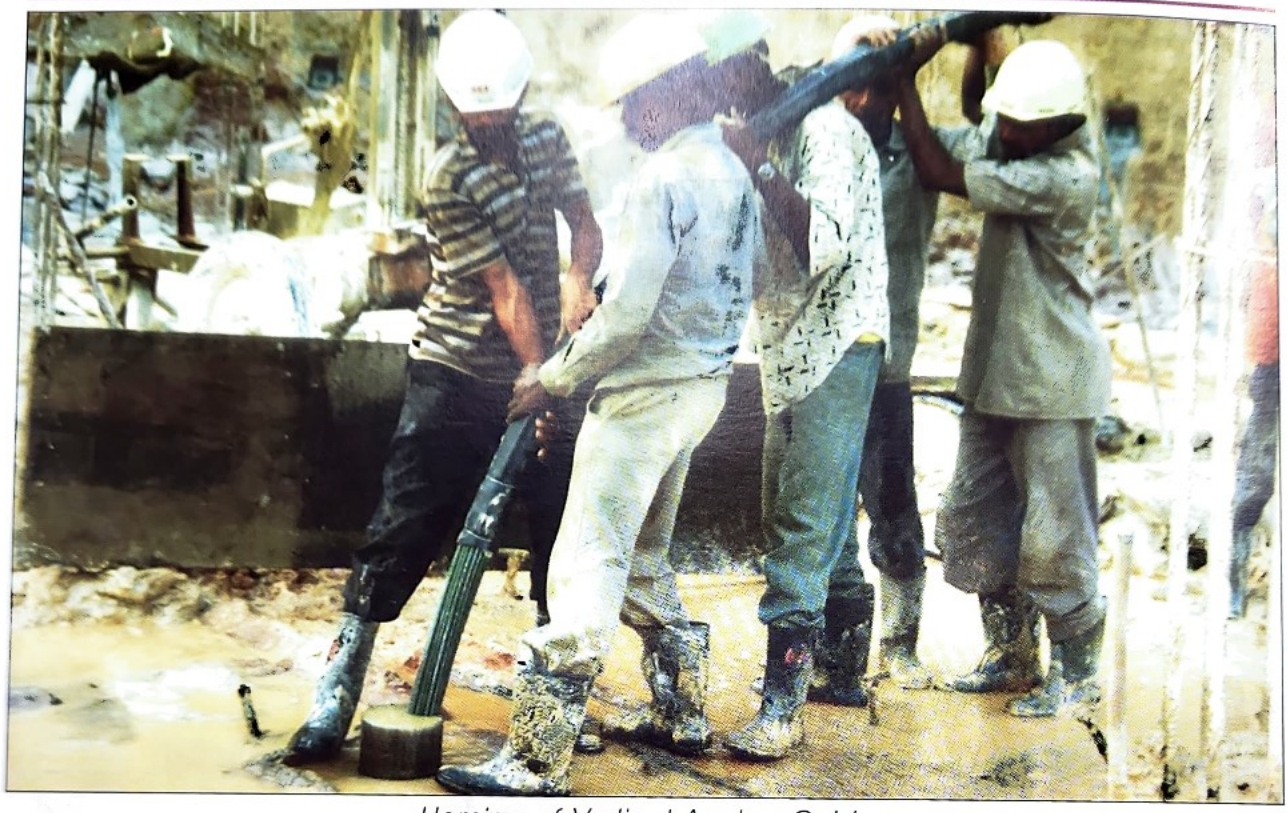
a) Trumpet pipe of 150mm diameter was placed vertically in reinforcement cage of raft before casting and extended upto top of the water proofing layer.

b) Minimum distance between anchor and column or wall was kept 80cm & anchors were avoided at pedestal locations.

c) Three nozzles of different lengths were provided around the trumpet pipe for subsequent grouting for water proofing.

d) The capacity of vertical rock anchors was 110t and anchor assembly was made of 33 nos high tensile wires in place of 18 nos wires used for inclined rock anchors.

e) Free length of anchor was grouted upto PCC of the raft and since the water proofing treatment over the PCC had been punctured by drilling for the rock anchors, the free length available in the raft depth was filled with cement grout



Homing of Vertical Anchor Cable



Pretressing Vertical Rock Anchor Cable

having non-shrink polymeric grouting compound as per the manufacturers specifications through the G.I. nipple welded on the stressing plate. In case any seepage was noticed, the top 30cm to 45cm of the free length was re-drilled and again grouted using non-shrink polymeric grouting compound.

7.0 EXCAVATION

It was estimated that nearly 2 lacs cubic metre of excavation is to be carried out in soft soil, hard soil, soft rock & hard rock partly in or under water having different lifts and leads. Use of heavy machinery became essential due to the mass excavation involved to be carried out in a limited period. Since no stack measurements were contemplated due to the site being very restricted, the measurement were based on levels. These levels were to be recorded initially before the start of excavation, then after completion of excavation in all kinds of soil (but before the start of excavation in rock) and finally after completion of the entire excavation work. Since costly item of rock excavation is involved, the recording of levels at closer interval of 1.25m was specified instead of the usual 5m.

7.1 Problems in Excavation

Following main difficulties have been encountered in the excavation.

a) The site being in a VVIP security area, the movement of trucks was restricted for limited hours only and that too during the nights.

b) Identification of dumping area for excavated stone/ boulders was difficult.

c) Excavation calls for continuous dewatering in certain pockets and the work was adversely affected during rains.

d) Since explosives were not permitted, extra efforts were required for breaking the rock and excavating them.

7.2 Dewatering

In order to improve the impermeability of the rock mass i.e. to reduce the ingress of water towards the rock/ mass, curtain grouting has been carried out in rock mass below the Diaphragm wall and below Retaining wall. This has helped a lot in arresting the water inflow and thus facilitated the excavation. Normal dewatering was however required for bringing down the water table below the working level. The rock level below ground level was varying from 1.2m near main entry to 13.5m near Talkatora Road. The excavation was started from the areas where the rock level was expected high and then moving towards lower levels. A variety of heavy machinery were employed at various stages in an effort to use the most appropriate equipment suited for the kind of rock stratum encountered.

7.3 Excavator Loader

Conventional hydraulic excavators were found to be very useful and fast for excavating soil, soft rock, moorum etc. To some extent they were also used to take out

large individual boulders by carefully prising them out at the naturally occurring rock fissures with the jaws of their buckets. The yield obtained in the soft rock was very less and these excavators with normal buckets could not work in hard rock.

7.4 Pneumatic Pavement Breakers

These are demolition tools suited for demolition of foundations, walls of concrete and bricks, cutting and breaking pavements, etc. Pavement breakers could not produce the desired yield owing to rocky strata.

7.5 Drilling

The drilling was tried with jack hammer drills since the holes are of short length and small diameter. Selection of the drilling equipment depends on a variety of local factors and expert opinion was sought before making a final decision. For the rock strata encountered at site a combination of Jack Hammers & Rotary Drills were employed.

7.6 Hydraulic Rock Splitter 'DARDA'

For splitting rock a "Hydraulic Rock splitter "DARDA" was imported from Germany by the agency at a cost of Rs. 21 lacs with two wedge sets on splitting cylinders. One splitter can split about 100-120 holes in 10 hours working with one splitting cylinder. DARDA rock splitter operates on the wedge principle. The wedge



Hydraulic Rock Splitter

assembly consists of one wedge or plug and two counter wedges inserted in a predrilled hole with the wedge in a retracted position. Hydraulic pressure pushes the wedge forward forcing the two counter wedges side wards against the wall of the hole.

To start with, the wedge set of the splitting cylinder is inserted in the previously drilled hole. As soon as the pump is started the wedge is slowly driven between the two counter wedges separating them with a lateral force upto 350t thus splitting the rock mass within seconds. Prior to the starting of the splitting process, a number of holes of required diameter and depth (approximately 70 cm deep) were to be drilled with the help of BBC Drifters or pneumatic Jack hammers at close intervals of about 30cm (depending upon the nature of rock) centre to centre.

This drilling process produced a lot of dust and noise at site besides proving very costly and slow in results. The drilling bit costing Rs. 2,000/- each which in the normal circumstances should have done about 60-70m of rock drilling could only produce 15-20m of drilling. Further on an average only 35-40 holes in normal rock and 10 -15 holes in hard rock per day per jack hammer could be drilled, 3 to 4 jack hammers with 3 labourers for each jack hammer could yield only one cum of split rock per six holes.

Seeing the quantum of rock excavation, time constraints and the cost of the drilling and splitting, the rock splitter was not considered suitable for mass rock splitting for the present site conditions, though was very useful for limited line drilling and splitting the rock near the retaining walls and diaphragm walls where vibrations and under mining were not desirable so as to maintain the stability of these walls.

Since the splitter was not found suitable for mass rock excavation, need was felt for more efficient methods. Therefore, it was decided to procure "Krupp" Hydraulic Hammer which again was imported from "Germany" costing nearly Rs. 22 lacs and could be fitted to an L&T-90 excavator.

7.7 "Krupp" Hydraulic Hammer

These hammers offer unbeatable performance, economy and efficiency and are environment- friendly. The 'double effect' system minimises noise and vibration levels. One "Krupp" Hydraulic Hammer was imported in November, 1994 from Germany by the Agency. The model of the hammer used was HM 960 CS. There are different types of tools which can be fitted into this hammer used for a wide variety of applications. The type of tool exerts a great influence on the performance, efficiency and economy of the hydraulic hammer.

The hammer performance per 8 hour shift, for different applications are as under.

a)	Non-reinforced concrete	270 - 500 cum
b)	Reinforced concrete	160 - 350 cum
c)	Reducing over sizes	350 - 750 cum



'Krupp' Hydraulic Hammer

Since the main application at this site was to break the rock in situ, we achieved about 40% of the performance level of "reducing oversizes", which proved to be quite encouraging for increasing the progress of excavation which was otherwise posing a serious challenge.

7.8 Pre-Heating and Hammering

Very hard blue quartzite rock was found in main entry block, BPST and AV Museum Block, which was too hard to be broken even by "KRUPP" hammer or manual cutters. These difficult locations hindered the normal raft concreting work upto three months.

Therefore, we had to resort to the "Preheating" and splitting of the rock. The rock belt was heated by burning inflammable material for about four to five hours and then cooled pouring cold water. Alternate heating & cooling resulted in cracking of the top crust which was then removed with the help of "Krupp" hammer and excavators.

Preheating of rock without cooling and applying "Krupp" hammer on heated rocks gave still encouraging results. The average top crust removal was found to be 30cm per preheating in very hard rock.



Preheating of Rocks



Drilling of Holes

7.9 Drilling – Preheating and Hammering

The preheating and splitting proved to be an infructuous exercise in some harder rock fragments. In these locations horizontal and vertical holes of 100mm dia were drilled at an average distance of 30cm or less, centre to centre by "Halco" drill machine. These were then preheated and broken by applying "Krupp" hammer. This gave slightly improved results thus slowly progressing to our goal of total desired excavation.

7.10 Jack Pushing of Rock

In this method large chunks of rock masses could be split from their separating planes by use of heavy duty hydraulic Jacks. Firstly, the separation planes were identified by cleaning the soil layer using compressed air and water under pressure. Then the space was created so that jack could be fixed against a bigger mass to generate the reaction and to give necessary thrust on rock mass to be pushed. The jack used was of 270mm dia and 480mm length with effective ram/dia of 200mm and maximum expanded length of 250mm. After fixing firmly the jack was activated



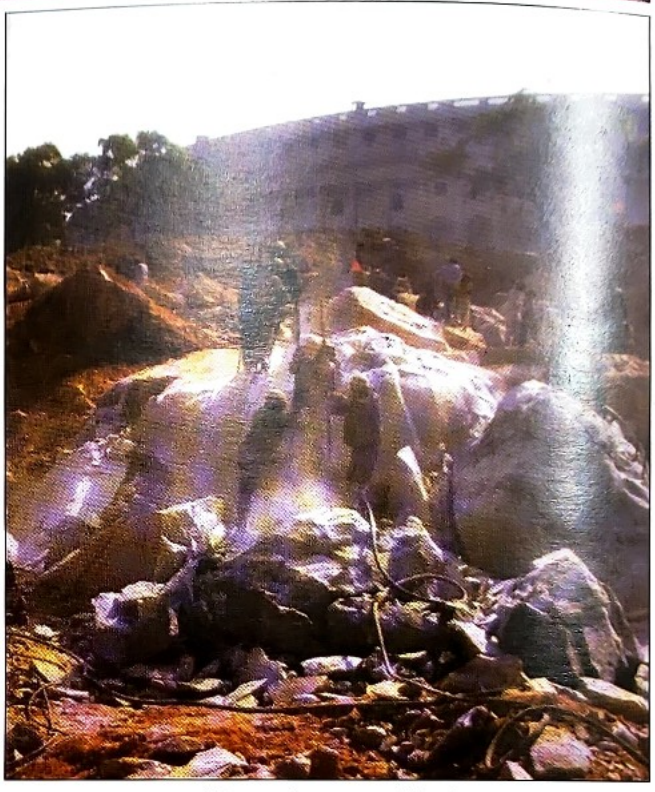
Jack Pushing of Rock

which can produce a total reaction of 200t.

This large force was thus able to push the rock mass from their position along the separating plane. This separated rock mass thus could further be easily reduced to small sizes either by "KRUPP" hammer or rock splitter and removed easily.

7.11 Khandars

The manual labourers known as Khandars are those who use the crow bars and make the efforts for separating the rock boulders/ mass from the already available cleavage/ stratification. After such separation, the hammer is applied for converting into small size boulders.



Khandars on Work

A series of small dia holes (20-25mm) having depth 3" to 4" are made depending upon the nature of rock. Then the wedges are inserted and the hammer is applied in succession to force the rock to crack along the defined line of the holes. The yield from the khandars in case of loose/ soft rock is more but the yield from hard rock mass is negligible.

8.0 RAFT

The plan of the raft is the same as that of the building. No joints have been provided in the raft, although the superstructure has been separated into eight blocks by expansion joints. The raft is at two levels, (-) 8.670m in the main building portion and (-) 9.345m in the parking area. The raft has been laid in slopes of 1:150 for drainage purposes. The total area of the raft is 19000sqm. Shrinkage strips (Fig 7.6) have been provided in the raft to allow for concrete shrinkage considering the large area of concreting. These are 1000mm in width with reinforcement bars bent in plan. Raft of 900mm thickness has been designed considering water table at three levels i.e. at ground level, below raft level and at a depth of 4m below ground level.

8.1 Structural Analysis

Considering the large and irregular geometry of the raft foundation and presence of 855 columns and 1752 Vertical rock anchors, it was decided that the heaviest loaded part of the raft should be analyzed to firm up the design procedures. It was found that the central block was the heaviest loaded. Since this particular area is symmetrical about both axes only a quarter of the block was analyzed in detail. The part of the raft has been analyzed using the "Finite Grid Method". This method discretises the raft into beam elements running between nodes. The width of the beam extends upto half the

internode spacing on both sides of the beam. At each node, there are 3 degrees of freedom. The soil system below the raft is idealized by the "Winkler's Bed". The compatibility of forces and deflections are ensured at each node. The vertical loads and moments are applied at the nodes.

The raft has been divided into column strips and middle strips as per the requirements of a flat slab. The columns are spaced at 5m x 5m, 7.5m x 7.5m, and 10m x 10m grids. The raft slab was checked for punching shear and it was found that for a few heavy columns spaced at 10m x 10m the codal limits were being exceeded. It was decided to provide pedestals at some locations and pedestal along with shearheads at others.

8.2 Placement of Reinforcement

Water proofing over the lean concrete base was first completed and reinforcement was placed carefully so that water proofing layer remains intact. Trumpet pipes for vertical anchors were placed in a grid form having centre to centre distance of 3.7m in the entire raft. M.S. nozzles of 20mm dia having length of 23cm, 45cm and 63cm were also fixed at a spacing not exceeding 1.5m centre to centre in both directions. At the construction joints the spacing was reduced to 75cm. The nozzles were used for subsequent grouting with cement admixed with non-shrink polymeric grouting compound.

8.3 Concrete Laying

1:1.5:3 (1 cement : 1.5 coarse sand : 3 graded stone aggregate 20mm nominal size) mix was used for concreting in raft. Proportion of various ingredients of cement concrete were by volume; however mixing was carried out with a weigh-batching plant after converting the proportion of ingredients into their masses considering their bulk density, percentage moisture content and percentage water absorption with an objective to obtain maximum possible density.

Concreting for raft was done using concrete pump. The capacity of concrete pump was 20cum/hour. The concrete of desired mix was unloaded in the chute of concrete pump from the weigh-batching plant from where it is passed through the pipe line under pressure. Pipe line was made to required length by clamping 125mm diameter highly abrasion- resistant carbon steel pipes each of 2m to 3m length. Approved plasticizer was also added in the mix for restricting water cement ratio upto 0.5 and to provide adequate workability to the concrete to flow through pipe line. At the end of pipe line a flexible hose pipe was connected for facilitating the movement of pipes for proper concreting. After concreting was over, the pipe lines were cleaned by passing a ball of adequate size with pressure so as to make it suitable for subsequent concreting.

Shrinkage strips at defined location with reinforcement having a kink or overlap were provided to allow the shrinkage of adjoining raft. The concreting in this strip was done after 28 days of concreting of adjoining rafts. Nozzles at 60cm intervals along



Concreting in progress

the construction joint were provided for grouting with non-shrink polymeric compound (Fig. 7.6).

In the raft the peripheral drain, drainage sump, sewage sump & lift pits were also provided as per structural drawings.

8.4 RCC Pedestals

Where the raft was founded on soil (rock level being much lower in these places) it had to be ensured that the loads are transmitted on to the rock strata to avoid any differential settlements in the continuous structure. To satisfy this requirement following alternatives were considered below raft level in Parking and Auditorium areas where such a condition was met.

a) Minipiles

b) Bigger dia piles

c) Sand filling

d) Diaphragm wall in grid pattern.

e) Expansion joint in the raft at the junction

f) Provision of pedestals

Each alternative was scrutinized with respect to financial, structural and time requirement after correlating with the existing site condition and provision of pedestals was found to be quite economical and faster as compared to other alternatives.

Structural drawing of pedestals shows cross-section of 1.3m x 1.3m in plan below each column location in parking area where the columns are on regular grid. The pedestals were taken up to 15cm in the rock. In the Auditorium area the pedestals are provided at 3.7m centre to centre as the columns are not on regular grid. The centre to centre spacing between vertical anchors are also 3.7m. Therefore, pedestals are provided in such a way that no where these interfere with vertical anchor locations.

Pedestals upto 3.25m depth have been cast quite successfully. The depth of pedestals varies from 75cm to 3.25m depending upon the depth of soil strata below raft level. All the 106 pedestals were cast in a period of one and half month and raft could be successfully laid before on set of monsoon.

9.0 WATER PROOFING

As already stated, the main building has two basements & parking is a three level underground structure. Unlike most of the buildings, both the basements in this building are functional and the lower one is to house a large volume of Library material, in open as well as closed stack system. The whole building is air conditioned not only from comfort point of view but also from consideration of protection to the library material. Any seepage in the building particularly in basements would defeat the very purpose of library i.e. storing of library material without any damage to it. This demanded a water proofing system which would ensure bone-dry conditions in the basements.

9.1 Selection of Water Proofing System

Water proofing consisted of surrounding the entire structure with a continuous membrane that will prevent water coming in contact with the structure. Solid stone slabs such as Kota stone treatment was not considered suitable since it would have resulted in making 1500 holes in the stones for anchors & ensuring water proofing of these holes besides treating joints between the stone would have been difficult. Factory made products i.e. Tarfelt or similar membranes also did not find favour because of the difficulty in treatment of joints, possibility of pinholes and air bubbles and their damage during construction. For long – term water proofing performance liquid membranes were preferred as they readily conform to all shapes and contours and are easy to apply. However, total dependence was not made on liquid membranes, and some layers which could perform a dual function- both as a protective layer for the liquid membrane, as also an additional water proofing layer- had to be introduced. To achieve this, cement plaster layers admixed with water proofing compound were introduced; both for horizontal & vertical faces. Another protective layer by way of guniting admixed with water proofing compound was also introduced for the vertical

faces. Curtain grouting upto 5m below the founding level was also done to retard the ingress of water into building.

9.2 Cement Curtain Grouting

Cement grout of varying consistency was pumped upto a depth of 5m below the excavation level with a view to fill up crevices in the rock. It served two purposes; consolidation of the rock to some extent and cutting off substantially the ingress of water. The curtain grouting was carried out in different stages. The first stage grouting was done in following areas upto 5m depth below bottom of PCC under raft.

a) Below diaphragm wall

b) Below retaining wall

c) From ground level through overburden

In diaphragm wall, three grout pipes of 65mm dia were lowered along with reinforcement cage of each panel. In case of retaining wall a base grout pipe was provided in the base of retaining wall during casting. Whereas in case of Ground Level a G.I. Pipe in the overburden or soil depth was provided in the ground and stabilised by cement grout.

A reciprocating Grout Pump was used for preparation of cement grout and pumping grout under pressure. The grout is mixed and agitated in the mixing tank and agitating tank respectively. These are fixed with puddles. After mixing, the required quantity of grout was taken to the agitating tank. The whole assembly of Grout pump and Grout Mixers is powered by compressed air. For developing desired pressure a rubber packer is provided in the stand pipe/Grout pipe, along with pressure gauge & flushing valve.

Drilling was carried out in alternate holes (or two outer grout pipes of Diaphragm wall) called primary holes, after the concrete of diaphragm wall attained sufficient strength. The drilling was done for minimum 38mm diameter with the help of drilling machine called BBC Drifter. After drilling to the required depth was complete, the hole was washed with adequate quantity of water for about 20 minutes so as to remove deposits of erodible materials till clean water comes on top of the hole.

After washing of the hole, percolation test was conducted, before grouting operation, at a limited test pressure to avoid hydraulic fracture. The pressure during water test was limited to 0.5 kg/sqcm. The injection of water at this constant pressure was continued for a period of about 20 minutes.

After conducting percolation test, the drilled hole was grouted. First stage drilling was done upto 50cm below the bottom of diaphragm wall and about 3m to 5m below in case of retaining wall. The first stage below diaphragm wall (which is in shattered & fractured condition due to chisel blows during trenching) was grouted and consolidated in a single mass by a comparatively thicker initial grout of water cement mix of ratio 5:1. In other cases initial grout mix used was 20:1.

Same grout mix was continued if the increase in pressure was observed during injection, if not, the grout mix was thickened gradually till the desired injection pressure was attained. When a surface leakage is observed on ground, thickened grout is pumped and hole is left till the grout is set.

After completion of grouting, holes were closed at top to maintain grout pressure for a sufficient period to prevent escape of grout due to back pressure, for about 2-4 hours. After this the grout was washed from the hole prior to its final set. Then percolation test was conducted not before 5-6 hours after completion of grouting. After which the hole was further drilled for the next stage.

The cycle of drilling, percolation test, grouting, washing or re-drilling and percolation test was repeated until the required depth of the hole was reached. After reaching final depth the cycle of water test was repeated till Lugeon value of less than 3 was achieved. Limiting pressures of 0.5kg/sqcm, 1.0Kg/sqcm and 2.0kg/sqcm have been adopted from stage one to stage three respectively.

During grouting of the primary holes, the effect in the adjacent secondary holes was also observed by way of percolation tests after each grouting in Primary holes. If LUGEON VALUE of less than 3 was observed no grouting was found necessary, otherwise secondary holes were also grouted and water tested till desired water proofing was achieved.

It is not possible to reduce the seepage 100% by curtain grouting. However, the overall objective of curtain grouting was to avoid concentrations of seepage and reduce the permeability of the rock.

9.3 Horizontal Water Proofing

A layer of an acrylic-based-Polymer, Tapecrete- CICO (Tapecrete P-151 is a vinyl acetate – ethylene accreylate copolymer emulsion in water. This emulsion is stabilised

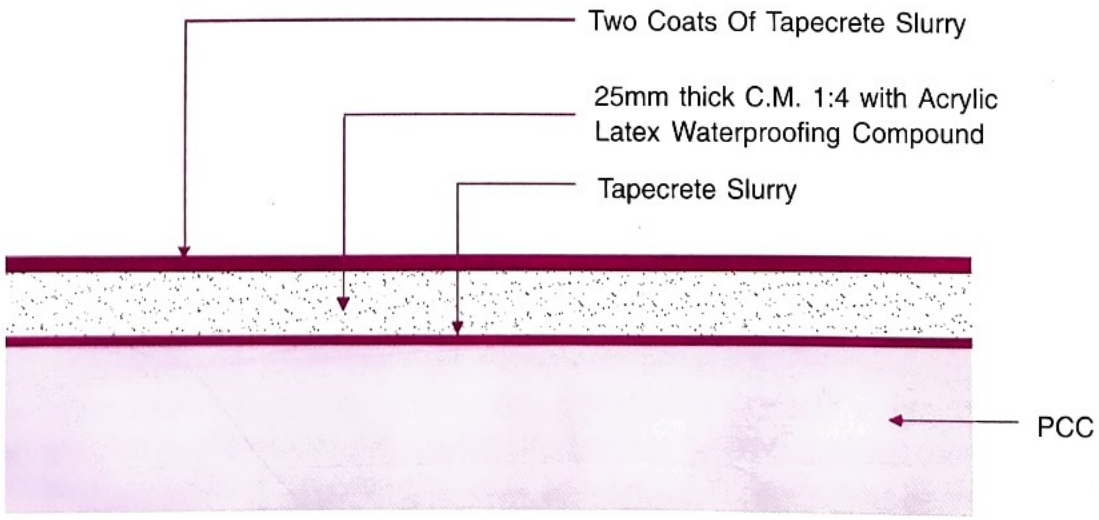


Fig 7.4 : Water Proofing Details on Horizontal Surface



Waterproofing on Horizontal Surface in Progress

and blended with other polymers which imparts extra bond strength to hardened cement mass when mixed with hydraulic cement), was brush applied on the clean but moist surface of PCC. A slurry was prepared by mixing 100Kg of cement and 52kg of Tapecrete P-151 polymer of CICO & was brush applied in a single coat. When this coat was still green 25mm thick cement plaster 1:4 (1 cement : 4 coarse sand) admixed with Acrylic Latex Integral water proofing compound @ 2% of cement was laid. Over the plastered surface after its setting and hardening again two coats of tapecrete slurry were applied. The tapecrete layers were cured for 3-4 days.

9.4 Vertical Water Proofing

The excess cut in the vertical surface of rock excavation were filled with cement concrete using proper shuttering, as far as possible to give fairly vertical surface. The vertical surface of diaphragm wall, retaining wall or rock cut face was thoroughly cleaned by the process of sand blasting. Shotcreting was done with cement mortar 1:4 (1 cement : 4 coarse sand) admixed with Acrylic latex integral waterproofing compound @ 2% by weight of cement. The average minimum thickness of shotcrete layer was 25mm but in no case thickness was less than 10mm. Shotcrete layer was cured for minimum 7 days.

One coat of tapecrete slurry was applied over the shotcrete surface. Over this layer of tapecrete two layers of cement plaster 1:4 (1 cement : 4 coarse sand), 12 mm thick each were applied admixed with Acrylic latex integral waterproofing compound with application of one coat of Tapecrete slurry in between these two layers. Finally two more coats of tapecrete slurry were applied over the plastered surface and adequately cured. This water proofing treatment was covered by RCC Protective wall.

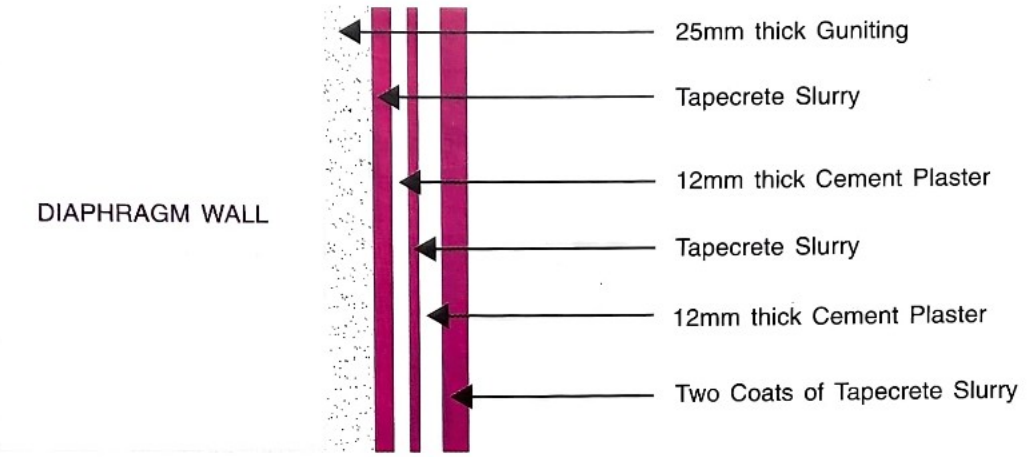


Fig 7.5 : Waterproofing Details on Vertical Surface

9.5 Cement Grouting of Protective Wall & Raft Joints

The diaphragm wall not only retains the soil / rock mass behind, but also acts as a first line of defence against water ingress whereas raft (after the water proofing layer) acts as second line of defence against water entering the building. The attempt was therefore to get concrete as dense as possible. Despite taking all care in design, mixing & laying of concrete, the fact that the concrete can never be totally impervious was always causing worry. Therefore the RCC members (the raft & protective wall) were grouted at construction joints and other critical locations with cement slurry admixed with non–shrink Polymeric grouting compound. The cement grout fills the pores of the concrete. The grout when it sets does not shrink but expands a little bit, thereby making concrete more impervious.

a) *Injection Grouting of Raft* : MS threaded nozzles of 20mm dia of lengths 25cm, 45cm & 67cm approximately were left welded to the reinforcement of the raft in a grid of approximate size 1.5m x 1.5m. These nozzles were plugged with a T-shaped rod to prevent clogging by concrete. After raft concreting was over, the rods were removed & nozzles plugged with threaded MS Cap. After the concrete has set, a non–shrink polymeric water proofing compound @ 1% by weight of cement mixed with cement slurry was injected into these nozzles under a pressure of about 2kg/sqcm. The consistency of the grout, pressure etc. vary in accordance with consumption pattern.

b) *Injection Grouting of Protective/Counterfort Retaining Wall* : MS threaded nozzles of suitable length were fixed in a grid pattern not exceeding 1.5m x 1.5m in the protective wall/ counterfort retaining wall. The nozzles were also provided at regular interval not exceeding 1.5m apart from along the construction joints and at critical points and the injection grouting was done as in case of raft. Such injection grouting was also done at the joints of diaphragm wall and the ring beam.

9.6 Critical Locations

The special precautions were taken for following critical locations:

a) *Junction of Vertical and Horizontal Waterproofing Layers* : Like any water- retaining structure, the joint of vertical & horizontal surfaces is very vulnerable from leakage point of view. At this junction, the shotcrete layer from the vertical face was taken atleast 230cm on the top of the PCC on the horizontal surface. The sharp right angle was avoided and a fillet was created to take care of this weak junction.

b) *Counterfort Retaining Wall* : The building has three courtyards open to sky. RCC retaining wall with necessary counterforts has been constructed as there was no diaphragm wall around these courtyards. The waterproofing treatment of same specifications as on the vertical face of diaphragm / retaining wall was done from outside on the counterfort retaining wall.

c) *Rock Anchors* : Water proofing of rock anchor holes & nearby area was done as explained in relevant para pertaining to rock anchors.

d) *Mica Pockets* : Micaceous layers both on the vertical rock face & also on horizontal surface pose difficulty in application of water proofing treatment. In such a situation shotcrete was done over a wire mesh laid over horizontal PCC as well as vertical faces as obtained during excavation. Over this gunited surface further treatment of Tapecrete application and plastering etc. was done in the manner as explained earlier.

e) *Junction of Diaphragm wall & Ring Beam* : A ring beam at the top of diaphragm wall has been provided to tie different panels of the diaphragm wall. The junction of ring beam and the diaphragm wall panels could be a possible point of leakage. Nozzles were provided at the junction through which cement grout was injected to seal the junction apart from providing a coat of cement plaster admixed with waterproofing compound on the outside face.

f) *Sleeves/ Earth Conductors* : Earthing conductors are left through the diaphragm wall panels at soffit level of ring beam. Contact surface between conductor and concrete may provide path for leakage. Similarly a number of sleeves for various services were left in the ring beam/ upper portion of retaining wall. These sleeves were specially manufactured having a puddle collar in between, which arrests the movement of water. To further check any possible leakage adequate nozzles were left for subsequent grouting and guniting was also done at these places.

g) *Construction Joints* : In order to ensure that the construction joint does not allow seepage or dampness, nozzles were left at varying depths along the construction joint and after the concrete attained strength and the main shrinkage in concrete had taken place, non shrink compound grouting was carried out. A proper key was also formed in the section of the raft and also in protective wall to give a proper bond between the old & new concrete and increase the water path.

h) *Shrinkage (Pour) Strips :* In the basements, the management of the expansion joints

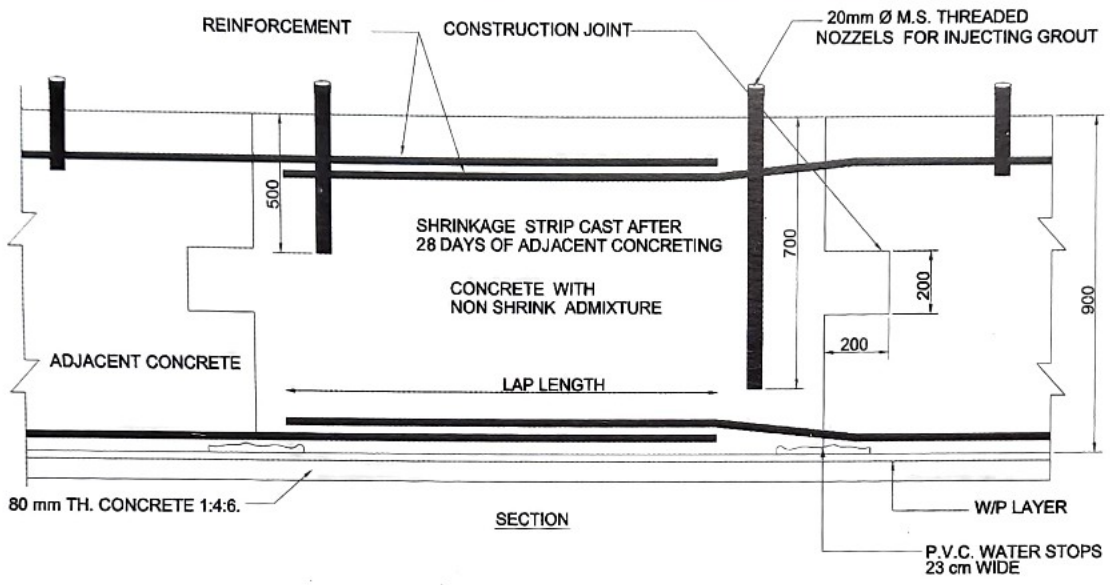


Fig 7.6 : Shrinkage Strip

in the rafts/ retaining wall posed a ticklish problem particularly in regard to its water proofing. Therefore, it was decided that no expansion joints shall be provided in the entire base raft/or the entire stretch of retaining wall. However, in order to provide for a significant part of the shrinkage to take place without inducing stresses, strips of about one metre width were left open for a minimum period of 28 days. The flexural reinforcement arrangement crossing the shrinkage strip was made such that it did not impede unrestrained shrinkage of the concrete units on either side of the strip. This strip was to be subsequently filled with the same concrete mix, having recommended quantity of the non-shrink grouting admixture. This admixture not only avoids shrinkage cracks in concrete but also expands on setting thereby sealing the joints on both sides effectively. Such a system avoids the ingress of water from outside and bottom of the building and also eliminates the expansion joints, which are otherwise potential sources of any leakage in the buildings.

i) *Dowels* : In the foundation system, necessary dowels for columns, beams & slabs were left to take on the corresponding element of the superstructure. It is always difficult to achieve proper compaction of concrete around dowels particularly when they are left in a wall. To take care of any water seepage, nozzles around the dowels were left through which grouting could be done after the main members have been cast.

9.7 Caution About Admixture/Water Proofing Compound

IS: 456-1978 permits use of admixture with the permission of Engineer-in-Charge. The admixture shall conform to IS: 9103- 1979. The requirements of integral waterproofing admixtures are covered in IS: 2645- 1975. The main worry remains that these chemicals

should not adversely affect the concrete and the reinforcement. Besides other tests prescribed, both the codes demand that the chloride content in admixture/ waterproofing compound should be declared by the manufacturer. This will enable the Engineer-in-Charge to compare different samples & be aware of the amount of chloride and sulphates entering the concrete. The BS code 5075 provides that the chloride content in admixture which are mixed at a rate less than 0.1% could be treated as Nil. Keeping in view the provision of the various codes, selection of admixture/ water proofing compound was made.

10.0 COUNTERFORT RETAINING WALL

Where the rock is available at shallow depths it was found expedient to provide cantilever retaining walls. However at a few locations on actual excavation, it was observed that depth of rock was much higher than anticipated. At locations where there were difficulties in providing large-base heel slab, the width was restricted by providing 110t capacity vertical rock anchors.

A counter-fort retaining wall 45cm thick was constructed around the Internal courtyards. The counterforts 50cm thick and 1.2m long were provided along the wall at 2.5m centre to centre. The layout was checked as per structural drawings after reconciliation with the Architectural drawing. To avoid a large number of horizontal construction joints height of lift in counter-fort retaining wall was kept about 1.8m by ensuring the height of fall up to 1.5m Plywood shuttering plate of 1.8m height was being used and concrete having adequate workability was placed by pump. Here it is to be noted that vertical water proofing was carried out on the outside face (front face) of counterfort wall whereas in case of protective wall, the vertical water proofing was completed prior to the protective wall and was allowed to be sand-witched.

11.0 R.C.C. PROTECTIVE WALL

Protective wall 20cm thick has been constructed over the water proofed diaphragm wall and retaining wall. At some locations the diaphragm wall and the retaining wall rest on rock at a level higher than the raft level. At such locations protective wall was constructed abutting the rock cut face. The vertical water proofing layer is sandwiched between protective wall and retaining wall/diaphragm wall/rock surface. The reinforcement of protective wall starts from the bottom of raft. Peripheral columns were also constructed along with the protective wall for stability.



Protective Wall in Progress

Concrete mix 1:1.5 : 3 was used for protective wall using weigh- batching plant. Concrete mix prepared from batching plant was brought by tippers and placed in position. Beam dowels in protective wall were left at desired locations at first basement level to take care of connecting beams. The beam dowels at ground floor level were cast along with superstructure beams. In parking area dowels were provided at three levels as per ramp profile or slab level.

12.0 LIST OF PLANT/MACHINERY/EQUIPMENT DEPLOYED FOR THE FOUNDATION SYSTEM WORK

1.	320 TATA Crane – 20t Capacity (Chain mounted/ Crawler type)	-	2 Nos
2.	TATA Hitachi Excavator (Ex 100 CC)	-	1 No
3.	L&T Excavator – CK-90	-	1 No
4.	JCB Excavator – 0.5cum Capacity	-	1 No
5.	Concrete Tipper – 10t Capacity	-	1 No
6.	Tipper – 10t Capacity	-	20 Nos
7.	Grabs/ Excavators 0.25cum Capacity	-	6 Nos
8.	Chisel – 3t Capacity	-	1 No
9.	Chisel – 1t Capacity	-	5 Nos
10.	Scrapers - 2t Capacity	-	2 Nos
11.	Stop End Pipes - 15m Length (Total 50 m)	-	3 Sets
12.	Tremie Pipes - Each 20cm dia	-	38 Nos
13.	Tremie Hopper	-	6 Nos
14.	Batching Plant –15cum/hour Capacity	-	1 No
15.	Generator – 100 KVA	-	1 No
16.	Welding Generator	-	2 Nos
17.	Welding Transformer – 400 AMP.	-	3 Nos
18.	Vacsel Pump/ Slurry Pump	-	3 Nos
19.	Compressor		
	- VT- 6 (330 CFM)	-	1 No
	- CPK (550 CFM)	-	2 Nos
20.	Concrete Pump - 22cum/hour Capacity	-	1 No
21.	Hydraulic Rock Splitter (DARDA)	-	1 No

22.	Pneumatic Pavement Breaker	-	2 Nos
23.	Halco Rigs	-	4 Units
24.	B. B. C. Drifters	-	3 Nos
25.	Stressing Jack	-	1 No
26.	Grout Pump	-	2 Nos
27.	Hand Injection Pumps	-	2 Nos
28.	Dewatering Pumps- Capacity 3 HP	-	15 Nos
29.	Concrete Mixer 10/7	-	1 No
30.	Concrete Vibrators	-	4 Nos
31.	Bentonite Mixing Plant	-	1 No
32.	Core Drilling Machine	-	1 No
33.	Surface Grinder	-	1 No
34.	Preumatic Grinder	-	1 No
35.	Equipped Mechanical Workshop	-	1 No
36.	Hydraulic Jacks–50t Capacity	-	3 Nos
37.	Hydraulic Jacks–30t Capacity	-	2 Nos
38.	Piling Winch	-	1 Set
39.	Laboratory Equipments	-	1 Set
40.	Survey Instrument Set	-	1 No
41.	Hydraulic 'Krupp' Hammer	-	2 Nos

13.0 SUMMARY

About 93,255cum of rock (all without blasting) and 1,19,190cum of soil was excavated, and the same were disposed at the dumping ground involving about 100 trucks per day (rather, per night as no truck movements were permitted in the day time) continuously for about 20 months.

The foundation system has thus adopted innovative techniques deploying sophisticated and heavy machines for the construction of Diaphragm wall with inclined Rock Anchors (60t capacity), RCC Base Raft with vertical Rock anchors (110t capacity) and curtain Grouting.

REINFORCED CEMENT CONCRETE

1.0 STRUCTURAL ARRANGEMENT

Parliament Library Building is a 4 Storeyed RCC framed structure, two storeys below ground and two storeys above ground. The building has been divided into eight blocks with expansion joints in between. The structural arrangement in general has grids of 5m x 5m (and in some locations 10m x 10m) with coffers of 1.25m x 1.25m. The floor height is 3.66m. The columns are generally circular in shape and dia of columns varies from 400mm to 750mm. The slab of all blocks except 2.5m corridor, AHU, Toilets, Dome area & Parking consists of waffle slabs with column capitals & concealed beams wherever required. Parking area is entirely below the ground and is in 3 levels with floor height of 2.4m each. The parking area slab is of flat-slab construction 200mm thick with spans varying from 5m to 6.5m and circular columns of 400mm to 650mm diameter with 300mm deep circular column capitals. The minimum grade of concrete used is M20 for slab system and M25 for columns. The building has been designed for live load of 8.3kN/sqm for Library portion and 4 kN/sqm for rest of the area. The library building has been designed for earthquake loading with an importance factor of 1.5.

The building has been modeled into a number of frames and a Three dimensional Analysis has been carried out using TABS (three Dimensional Analysis for Building System) programme. The design has been done according to IS: 456 by Limit State Method. Detailing has been carried out as per the detailing practices for earthquake resistant structures as per IS: 13920- 1993. The drafting has been carried out on computers using AUTOCAD version 12.

2.0 DESIGN MIX CONCRETE

The RCC work has been executed with design mix concrete. Since there was no provision of Design Mix Concrete in CPWD Specifications 1977 & DSR 1993, the codal provisions for the design mix concrete as per IS 456, IS 10262 & SP-23 have been followed. The design mix for different grades had been carried out by Indian Institute of Technology, Delhi. The mix design for a specified grade of concrete has been done for a target mean compressive strength

$T_{ck} = f_{ck} + 1.65\ s$

Where: f_{ck} = Characteristic compressive strength at 28 days.

s = Standard deviation which depends on degree of quality control

The degree of quality control for this work has been taken as "good" for which the standard deviation (s) for different grades of concrete as below have been followed as per I.S. Code.

Grade of Concrete	For "Good" quality of control
M20	4.6
M25	5.3
M30	6.0

The design mix for various grades of concrete has been done separately with each brand of cement. The maximum cement content for various grades of concrete has been limited to 550kg/cum as per provision in agreement. The final design mix proportions were arrived on the basis of trial mixes.

The Mix proportions of various ingredients of concrete by weight in Kg/cum are as per details given below:

Sl. No.	Date	Cement Brand	Slump in mm	Water in Kg/cum	Cement in kg/cum	Fine aggregate in kg/cum	Coarse aggregate in kg/cum	
							10mm	20mm
1.	M20 Concrete Mix Designed by IIT							
a	24.09.96	JP Rewa	15-20	195	390	625	458	658
b	17.04.97	Birla Uttam	15-20	195	500	523	442	663
c	14.10.96	JP Rewa	20-30	195	400	615	438	658
2.	M25 Concrete Mix Designed by IIT							
a	24.09.96	JP Rewa	15-20	200	435	576	437	656
b	14.10.96	JP Rewa	20-30	200	450	562	438	656
c	10.02.97	Birla Chetak	15-20	195	425	592	439	659
d	03.04.98	Birla Chetak	15-20	195	400	615	438	658
e	17.04.97	Birla Uttam	15-20	200	520	499	440	660
f	11.07.97	Birla Uttam	15-20	195	440	577	440	660
g	15.07.97	JK Raymond	20-30	195	390	623	438	658
h	29.08.97	JK Raymond	20-30	192	390	627	440	659
3.	M30 Concrete Mix Designed by IIT							
a	19.10.96	Birla Chetak	15-20	200	460	553	437	656
b	17.04.97	Birla Uttam	15-20	200	550	470	441	662
c	24.09.96	JP Rewa	15-20	200	490	573	420	629
d	14.10.96	JP Rewa	20-30	200	475	539	438	658
4.	M35 Concrete Mix –Designed at Site							
a.	21.02.97	Vikram	65	196	490	490	469	703

3.0 ADMIXTURES

The desired workability was achieved by adding water upto the maximum permissible water cement ratio, hence no admixture have been used.

4.0 BATCHING PLANT

The cement concrete mixing was done at site in automatic modular batching plant Millers-MRS 1000/1500. The output of batching plant used was one cum per batch & 30 cum per hour.

The required quantities of ingredients like cement, water, fine & coarse aggregates were controlled automatically by the batching plant. The quantity of water was adjusted depending upon the weather condition & the desired slump value. The surface moisture content in the fine aggregates and in the coarse aggregates was checked everyday and the quantity of water to be added was regulated and adjusted accordingly. Pre-washed sand was used in the concrete.



Batching Plant

5.0 WEIGH BATCHER

In addition to automatic Batching Plant, two swing type weigh batching machines were also used for batching and mixing the concrete at some places when the quantity of concrete required was small and also for batching and mixing of lean concrete in small quantities.

During RCC/ PCC work of superstructure these weigh batchers proved very helpful. In addition to meeting the requirement of concreting for small quantities where running automatic batching plant was not practical, these weigh batchers also proved extremely helpful to complete the concreting work at least upto desired location of construction joints in the event of breakdown of batching plant. These were also used for batching and mixing of cement mortar.

During the construction of domes & ancillary works, the daily requirement of concrete for most of the days was small and hence installation of batching plant was not practical. The concreting for FRC bubbles was done with pan type mixer and the concreting for all other works was done using weigh batcher. The volumetric proportion

of various ingredients of normal mix concrete were converted into weights and batching & mixing was done with weigh batchers.

6.0 CONCRETE PUMP & PLACING OF CONCRETE

Concrete pump of make Schwing BP 350E was used for transporting the concrete mix through pipe laid from the batching plant to the place of casting. The pipes were lubricated by flushing with cement slurry before starting pumping of concrete. The pipe was cleaned after completion of concrete work by passing a ball through the pipe under pressure. As per CPWD Specifications 1977 Vol.1 Para 5.4.1 the maximum slump allowed for reinforced beams, slabs & columns is 25mm to 40mm, whereas as per design mix done by IIT the slump allowed is 15mm to 30mm. Since the concrete was transported to place of casting through pipes by concrete pump more workability was required. As per IS: 456-1978 Para 6.1, the slump allowed for pumped concrete is 25mm to 75mm. Hence maximum slump of 75mm was allowed.

7.0 TESTING

The provision for extensive testing of cubes for compressive strength was made in agreement for better quality control as per details given below.

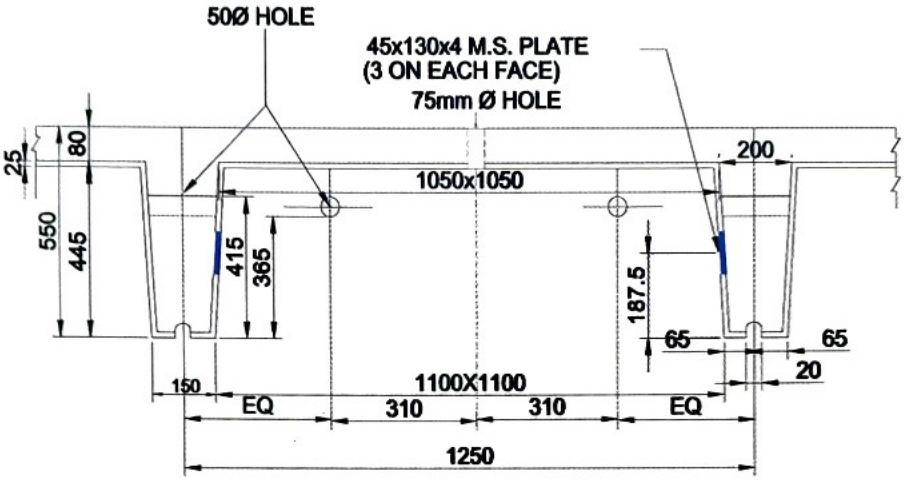
<table>
<tr><th rowspan="2">Quantity of concrete in cum per day</th><th colspan="2">No. of samples required</th></tr>
<tr><th>As per agreement</th><th>As per specifications</th></tr>
<tr><td>Minimum for each shift of concrete work</td><td>1</td><td rowspan="5">(i) For every 20cum or part thereof for beam slabs & connected columns.</td></tr>
<tr><td>1-5</td><td>1</td></tr>
<tr><td>6-15</td><td>2</td></tr>
<tr><td>16—30</td><td>3</td></tr>
<tr><td>31-50</td><td>4</td></tr>
<tr><td>50 & above</td><td>4 plus one for every 50cum.</td><td>(ii) For every 5cum or part thereof for independent columns</td></tr>
</table>

The frequency of sampling was too high for such a massive work. There were occasions when 60 cubes (10 samples) were filled for testing in a single day. Testing of such a large numbers of sample was a difficult & time consuming task.

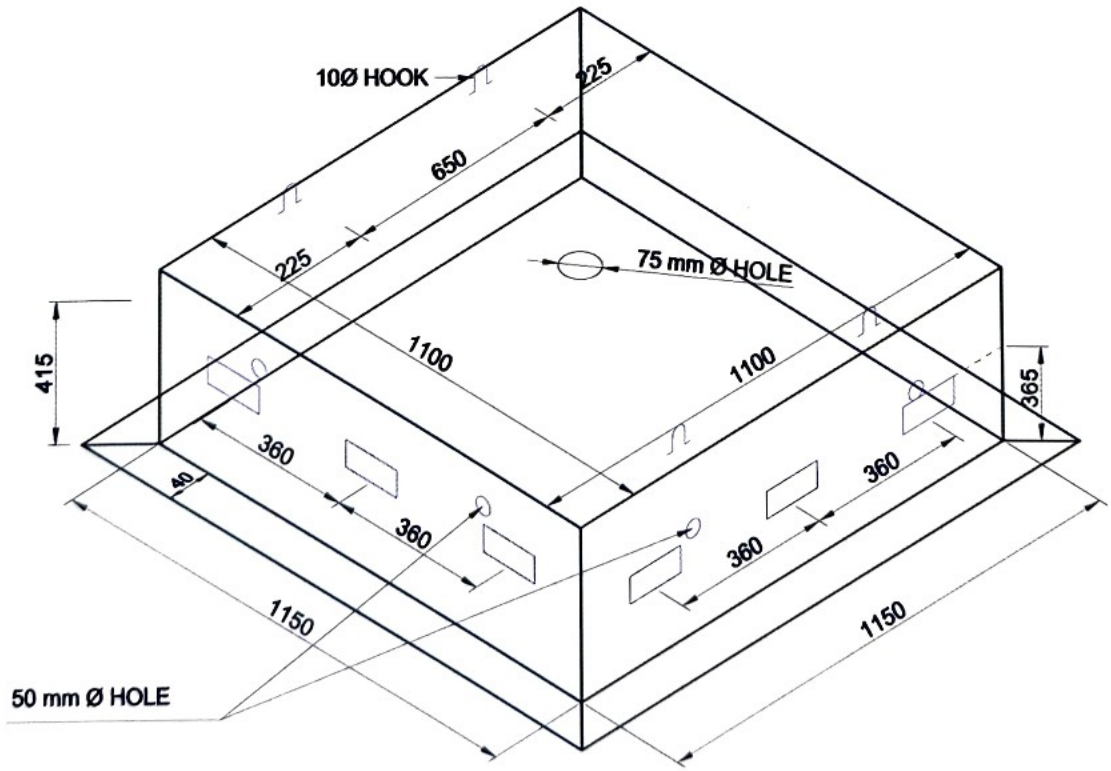
8.0 RCC SLAB WITH PRECAST RCC COFFERS

8.1 Precast Reinforced Cement Concrete Coffers

The mix used for Precast RCC Coffers is volumetric mix of cement concrete 1:1.5:3 (1 cement : 1.5 coarse sand : 3 graded stone aggregate 10mm nominal size). The formwork was designed properly in order to achieve perfect finish, as also to achieve maximum number of repetitions. The sample of Precast RCC coffer was prepared before preparing tender documents so as to decide about type of shuttering to be used and other provisions to be made for functional requirement. As far as shuttering is

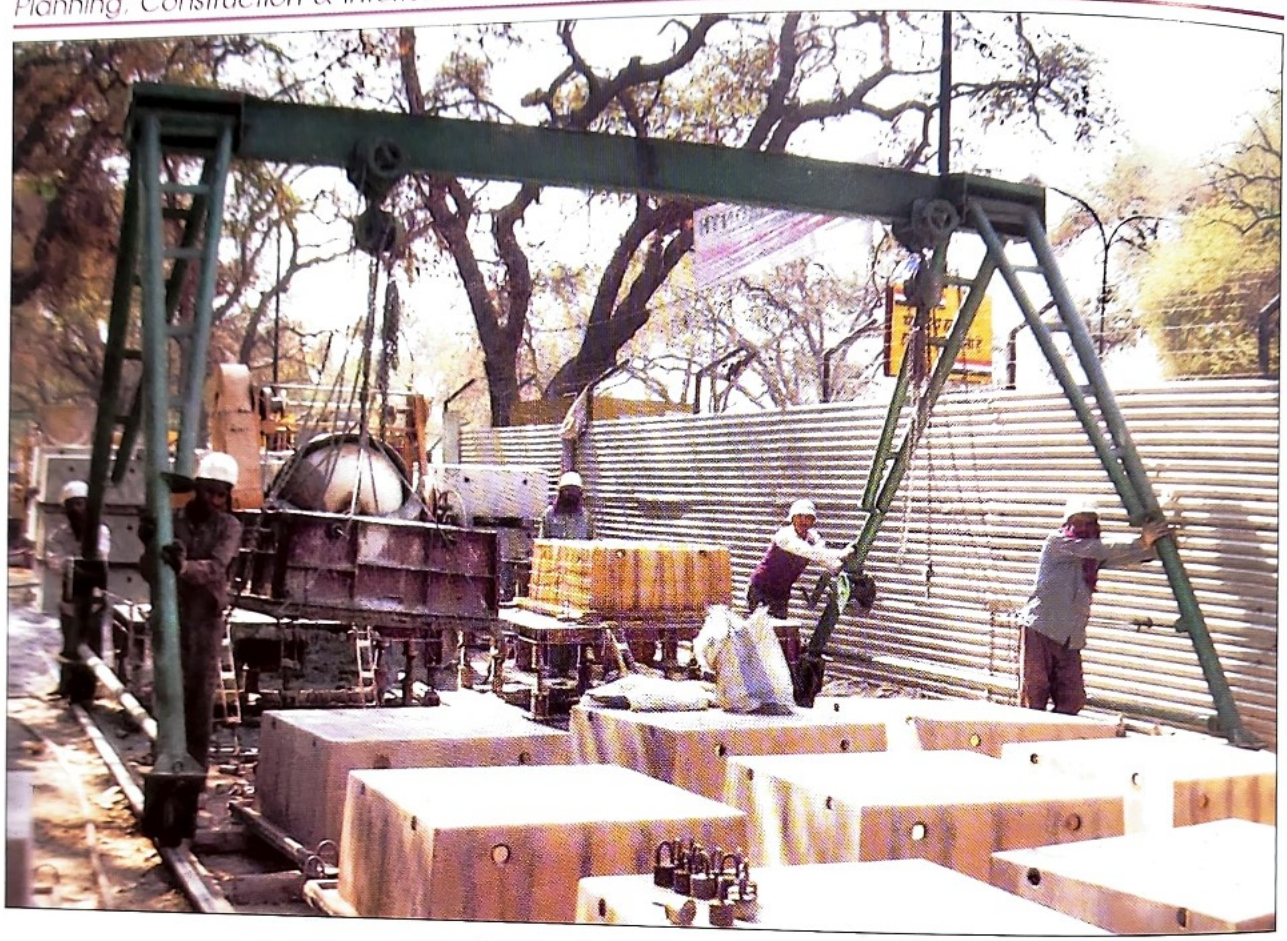


SLAB SECTION



ISOMETRIC VIEW

Fig 8.1 : Sketch Coffer Unit



Inner Moulds of Coffers

concerned, the inner mould for exposed surfaces was of fibre glass of thickness 8mm and outer mould for unexposed surface was of Mild steel of 3mm thickness.

4mm thick MS insert plates were placed in position while casting RCC Coffers as per details above. The insert plates were required for welding frames for supporting different types of false ceiling and suspenders for various services. Two holes of 50mm dia. on all sides in all coffers and one hole of 75mm dia in center of the coffer unit was provided for laying electrical conduits/cables and for junction boxes etc. The reinforcement used for Precast RCC Coffers consists of 4mm dia Mild Steel bars @ 150mm centre to centre in both directions. Steel hooks of 10mm dia one at each corner were provided for lifting the coffers by gantry girder in the coffer yard & by tower crane from yard to work-site for placement. The slump of concrete was limited to 25mm to 40mm. The coffers were cast on a vibrating table so as to achieve homogeneous and compact RCC.



Inner Moulds with Reinforcement

During the trial casting of RCC coffers following problems were encountered.

a) Loss of cement slurry from the joints of outer steel moulds.

b) Non-uniform appearance of exposed surface.

c) Pitting on exposed surface of coffers.

Above problems were studied and following solutions were adopted.



Coffer with Outer Mould & Vibrating Table

i. It was found that loss of slurry was due to heavy vibration of vibrating table and the gap between joints of outer steel moulds. To reduce the vibration, rubber pads were provided below the vibrating table and also the speed of vibration was reduced. Expanded polysterene sheets (2mm thick) was used as packing and the joints were tightened using C-clamps. These provisions stopped the leakage of cement slurry.

ii. The non-uniform appearance of exposed (inside) surface was due to reddish colour of Badarpur sand. To solve this problem, river sand having uniform colour brought from Chambal was used. The non-uniform appearance disappeared after use of Chambal sand.

iii. The pitting on exposed surface of the coffers was due to small air bubbles on the sides of the inner mould. Since the thickness of coffer walls was 25mm and height 450mm the air bubbles created during vibration were not able to rise to the surface. To eliminate the air bubbles during vibration itself, the compaction of the concrete using 10mm dia rods and tapping from the sides using wooden mallets was done during vibration of concrete. With these measures the pitting on exposed surface of coffers vanished.

8.2 Steam Curing of Precast RCC Coffers

a) *Purpose of Steam Curing* : The primary purpose of steam curing was to accelerate concrete strength development so that forms can be removed and reused at more frequent intervals, and the precast coffers can be put into use at an early

age. The advantages of steam curing are high early strength of concrete, early removal of forms, early handling of coffers, less storage space and smaller precasting areas.

b) *Concept of Steam Curing* : Steam curing is a procedure used for promoting the hydration of cement, and includes control of temperature and of moisture movement from and into the concrete. The object of steam curing is to keep concrete saturated or nearly saturated until the originally-water-filled space in the fresh cement paste has been filled to the desired extent by the product of hydration of cement.

The temperature during curing controls the rate of progress of reactions of hydration and consequently affects development of strength of concrete. A rise in curing temperature speeds up the chemical reactions of hydration and affects beneficially the early strength of concrete. Moisture is required for hydration of cement and heat raises the temperature of the precast coffers to accelerate the rate of reaction. Steam is an efficient and economical means of supplying both heat and moisture to a concrete product.

c) *Effects on Concrete Properties*

i. Compressive Strength : The primary benefit of low pressure steam curing is the rapid strength gain which it imparts to concrete products. With proper steam curing procedures 60% of 28 day compressive strength may be obtained in 24 hours. It is true that higher initial temperatures reduce the potential strength at later ages and the ultimate compressive strength of steam cured concrete may not be as great as that of concrete continuously moist cured at lower temperature. However, this difference is usually not significant.

ii. Tensile and Flexural Strengths and Modulus of Elasticity : Tensile and flexural strengths and modulus of elasticity of concrete are affected similar to compressive strength but to a lesser degree. The steaming conditions favourable for compressive strength development are also favourable for other properties.

iii. Creep and Drying Shrinkage : By steam curing, creep may be reduced by as much as 50 percent and drying shrinkage, as much as 30 percent.

iv. Permeability : Permeability of concrete specimens subjected to steam curing is greater than that of the continuously cured for 28 days. In normal construction, however, this difference is not significant.

v. Influence of Temperature : Owing to the adverse influence of the temperature during the early stage of hardening on the later-stage strength of concrete, a rapid rise in temperature must not be permitted. The adverse affect is more pronounced the higher the water cement ratio of the mix and

is more noticeable with rapid hardening than with ordinary Portland cement. On the other hand delay in the application of steam curing is advantageous. After a sufficient delay, rapid heating has no adverse affect. The delay recommended is approximately 2,3,5 and 6 hours respectively for 38,54,74 and 85°C. Longer period of curing at a lower temperature leads to higher optimum strength as compared to application of high temperature for shorter time.

d) *Procedure of Steam Curing* : In the steam curing of precast concrete products all factors are interrelated. The optimum curing cycle depends on water cement ratio and size of the structural member. The optimum curing cycle can generally be determined only by trial. The optimum curing cycle for steam curing of Precast RCC Coffers was worked out & followed as below:

i. The steam curing was started after a waiting period of 3 to 5 hours of completion of casting at vibration table. This time lag is known as the pre-steaming period.

ii. The chamber was made airtight with the help of hood and mud packing. The size of the chamber was 4m x 20m x 1.5m to accommodate 120nos coffers in three layers.

iii. Perforated pipes were provided inside the chamber.

iv. Three thermometers at 0.6m, 0.9m & 1.2m below the hood & two humidity meters were provided to record the steam temperature & humidity inside the chamber at various places.

v. The pre-steaming period was maintained for 3 to 5 hours while starting the boiler.

vi. The rate of rise of temperature was kept between 20°C to 30°C per hour.

vii. A constant temperature of 70°C was maintained for 4 to 6 hours.

viii. After constant temperature was maintained the cooling period of 2 to 3 hours was allowed. The maximum cooling rate was less than 30°C/hour.

ix. The hood and mud packing were removed.

x. Concrete cubes were sent to lab for testing.

xi. The entire process as above from casting to steam curing was completed in 15 to 18 hours.

xii. The steam cured coffers were demoulded & taken to yard for water curing for 6 days.

xiii. The coffers were finally placed in position after 6 days of water curing and further curing was ensured at the final location of placement of coffers.

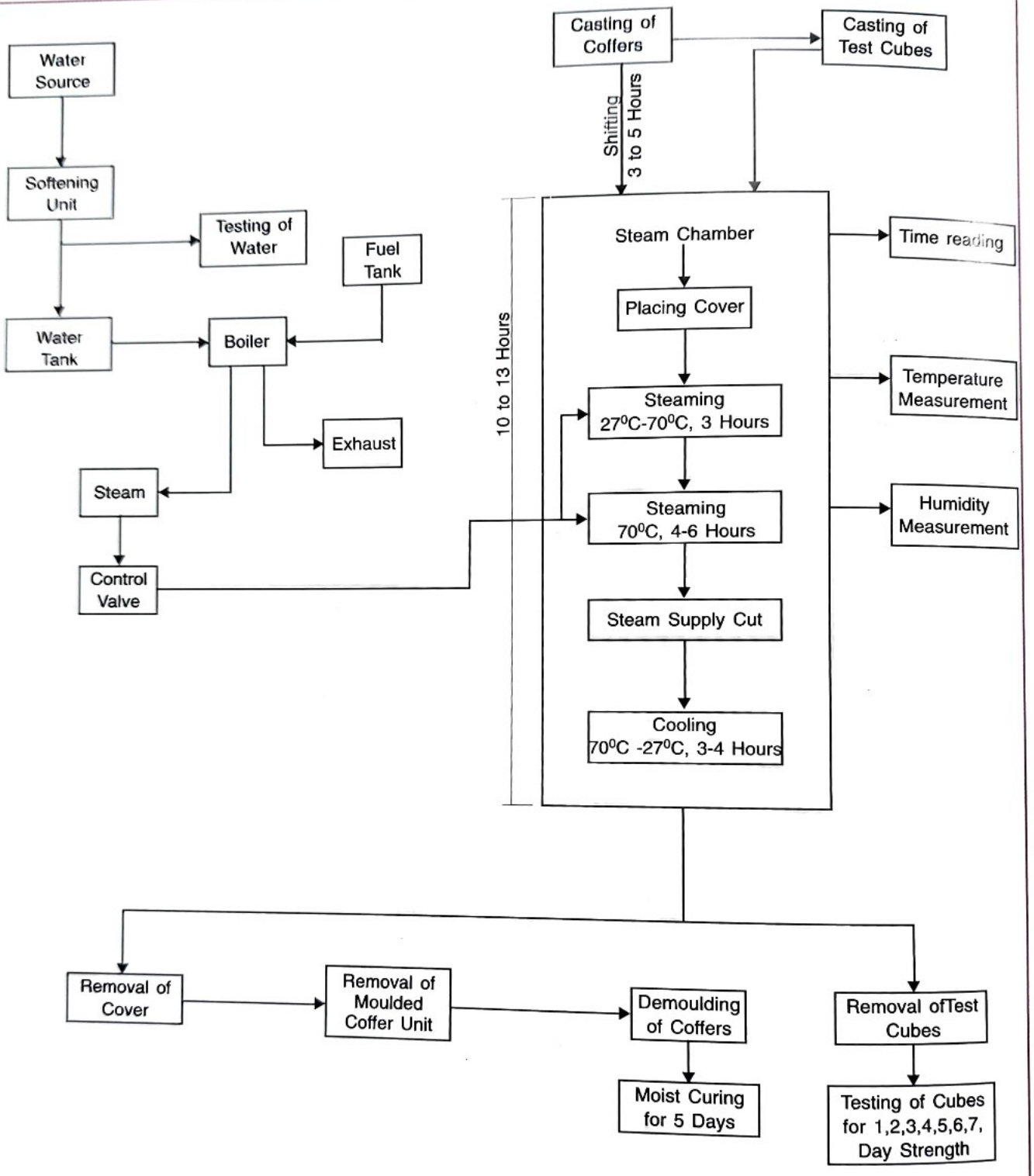


Fig 8.2 : Flow Chart - Steam Curing of Coffers

e) *Details of Coffers Cast* : The position of various sizes of Precast RCC Coffers (total 18335 nos) used are as per details given below:

Sl. No.	Coffer size in mm	Inside Dimensions in mm		Rib Thickness in mm	Overall depth in mm	Total numbers	No.of Moulds used
		Top	Bottom				
1.	1230 x 1230	1050 x 1050	1100 x 1100	25	470	9166	55
2.	1105 x 1230	925 x 1050	975 x 1100	25	470	7565	55
3.	1105 x 1105	925 x 925	975 x 975	25	470	736	25
4.	885 x 1230	705 x 1050	755 x 1100	25	470	330	10
5.	1190 x 1230	1010 x 1050	1060 x 1100	25	470	167	10
6.	885 x 1105	705 x 925	755 x 975	25	470	117	11
7.	1285 x 1230	1105 x 1050	1155 x 1100	25	470	134	05
8.	Mixed sizes as above for S.No.1 to 7			25	870	120	08

Maximum number of coffers cast in a single day was 112 nos on September 27, 1997.

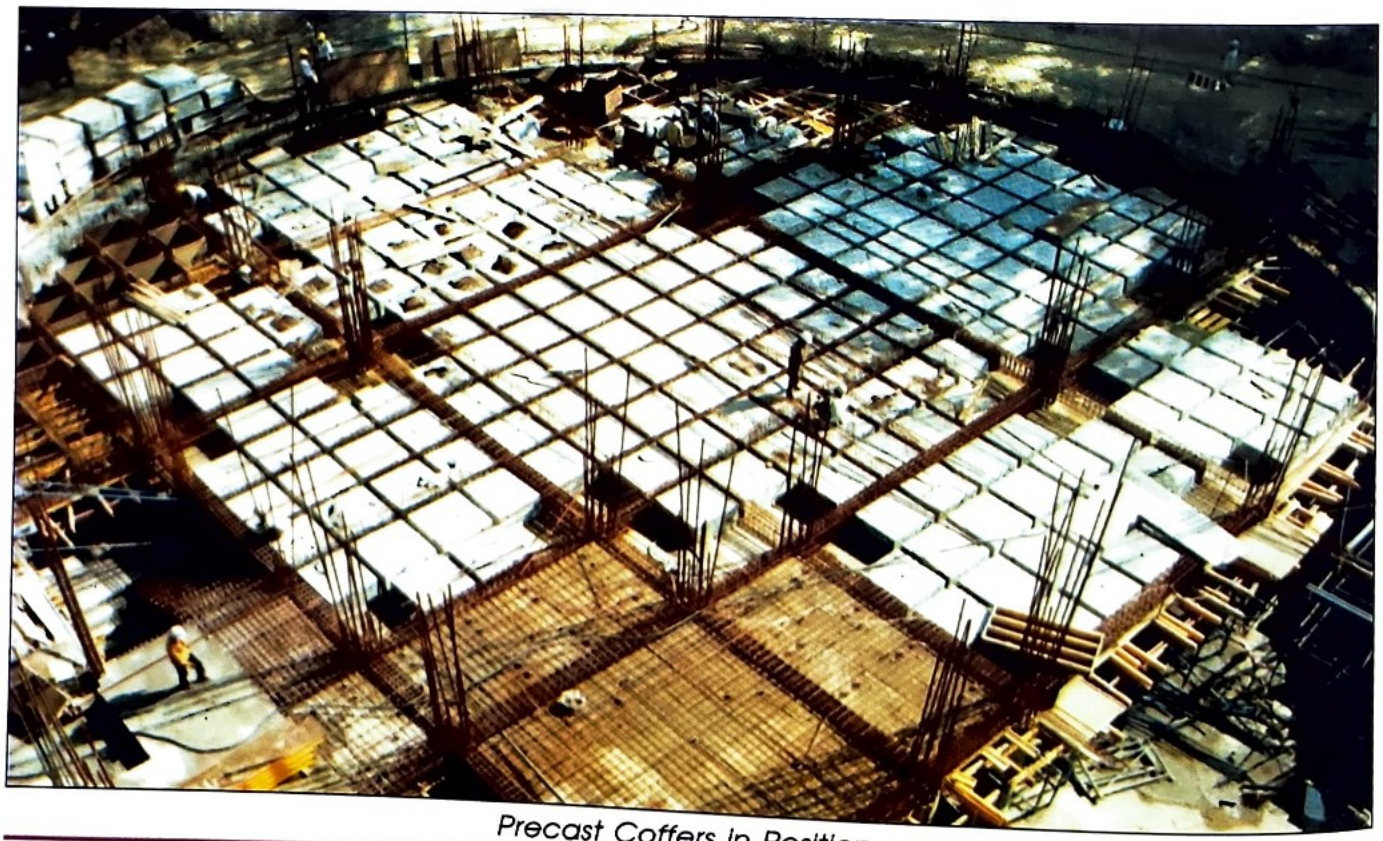
f) *Testing of Precast Coffers* : The position of test results is as below:

No.of Tests	Required 7 days strength (N/sqmm) as specification	Average compressive strength in N/sqmm			
		Actual days of Testing	Strength	Required 28 days strength as per specification	Actual Strength for steam cured after 28 days
193	17.5	1 day	16.84	26.5	28.73
		2 days	18.56		
		3 days	19.20		
		4 days	19.92		
		5 days	20.32		
		6 days	20.59		
		7 days	22.96		

g) *Casting Slab/Beams with Precast RCC Coffers* : After erecting shuttering, the coffers were lifted by tower crane & placed at the earmarked location to the desired line & level. Reinforcement was then placed for the rib beams/ main beams as well as screed slab over the precast coffers and 25mm dia chairs were also welded at the pre-determined locations to receive stone mullions over it. The necessary GI pipe sleeves were then placed in the holes already left in the coffers



Tower Crane Lifting Coffer Unit



Precast Coffers In Position



Reinforcement and Coffers in Position

to have through-and-through access between various coffers. The mild steel twisted clamps were also placed at bottom of ribs/beams at groove location at pre-determined locations which were later on utilized to weld the MS cleats required for hangers for various services such as cable tray, AC ducts etc. All the GI sleeves in coffers in one direction were in the same line which was checked by shining a torch on one end and observing the light from the other end. The shuttering surface was then cleaned thoroughly by compressed air & water. After completing all these activities concrete was laid simultaneously for rib beams/ beams & slabs.

9.0 CENTERING/SHUTTERING & SCAFFOLDING

As per agreement there was provision for use of M.S. centering/shuttering and scaffolding materials to give a smooth finish to the concrete surface. The provision for use of marine-ply shuttering was also stipulated for exceptional locations as per site requirement. The building has a complex structural form, some of these are illustrated as below:

a) The general span of the beams are 5m with design live load of 830kg/sqm for Library area as compared to 400kg/sqm for normal non residential buildings and the size of beam was restricted to 400mmx550mm due to architectural requirement.

b) There are curved & circular beams in the building. The curved beams in the Auditorium block at balcony level of spans varying from 3m to 30m are running concentric to each other at 900mm center to center. The height of beam from floor level varies from point to point.

c) The precast coffer slabs acted as shuttering plate but needed proper formwork. Also for areas having cast-in situ portion of beams, irregular coffers & column capitals the shuttering required varied from location to location.

d) In order to provide sunken slab in toilets etc., the level of top surface of RCC was to be adjusted alongwith centering & shuttering again requiring variation in centering/shuttering heights.

In view of various complexities, normal centering & shuttering was not suitable for this building. The form work used in the building (except for FRC bubbles for Domes) was based on the know-how of Doka Formwork Company of Austria with 'H' beam used in combination with props of metallic tubes and steel channel which is economical & versatile. It has ready to use formwork system components which can be assembled at site.

9.1 Doka System Form Work

The Doka System Form work consists of following elements :

a) *H-Beam* : These are stable & adaptable solid H shaped timber beams with chamfered edges which enhances the life.

b) *Universal Inside Corner :* This is used for making standard corner in conjunction with H-Beam

c) *Head Adapter Assembly :* This is used to correct the alignment of props at top to the form panel

d) *Foot Adapter Assembly :* This is used to connect the alignment props and supporting brackets to the floor to give lateral support to columns form work.

e) *Standard Steel Walers :* These are used to hold the timber form work H-beams in position and give stability and rigidity to the form work.



Doka System

f) *Flange Claw Assembly:* This is used to clamp H-Beams to any desired point to the standard steel walers.

g) *Angle Plate :* This is double splice plate to connect two formwork elements.

h) *Alignment Props :* These are props having threaded spindles. These are used for proper alignment of form work.

i) *Telescopic Floor Props :* The telescopic floor props have adjustable height & also provide for jacking arrangement for adjusting the height. The floor props have removable folding tripods. The floor props can stand on its own without any lateral support or bracing and are suitable for flat slabs at lower heights.

j) *Fourway Heads :* The fourway head helps in stabilising the longitudinal H-Beams against tilting, which can accommodate one/two H-beam so that length of H-Beam can be adjusted without cutting the H-Beam depending on size of room.

k) *Basic Frame :* It consists of 4 nos vertical MS pipes braced horizontally & diagonally, which can be used for staging & stair towers and can be combined with other basic frames. This can also be used as free standing scaffolding.

l) *Coupler :* The couplers are used for vertical stacking of basic frames.

m) *Foot Plate :* It is used to rest basic frames on level surfaces.

n) *U-Head :* A fast and precise connection between leg of frame decking in form work. It is attached to basic frame and is primarily designed for members like H-beams, standard walers etc.

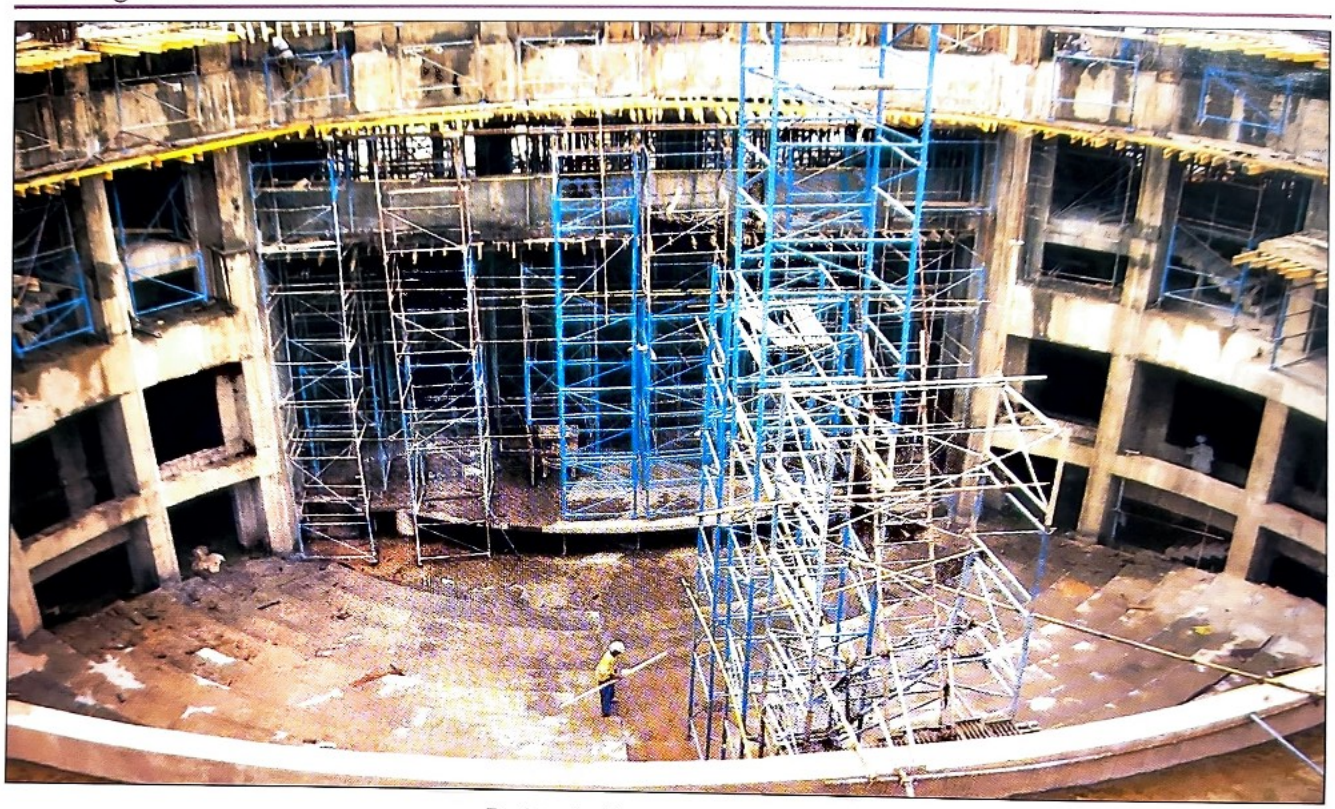
o) *Tower Spindle :* These are heavy duty threaded spindles for joining at base and top of towers. These are used for height adjustment with basic frame for form work.

p) *Spring Locked Connecting Pins :* It is used in all vertical connections in basic frames for locking the arrangement at the particular location.

q) *Doka Stair Tower :* This is used as temporary stair between various



Doka Stair Tower



Doka System - Auditorium

floors to carry men and materials. This can be used upto 100m height with proper bracing. The Doka stair tower system can be assembled and dismantled very fast. The system has provision for hand rails to ensure user safety.

9.2 Circular Column Form Work

The Parliament Library Building has approximately 2000 nos of circular RCC columns cladded with sand stone. In order to achieve high degree of accuracy of finished column surfaces accurate form work was required. Since the number of circular columns of same dia was very large, it was decided to fabricate sturdy and accurate form work using MS sheet and MS angles.



Column Starter

The column starter was first made in two halves. In order to achieve the desired tolerance of 2mm in dia, the inner surface of the starter form work was machined on lathe machine. Similarly the column form work was made in two halves. The straightness and dimensional accuracy was

achieved within 2mm by turning the form work on lathe machine.

Fixing of form work at site was done using props with jack arrangement. The two halves of form work were joined together using nuts and bolts along the edges. Foam strip was used along the joints to make the form work leak proof to avoid any leakage of slurry through joints. The alignment of form work was checked using theodolite. The verticality was also checked before starting the concreting operations.

9.3 Rectangular/ L Shaped Columns

The formwork for rectangular or L shaped columns was made using DOKA form work system. The sides of these columns were prepared using marine grade ply fixed to H-beams with nails. After placing these sides vertically in position, steel walers were tightened at three levels along the height of the form work. Two sides were rigidly connected using steel angle plates and other two sides were connected using fixing brackets and tie rods. The alignment was checked using theodolite. The joints were sealed after checking the verticality of the columns. The lateral stability of the form work was achieved using foot adapter assembly, supporting brackets and alignment props having jack arrangements. After erecting the form work, a raised platform for concreting was made with H beam



Circular Column Shuttering



Rectangular Column Shuttering

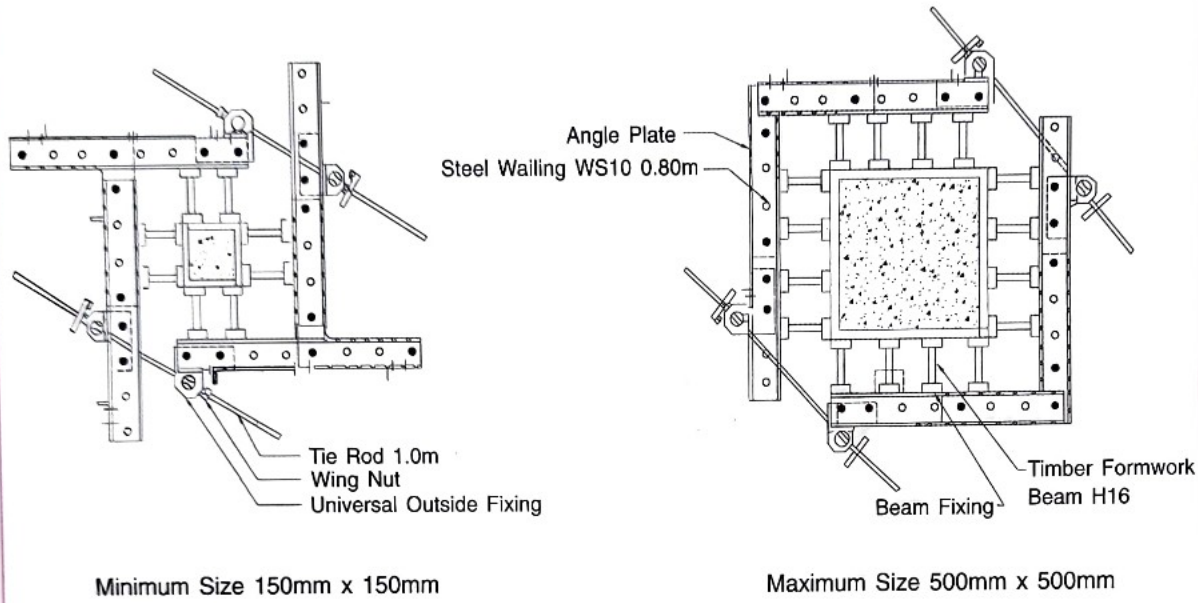


Fig 8.3 : Details -Adjustable Rectangular Column Form Work

supported on flex form work braced together.

9.4 Form Work for Flat Slabs

For flat slabs of parking, the flex system was used. It is simple and quick and suitable for flat slabs at low heights. It consists of independent telescopic props supported by folding tripods.

After placing the props (prop-CT-300) at required intervals (1500mm to 2000mm), light weight longitudinal H-beams were fixed on four-way heads to give a versatile form work system. Transverse H beams were fixed over longitudinal H-beams at spacing of approximately 400mm centre to centre. The marine grade shuttering ply was nailed to the transverse H-beams. The levels were checked at every 1250mm intervals using levelling instrument and any variation beyond 5mm was adjusted using jack screws. The joints were sealed using



Sample – Form Work for Flat Slab

cotton waste and putty and finally shuttering oil was applied.

9.5 Form Work for Waffle Slabs

Heavy duty towers were used to support the form work for coffer slabs which consists of basic frames, couplers etc. After erecting the Heavy duty towers, H-beams were placed in both the directions at general spacing of 1250mm centre to centre. The spacing of H-beams were adjusted to match with the ribs of coffers. Marine grade ply of width 150mm was then nailed to the H-beams.



Form Work Waffle Slab

Trapzoidal shaped beading having 15mm top, 20mm bottom and 10mm height was nailed on the shuttering ply to give a uniform and straight groove at the meeting point of two adjacent coffers in both the directions. The level was checked at every junction of the coffer units.

10.0 REINFORCEMENT

Steel reinforcement predominantly used in RCC work was cold twisted deformed bars. The estimate was based on the normative coefficient for different members but in actual execution the quantity increased to almost 80%. This was due to complicated structure, long spans & higher imposed load of 830kg/sqm considered against the normal load of 400kg/sqm. Structural sizes of the beam members were also restricted to 550mm overall depth due to architectural requirement. All these factors resulted in congestion of steel in beams & columns.

The average quantity of steel for various members of structure works out as below:

Sl. No.	Type of member	Concrete quantity in cum	As per Estimate Steel in kg/cum of concrete	As per actual Steel in kg/cum of concrete
1.	Walls	1925	110	233
2.	Beams	8990	110 for ribs & 200 for beams	243 to 634
3.	Columns	3371	300	282 to 340
4.	Screed Slabs/ cavity floor	8041	90	183
5.	Coffers	1299	90	94

11.0 WORK DONE

Sl. No.	Concrete Mix	Foundation	Superstructure	Domes & Ancillary works	Total
1	RCC 1:1:2	Nil	Nil	419 cum	419 cum
2.	RCC 1:1.5:3	24054 cum	1299 cum	48 cum	25401 cum
3.	RCC 1:3:6	412 cum	Nil	Nil	412 Cum
4.	M20 in walls	Nil	112	Nil	112 cum
5.	M25 in foundation	Nil	Nil	127	127 cum
6.	M25 in walls	Nil	1813 cum	Nil	1813 cum
7.	M20 in suspended floors	Nil	794 cum	Nil	794 cum
8.	M25 in suspended floors	Nil	7247 cum	Nil	7247 cum
9.	M20 in lintel, beams	Nil	230 cum	Nil	230 cum
10.	M25 in lintel, Beams	Nil	8760 cum	Nil	8760 cum
11.	M25 in columns	Nil	3228 cum	Nil	3228 cum
12.	M30 in columns	Nil	143cum	Nil	143 cum
13.	M25 in staircases	Nil	240 cum	Nil	240 cum
14.	Centering & shuttering				
a)	Foundations	4298 sqm	Nil	Nil	4298 sqm
b)	Walls	13724 sqm	14622 sqm	1148 sqm	29494 sqm
c)	Suspended floors	Nil	23157 sqm	339 sqm	23496 sqm
d)	Lintel, beams	758 sqm	33045 sqm	1056 sqm	34859 sqm
e)	Columns	Nil	18218 sqm	293 sqm	18511 sqm
f)	Staircases	Nil	1910 sqm	Nil	1910 sqm
15.	Reinforcement				
a)	Mild steel bars	Nil	122 MT	54 MT	176 MT
b)	Cold twisted bars/TMT	3188 MT	5603 MT	156 MT	8947 MT
16.	Precast RCC Coffers	Nil	24318 Sqm	Nil	24318 sqm

STONE AND BRICK WORK

1.0 TYPE OF STONES

Parliament Library Building has been cladded with different kinds of stone work to conform to the external facade of the Parliament House. The effects is at once sober, elegant, aesthetic & traditional. On the exposed surface of all stone works silicone based water repellant (DF 105 of GE Silicone) has been applied to prevent deterioration of stone due to ingress of moisture, gases etc. into the pores of stones. The various types of stones conforming to CPWD Specifications as below have been used.

1.1 Red Sand Stone (Agra Stone)

It is a sand stone red in colour also known as Agra stone, available in Karoli, Sarmathura and nearby quarries in Rajasthan. This stone has been used for making mullions, Bond Stones, Copings, circular column cladding, wall lining, louvers, spouts, jalis, hand rails and flooring in open area and terrace etc. At most locations fine-chisel hand-dressed red stone have been provided except on the external wall of the building which has quarry face finish. In a few cases machine finished stones have also been used.

1.2 White Sand Stone (Dholpur Stone)

It is a Sand stone, off-white in colour available from Dholpur and nearby hills in Rajasthan. This stone has been used for wall lining, copings, Rain water spout and making jalis. The white sand stone used is machine cut and fine chisel hand-dressed.

1.3 Pink Sand Stone (Bansi Paharpur Stone)

It is a sand stone pink in colour and available in "Bansi Paharpur" and nearby quarries in Rajasthan. This stone is used for bond stone in wall lining in combination with white sand stone.

2.0 STONE CHARACTERISTICS

All the above three types of stones are similar in composition and characteristics except colour. These stones were expected to conform to the following characteristics as per IS codes.

a)	Compressive Strength		200-1700kg/sqcm as per IS 1123-1975
b)	Water Absorption	<	2.5% as per para 4.1 of IS:3622-1977
c)	Specific Gravity		1.85 –2.7 as per IS 1123-1975

In order to ensure that best quality of stone is used for such a prestigious building, the samples were collected from various quarries and tested for water absorption. The test results showed that none of the same passed through required characteristics of water absorption. The provision of IS code was relaxed and sand stones of less than 5% water absorption were allowed to be used for work. The decision was taken to use sand

stone conforming to the following criteria.

i.	Compressive Strength	>	300 kg/sqcm
ii.	Water Absorption	<	5%
iii.	Specific Gravity	>	2.1

3.0 PREPARATION OF STONE PIECES

3.1 Procurement

The large blocks of sand stone were excavated from quarry and then split manually or by gang saw in rough sizes required for various sand stone members/ elements. The sand stone of required rough sizes were transported to site for further preparation as per actual sizes/finish required.

3.2 Shaping of Surface

In order to make mullions, bond stones, sill stones, threshold stones with perfectly plane and parallel surface and with edges truly at right angles, stone grinding and cutting machines were installed at site. The working with grinding and cutting machines also expedited the speed of construction. The surfaces of mullions, bond stones, sill stones, threshold stones etc. were first made truly plane and parallel using grinding machines. The stone pieces of required thickness with margin of plus 3mm for finishing were obtained while making the surfaces truly plane and parallel.

3.3 Cutting to Sizes

The stone pieces as above were loaded on cutting machines. All the edges were then cut exactly perpendicular to each other using cutting machines having the stone cutting wheels of 200mm dia, mounted vertically. The stone pieces of plus 3mm size were cut to allow for fine chiseling/finishing of surfaces.



Cutting of Stone

3.4 Fine Chiselling/Finishing

After cutting the pieces to required sizes the exposed surfaces were fine chisel dressed using hand chisels. The grooves or tongues as per the requirement were cut in the finished stones.

4.0 STRUCTURAL AND NON-STRUCTURAL SAND STONE MEMBERS

The stone has been used for structural purposes (as bond stones in masonry) and also for non structural purposes (as mullions, sill stones etc.).

4.1 Threshold Stone

The threshold stone is placed at floor level. The finished size is about 555mm to

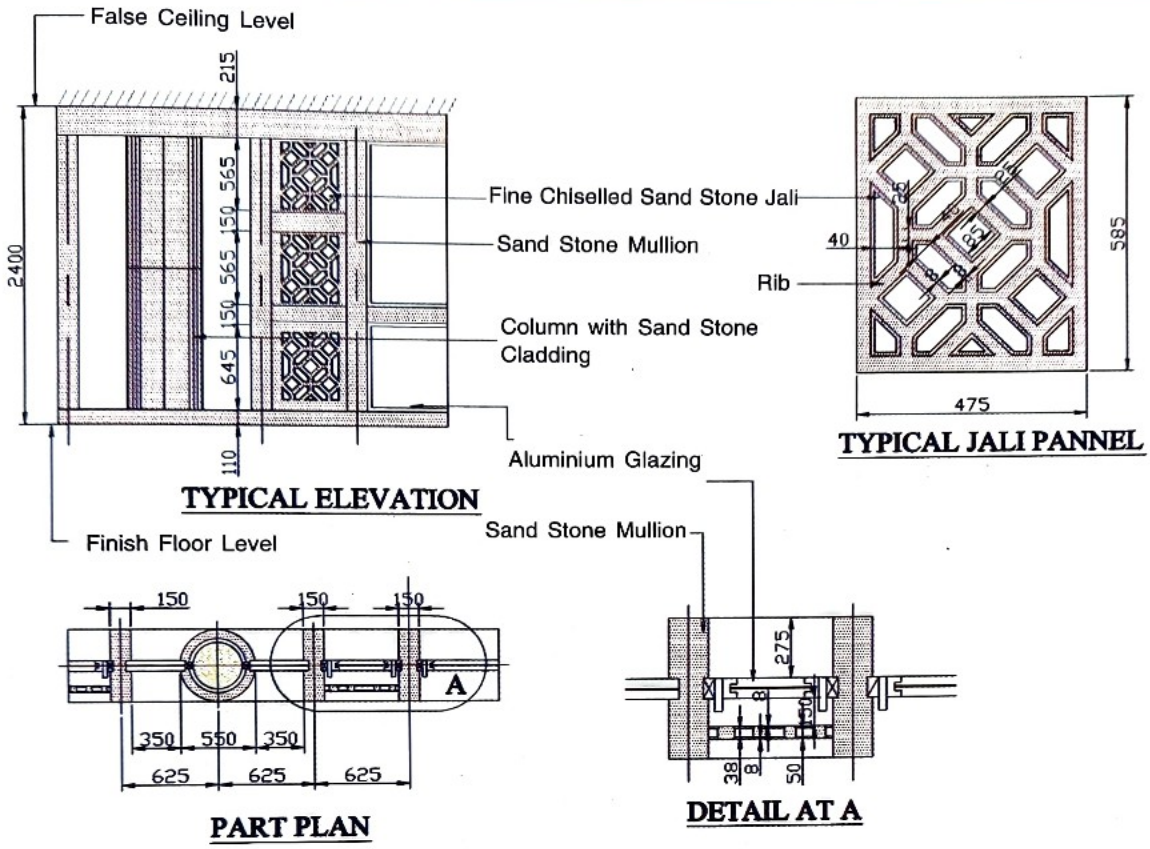


Fig 9.1 : Showing various Stone Elements

600mm in width, 150mm thick and of different lengths as per site requirement. Three sides of stones were prepared as fine chisel dressed whereas the bottom surface coming in contact with RCC slab was kept as rough dressed for proper bonding with RCC Slab. The groove of 30mm x 30mm size was made at the top surface to receive tenon portion of veneering stone wherever required. Prepared stones were placed at site on a bed of cement mortar 1:6 (1 cement : 6 coarse sand) in horizontal plane and all joints of stone were finished with pointing in cement mortar 1:2 (1 cement : 2 stone dust) providing a groove of 8mm x 8mm.

4.2 Sill Stone

The sill stones are used as sills for window. Sill Stones were used of size 550mm to 600mm in width, 150mm thick and different lengths as per requirement at site. The preparation of sill stone is similar to threshold stone except following:



Threshold, Sill, Mullions & Partitions

a) All four sides are fine chisel dressed.

b) Fixing of sill stone is done with the help of tenon & groove joints with mullions and accordingly tenon of size 100mm x 25mm in full width is left on one/both sides depending on location of use. Where the sill stone meets the cladded column, it has been rested over column cladding and extra supports have been given with stainless steel cramp fixed with anchor fastener.

4.3 Mullions & Partitions

Mullions and partition are vertical member of stone 300mm to 600 mm in width 100mm to 150mm thick & 2200 mm in length. The method of preparation of mullion and partition are similar to sill stone except that a slit is cut in bottom of mullion for holding the stone on the RCC slab/beam with the help of steel chairs of 25mm dia placed in the concrete during casting of RCC slab/beam. The vertical grooves of required sizes were also cut into the mullions to receive the wooden rough ground for door or window frame. Two holes of 30mm dia were drilled at top to secure top end of mullions to the lintels/beams with the help of MS bars of 25mm dia. The slit of required size were cut to accommodate the tenon portion of a sill stone wherever required.

Fixing of mullions was done by placing the mullion over 25mm dia steel chairs and filling the space with cement mortar 1:6 (1 cement: 6 coarse sand) before laying of flooring and top side of mullion was anchored with the help of two numbers 25mm dia MS bars with lintel. Top groove of mullion have been finished with cement mortar 1:2 (1 cement : 2 stone dust).

4.4 Bond Stone

Bond stones are generally 565mm in length, 305mm/185mm in width and 150mm in thickness. The method of preparation of Bond stone is similar to that of threshold stone except that only front face of 565mm x 150mm is fine chisel dressed and other sides of stones are kept rough dressed for proper bonding with mortar. The groove at top and bottom or only at top depending on locations of use (middle bond stone/threshold bond stone) are cut to accommodate the tenon of the veneering stone. The fixing arrangement is discussed in composite masonry.

4.5 Fine Chisel Dressed Stones for Wall Lining

The stones used for wall lining are 50mm/25mm thick, 695mm/615 mm in height and 565mm wide in general. The stones are chisel dressed at front face and rough dressed on other sides. Fine dressing was done in the vertical plane so as to check with a 60cm straight edge so that the variation was not more than one mm. The tenon were provided on top and bottom of stone to accommodate the same in the groove made in bond stone where veneering was to be provided with bond stone. Two notches each at top and bottom for cramps were provided for locations where wall lining was to be provided on RCC surface. The details of fixing arrangements are discussed separately.

4.6 Quarry Face Stones for Wall Lining

The stones for quarry-face wall lining were brought direct from quarry which has normal surface formed when a stone is detached from its parent mass along the surface of fracture formed by splitting the stone. The front surface is also kept rough. Exposed face when checked with straight edge in plumb with respect to exposed finished faces of bond stones at top & bottom is such that variation does not exceed plus or minus 3mm. However, it has been observed that it is very difficult to obtain stones which fulfill this criteria and this tolerance needs to be reviewed while stipulating in future contracts. The fixing arrangement is discussed in composite masonry.

5.0 PREPARATION OF MOCK UP

Mock-up for the stone work such as wall cladding (in brick masonry), circular column cladding, fixing of stones over lintel was prepared to ensure quality work and got approved from the Consulting Architect before taking up the stone work on mass scale. This mock up served as a guide for the field staff and was kept at site till completion for work.

6.0 STONE WALL LINING /CLADDING

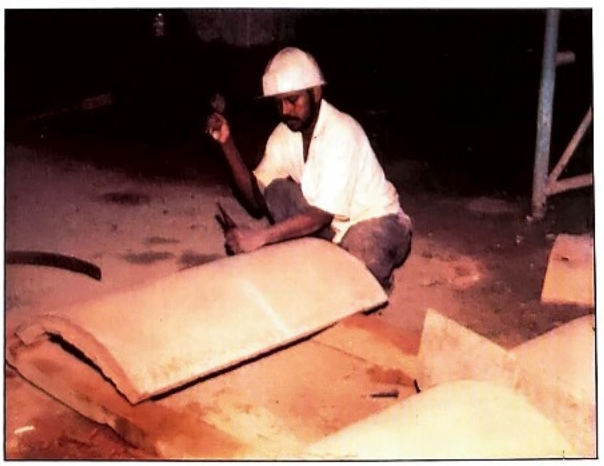
The following types of stone wall lining/cladding have been used :

6.1 Red Sand Stone Wall Lining for Circular Columns

Total 2436 nos circular columns were to be cladded with sand stone. The total area was approximately 10500 sqm. The dia of column cladded varies from 400mm to 750mm excluding thickness of stone cladding. Thickness of stone cladding is 75mm which includes 50mm thick sand stone with backing of 25mm thick cement mortar 1:3 (1 cement: 3 coarse sand). The stone cladding has been done in four quadrants in two or three levels (in height) as per details given below.

a) *Procurement of Stone :* The column cladding has been done with four quadrants. The most common size of column was 650mm dia which became 800mm after cladding. The finished stone required for this column was approximately 620mm in width, 1220mm in height and 50mm in thickness. Rough stones of approximately 1350mm x 650mm x 180mm size for columns of 650mm dia were brought to site.

b) *Profile Marking & Rough Dressing*: The profile of circular quadrants was marked on stone with template prepared by ply wood/MS sheet. The inner and outer surface of stone was chipped off with the help of chisel to keep 3-4mm more thickness than required to give a proper finish.

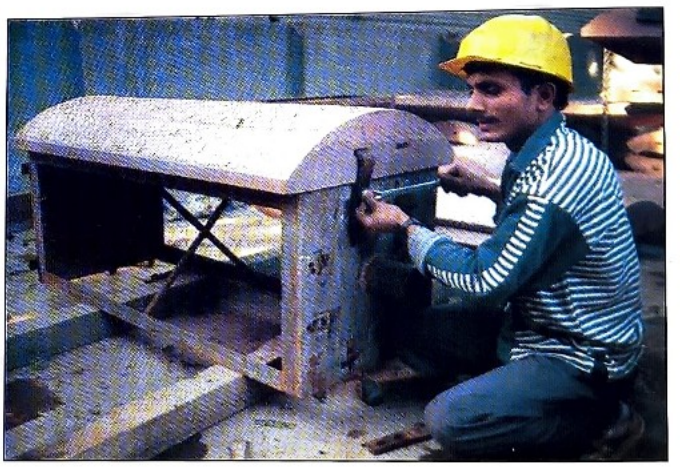


Manual Preparation of Stone Quadrant

c) *Fine Dressing* : The exposed surface was finished with grinder/fine dressing tools. The curvature was checked with template and straightness with straight edge. After fine dressing, stones were cut to proper size. The groove of 25mm x 6mm size was made on the bottom of stone along the perimeter to accommodate the 25mm x 4mm size stainless steel ring. (See para (d) ahead)

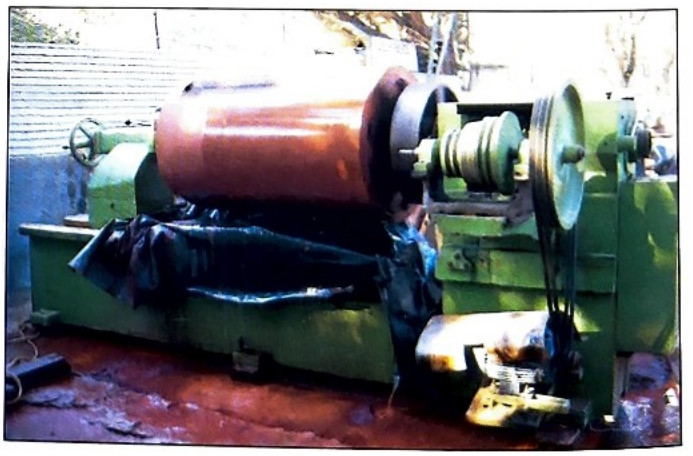
About 25000 pieces of circular cladding quadrants were to be made and each quadrant segment required about 7 man days hence it was realized that required progress would be extremely difficult to achieve by employing only manual labourers. Moreover, the specialized stone workers required for such high precision work were also not available in plenty. In order to expedite the work of making circular stone quadrants and also to achieve uniform finish it was decided to use improvised lathe machines to finish the exposed surface of circular quadrants. Six nos of lathe machines were specially fabricated and installed at site for finishing the exposed circular surface of the stone quadrants.

The rectangular stone pieces were first rough dressed to give the external surface a rough circular shape. Three such rough-dressed stone quadrants were then mounted on lathe machine to give the desired finish and curvature to the quadrants. As a spin-off of such accurate fine finish the finished quadrants exhibited a timber-like grain structure which is unusual in normal stone cladding work. To this day, visitors to the building cannot but marvel at such an exquisite finish to stone cladding.



Rough Stone Quadrant being loaded on Lathe Machine Frame

The finished pieces were then unloaded and internal surface was given rough dressed circular shapes. The edges of the quadrants were then straight cut and the circumferential grooves of size 25mm x 6mm at bottom were cut using hand held stone cutting machines.



Lathe Machine in Operation

d) *Fixing* : The following steps were followed to fix the circular stone cladding –

i. The stainless steel flat ring (welded at one end) 25mm x 4mm was placed at the bottom of RCC column.

ii. The stone quadrants were placed on the ring inserting flat in groove already provided in stone.

iii. After checking the profile and plumb, the top and bottom of stone pieces were temporarily fixed with POP and MS flat ring. Proper support were provided to keep stone in position while grouting.

iv. The gap between stone pieces and RCC column was filled up with cement mortar 1:3 (1cement : 3*coarse sand) in 3 layers and proper compaction was done to ensure that no hollow space is left.

v. The plumb and profile was again checked after filling the gap with mortar.

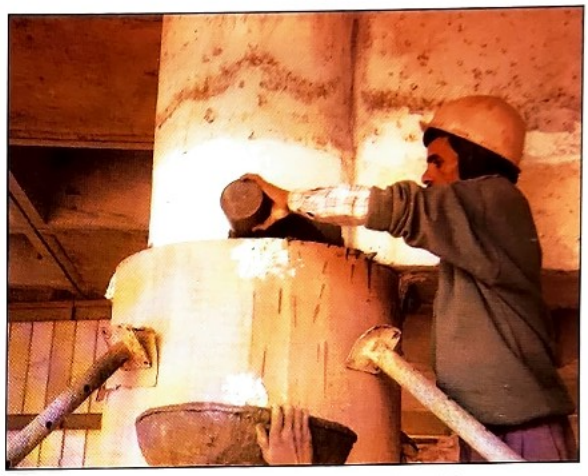
vi. After curing period was over the top surface was cut to proper level.

vii. The groove of 25mm x 6mm size was made on top surface of cladding all-around.

viii. The stainless steel flat ring of 50mm x 4mm size was placed in the groove leaving 25mm exposed and 25mm inserted in groove provided.

ix. Second layer of stones were placed over first layer by repeating the steps as mentioned above.

x. POP was removed & surface cleaned.



Mortar Filling for Stone Backing

e) *Finishing* : The vertical and horizontal grooves of 8mm width were cut in true vertical and horizontal plane and finished with pointing with cement mortar 1:2 (1 cement : 2 stone dust). The circular cladding was done with dimensional accuracy within 2mm tolerance in verticality and 10mm tolerance in perimeter.



Stone Cladding showing Stainless Steel Ring

6.2 White Sand Stone Circular Solid Columns

As per architectural concept, 42 nos columns along the periphery are constructed with solid white sand stone. In basements, all these columns are 400mm dia RCC columns and are part of protective wall. As per original concept, solid circular stone blocks were to be fixed with key-stones of size 150mm x150mm x150mm placed in the holes cut in the blocks. But this arrangement was not found stable and therefore changed as described below:

One reinforcement bar of 32mm dia was provided in the center of RCC column to ensure required bond length below the curtailment level of RCC. All the reinforcement bars except central 32mm dia bar were curtailed at this level. The central 32mm dia bar was further extended by 25mm MS tie rod

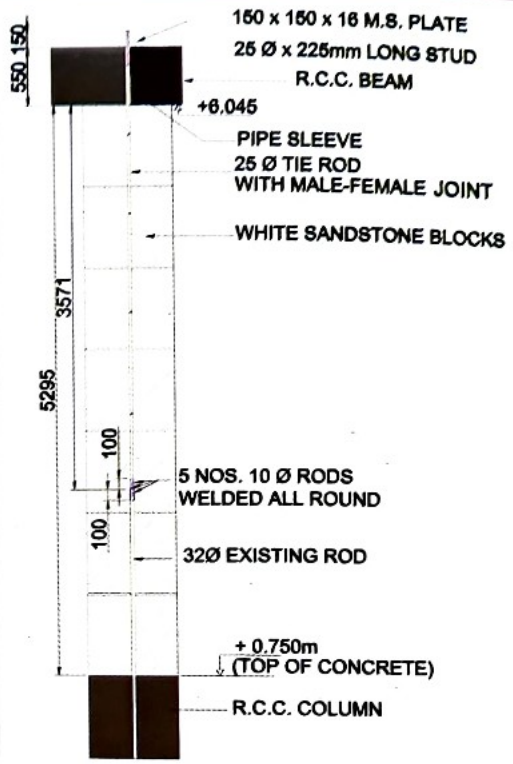


Fig 9.2 : Fixing arrangement – Solid Circular Column



Completed View - Solid Stone Circular Column

pieces 720mm long threaded with male-female joint with threading arrangement. A hole of 75mm dia was drilled through & through in the solid sand stone blocks. These blocks were then lowered down along the central tie rod. Remaining space around the tie rod was grouted with cement mortar 1:2 (1 cement: 2 coarse sand) mixed with non-shrink compound. Pipe sleeves were provided in the beams at the locations of these columns at terrace level. The tie rod was passed through this sleeve & tightened with a nut provided over a base plate so as to give a rigid & stable arrangement. After fixing all the blocks of a column, 8mm horizontal groove was made at all the joints of blocks & finished with cement mortar pointing.

6.3 Composite Brick & Stone Masonry with Stone Cladding

Most of the external walls of the building have quarry faced stone wall surface. However, inside the building the wall surfaces along 5m wide corridors in second and first basement and the peripheral corridor at all floors have fine-chisel-dressed sand stone finish cladding. The types of stone with required thickness as below have been used.

a) Fine chisel dressed white sand stone 50mm thick with 25mm thick cement mortar backing.

b) Fine chisel dressed/quarry faced Red sand stone 50mm thick with 25mm thick cement mortar backing

c) Fine chisel dressed/quarry face Red sand stone 25mm thick with 15mm thick cement mortar backing for L-shaped columns.

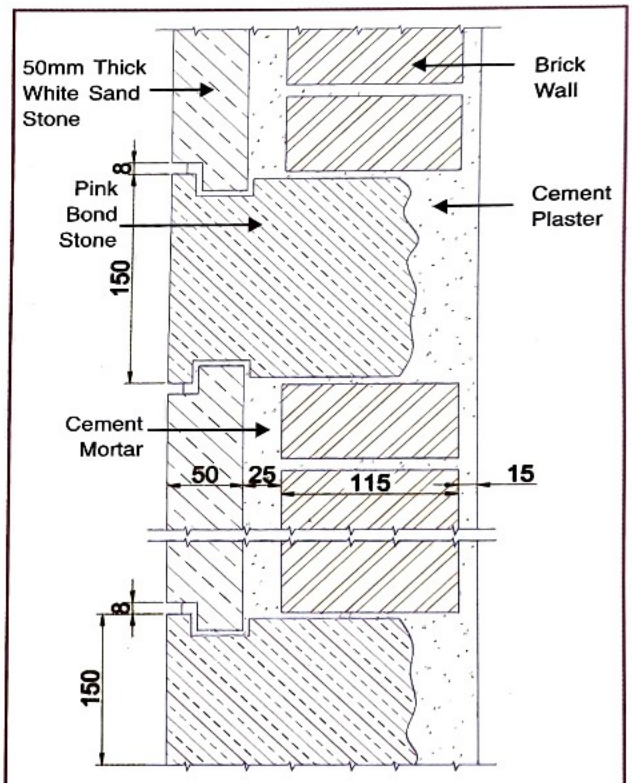


Fig 9.3 : Composite Masonry

The conventional method of fixing stone cladding to brick walls is by the use of metal cramps. This has the danger of giving way with passage of time. Instances of such cladding stones falling off are many. To avoid such a contingency innovative composite brick-and-stone masonry was provided to make the stone cladding an integral part of the walls. The sequence of execution of composite masonry was such that the bond stones, cladding stones and brick work were mechanically bonded to each other.

The following sequence was adopted in execution of composite masonry.

i) Threshold/bond stone prepared with groove to receive cladding stone was laid over cement mortar 1:6 (1 cement: 6 coarse sand). The cross joints were filled with mortar.

ii) The brick work was started leaving 75mm space from proposed finished stone cladded surface. The brick work continued upto the top level of first cladding stone. The cladding stone 50mm thick were then placed in such a way that bottom edge tenon of the cladding stone fits in the groove of threshold/bond stone. All cladding stones were then aligned checked for lines & levels and properly supported to the brick work using C-clamps. The vertical joints were sealed using plaster of paris. The top edges of cladding stone were then temporarily fixed using POP at intermittent places. The 25mm gap between the brick work and the stone veneer was grouted using cement mortar 1:3 (1 cement: 3 coarse sand).

iii) The cement mortar was then allowed to set for about two days. The POP used for temporary fixing of veneer stones and the C-clamps were removed. The laying of one layer of the wall was now complete and ready to receive the bond stone.

iv) The bond stones prepared with grooves to receive the stone veneers were then fixed on the first layer of composite masonry using cement mortar 1:6 (1 cement: 6 coarse sand) in such a way that the top edge of the veneer stone fits into groove of bond stone.

v) The brick work for next layer of composite masonry was then started over the bond stone. The entire composite masonry was completed with alternate layer of brick masonry cladded with stone and bond stone.

vi) After completion of the laying of composite masonry, the joints sealed with POP were raked and horizontal and vertical grooves of 8mm width were straight cut using hand cutting machines. The pointing of 8mm width groove with cement mortar 1:2 (1 cement: 2 stone dust) for uniform depth of 8mm was done using 8mm x 8mm wooden templates while mortar was still green. The composite brick and stone masonry was then water cured from both the sides.

vii) After curing was complete the cladded surface of composite wall was checked using straight edge to see any unevenness in level etc. Any unevenness in levels or offsets at joints etc. were corrected by grinding and fine chiselling.

The filling of holes left for supporting scaffolding at later stage was not feasible in composite masonry, hence provision was made in agreement for double scaffolding having two sets of vertical supports.

6.4 Stone Cladding on RCC Surfaces

The stone veneering has also been done on RCC wall/beam surface, where laying of bond stone was not feasible. The fixing arrangement for such locations has been done by providing two numbers of stainless steel cramps each at top and bottom of

each stone in the notches provided in stone. The back side of the cramp is embedded in RCC wall with 10mm dia & 80mm long stainless steel anchor fasteners. The mortar filling and finishing of joints has been done as explained above.

The stainless steel angle of 50mmx50mmx4mm have been used for supporting stone veneering wherever the building has opening e.g. at entrance doors, the external facia of planter at roof level, to support the sand stone cladding. The angles have been fixed to wall with the help of dash fasteners placed @ 600mm centre to centre.

7.0 CALCIUM - SILICATE BRICK WORK

There are ten AHUs located in second basement below Auditorium stage. The walls of these AHUs have been constructed with good quality of Calcium Silicate Bricks conforming to IS: 4139: 1989 in exposed brick work. The Calcium Silicate bricks have been procured from M/s Sanplast India Ltd., Bahrore.

8.0 WORK DONE

The following quantities of various items have been executed.

Sl. No	Item	Superstructure	Domes and Ancillary Works	Total Quantity
1.	15 mm thick white sand stone tiles	Nil	3052 sqm	3052 sqm
2.	Red sand stone wall lining 50 mm thick	2252 sqm	1818 sqm	4070 sqm
3.	Red sand stone in chhajja	NIL	919 sqm	919 sqm
4.	10 mm thick machine cut grey granite tiles	NIL	1567 sqm	1567 sqm
5.	50 mm thick			
	i) Red sand stone veneer for circular column	10493 sqm	291 sqm	10784 sqm
	ii) white sand stone	86 sqm	NIL	86 sqm
6.	Quarry faced red sand stone work	4617 sqm	263 sqm	4880 sqm
7.	Red sand stone work for wall lining in courtyards	NIL	357 sqm	357 sqm
8.	Red sand stone lamp post	NIL	76 Nos	76 Nos
9.	Red sand stone slab	NIL	210 sqm	210 sqm

Sl. No	Item	Superstructure	Domes and Ancillary Works	Total Quantity
10.	75 mm thick red sand stone path way	NIL	77 sqm	77 sqm
11.	Sand stone mullions/coping			
	i) Red sand stone	1312 cum	82 cum	1394 cum
	ii) White sand stone	292 cum	NIL	292 cum
	iii) Pink sand stone	164 cum	NIL	164 cum
12.	Stone wall lining			
	i) White sand stone	7982 sqm	NIL	7982 sqm
13.	Fixing sand stone jali	270 sqm	NIL	270 sqm
14.	Sand stone spouts			
	i) Rectangular	107 Nos	NIL	107 Nos
	ii) Cylinderical	151 Nos	NIL	151 Nos
15.	Stone louvers	104 sqm	NIL	104 sqm
16.	Plain ashlar (white sand stone)	26 cum	NIL	26 cum
17.	Half Brick work (Infil walls & composite masonry)	5239 Sqm	NIL	5239 Sqm
18.	Full brick work (Partition/ Infill walls & composite masonry)	5062 Cum	NIL	5062 Cum
19.	Calcium Silicate Brick work (Auditorium AHUs)	70 Cum	NIL	70 Cum

DOORS & WINDOWS (WOODEN & ALUMINIUM)

1.0 GENERAL

The door frames, door shutters and architraves in the building have been made of first class Burma teak wood except for few locations (entrance doors) where aluminium glazed shutters have been used. First class Burma teak wood has also been used for hand rails, false ceiling & wall lining. In addition to Burma teak wood, Cedar wood & shisham wood have also been used in various types of decorative false ceiling. The rough ground for doors & frame work for false ceiling & wall lining have been generally made with sal wood.

However, powder coated aluminium section were preferred over Burma teak wood for glazed windows, glazed entrance doors and glazed doors opening in courtyards etc. due to following reasons.

a) The aluminium sections are very sleek and versatile and cover very small area of openings leaving major area for glass as compared to wooden members.

b) Most of the aluminium windows are provided on external walls i.e. along outer periphery and along the internal court yards. These windows / doors are exposed to sun, rain etc. The wooden frames when exposed to rain and sun are susceptible to deterioration whereas aluminium frames are not.

c) Powder coated aluminium section do not require frequent maintenance such as polishing etc.

d) The fixing of glass with aluminium section is also easy with proper aluminium beading and EPDM extruded gaskets.

Powder coated aluminium glazed windows and aluminium glazed doors have been provided in the building. The sizes of glazed windows vary from 541mm x 459mm to 2051mm x 2051mm.

2.0 MATERIALS

The specifications for materials used are as below :

2.1 First Class Burma Teak Wood

As per contract for the superstructure work, "timber shall be of good quality & well seasoned. It shall have uniform colour, reasonably straight grains and shall be free from knots, cracks and sapwood. It shall be close grained and there shall not be less than six growth rings per inch width measured across the rings".

However, in case of contract for Domes & Auditorium stage work the specifications were relaxed a little bit (based on experience in the Superstructure contract) by allowing individual hard & sound knot upto 12mm in diameter and aggregate area of all the knots upto half percent of the area of piece. The comparative position of

specifications of superior class teak wood as per CPWD specification and first class Burma teak wood as provided in the agreement is given as below:

Sl. No.	Characterstics	First Class Burma Teak Wood			Superior Class Teak wood as per CPWD Specification 1977 Vol.1
		As per CPWD Specifications 1967- Vol.I	As per contract for Superstructure & Fire Check Doors	As per contract for Domes & Auditorium (Stage) work	
1.	Colour	Uniform	Uniform	Uniform	Uniform
2.	Grains	Reasonably straight grains not less than 6 growth rings per inch width	Reasonably straight grains not less than 6 growth rings per inch width	Reasonably straight grains not less than 6 growth rings per inch width	Reasonably straight grains with close grains
3.	Dead Knots	NIL	NIL	NIL	NIL
4.	Hard and Sound Knots	NIL	NIL	Not more than 12mm in dia & 0.5% of total area of piece	Not more than 12mm in dia & 0.5% of total area of piece
5.	Cracks	NIL	NIL	NIL	NIL
6.	Shakes & Sapwood	NIL	NIL	NIL	NIL
7.	Moisture content	Max. 10% For less than 50mm thickness and Max. 12% For 50mm & above thickness	Max. 10% For less than 50mm thickness and Max. 12% For 50mm & above thickness	Max. 8%	Max. 10% For less than 50mm thickness and Max. 12% For 50mm & above thickness
8.	Specific Gravity at 8% Moisture content	Not specified	Not specified	Min. 0.6	Min. 0.64

As seen from above table the specifications adopted for first class Burma teak wood are richer than superior class teak wood in respect of grains, hard & sound knots and moisture content. The number of growth rings per inch width have been specified so as to ensure that the wood used is from a fully matured tree. Strict quality control measures were taken to ensure quality of work, each and every piece of the shutter/ frame/batten after preparation was duly checked & signed by Assistant Engineer/Junior Engineer before fabrication and finishing. First class Burma teak wood has been procured from Burma. The import- documents & cash vouchers have been verified during execution so as to ensure that wood procured is in fact Burma teak.

In order to ensure proper seasoning of timber provision was kept in agreement for

submission of cash voucher & certificates from kiln seasoning plants. The seasoning of first class Burma teak wood was done at Jodhpur & Delhi and cash voucher for seasoning charges were verified for correctness.

Though the timber pieces required were cut as per size from selected logs of best quality, large quantity of wood had to be rejected from various lots to provide wood of required specification. Difficulty was faced to large extent in selection of wood for the following works.

a) The thickness of fire check doors was 75mm and first class Burma teak wood as per specification could not be procured inspite of best efforts and timber with relaxed specification was accepted with reduction in cost which was unavoidable.

b) First class Burma teak wood battens used for false ceiling of domes were curved in shape and it was very difficult to obtain battens with "reasonably straight grains" due to overlapping of grains of different planes when cut in curved shape. This resulted in a large percentage of rejection and consequently, wastage of precious timber.

2.2 Sal Wood

Sal wood rough grounds have been fixed by making grooves in stone work for fixing door frames. The rough ground has been fixed in walls/columns/stones as the case may be with minimum 3 nos of 10mm dia stainless steel dash fasteners. Sal wood has also been used for frame work of various types of false ceiling & wall lining. The kiln seasoning and chemical treatment was got done from Laxmi Panel Door Industries, Jodhpur for superstructure work for which payment vouchers were verified.

2.3 Cedar Wood

This has been used for making cross combed planks in false ceiling in superstructure & domes, Cedar battens have also been used in auditorium false ceiling below balcony & for AC grills in Auditorium. As per agreement, the timber shall be of good quality & well seasoned. It shall have uniform colour, reasonably straight grains and shall be free from dead knots, cracks, shakes & sapwood. Individual hard & sound knot shall not be more than 12mm in diameter and aggregate area of all the knots shall not exceed half percent of the area of the piece. Moisture content shall not be more than 8% and specific gravity at 8% moisture content shall not be less than 0.60. The cedar wood has been procured from M/S Union Timbers, Karivelipady, Kochi & M/S Patel Lalji Khimji & Co., Perumbavoor, Kerala for which purchase documents have been verified.

2.4 Sisham Wood

As per agreement "the timber shall be of good quality and well seasoned. It shall have reasonably uniform colour. It shall be free from dead knots, cracks, shakes & sapwood. It shall have reasonably straight grains and there shall not be less than 5

growth rings per inch. Individual hard & sound knots shall not be more than 12mm in diameter and aggregate area of all the knots shall not be more than half percent of the area of the piece. Moisture content shall not be more than 8%. The specific gravity at 8% moisture content shall not be less than 0.7.

2.5 Laminated Particle Board

Exterior grade both side laminated with decorative shade particle board grade I, type II of Novapan Company conforming to IS: 12823: 1990 have been used for doors in WCs & Janitor rooms. The board used bears ISI mark, hence no further testing was got done at site.

2.6 Bison Board

Bison Board of NCL Industries Ltd. have been used as infill material for fabrication of shutters for EDBs. Bison Board is made of wood particle bonded together with portland cement and is highly compressed and heat treated during the manufacturing process. It is highly fire resistant with fire rating upto 2½ hours.

2.7 Mineral Wool (Rock Wool)

The mineral wool conforming to IS:8183 having minimum density of 48kg/cum have been used as infill panels for auditorium shutters.

2.8 M.S. Powder Coated Hinges

The M.S. powder coated hinges having Nerocoat epoxy polyster powder coating (Goodlass Nerolac Paints Ltd. or equivalent) of 50 micron thickness have been provided. The powder coating has been done from Sharma Electro Plating, Okhla, New Delhi.

2.9 Stainless Steel Fittings

For Wooden Doors, the following types of stainless steel fittings conforming to AISI 304/316 grade imported from Germany & Denmark have been used. The tests have been conducted from Sri Ram Test House for conformity of stainless steel used to the specified grade i.e. AISI 304/ 316.

a) Mortice latch & lock (100 mm) with 'D' Type lever handles (both side operated by key).

b) Mortice latch & lock with 'D' Type lever handles (one side operated by key & inside blank).

c) Box type (heavy duty) cam-action Door Closers- Box type cam-action door closer have been used in place of normally used rack & pinion door closer due to following

   i. Rapid decreasing of door opening force especially in large doors.

   ii. These are designed for doors upto 1600mm width whereas rack & pinion door closer are designed for maximum width of 900mm.

iii. The life for cam action door closer is 10lacs operations as compared to 60,000 operations as required by BIS specifications.

iv. Has hold-open facility and adjustable latching speed.

d) 'D' Type pull handles.

e) Heavy duty six lever dead bolts.

f) Flush bolt.

g) *Floor Door Stoppers* : The stainless steel floor door stoppers 75mm, 100mm and 150mm long have been fixed on shutter to avoid direct hitting of shutter to the structure. The initial offer from M/s Soft Sensations was for Rs. 1010/- per floor door stopper. On examining a sample of the door stopper, it was clear that the cost was exhorbitant and could be easily manufactured by local suppliers at much lesser rate. In the event, the stoppers were got manufactured from M/S Kapoor Associates at Delhi with per piece cost of Rs. 235/- resulting in saving of Rs. 1,95,300/- for 252 numbers pieces.

h) Thumb turn latches.

2.10 Aluminium Sections

The aluminium sections approved as per architectural/ shop drawings were not readily available in the market and agency was asked to go ahead for extrusion of sections. First the sample piece of each section was extruded and checked for dimensional accuracy as per IS 6477-1983, then the extrusion was allowed. The aluminium section was extruded by M/s Mahavir Aluminium Ltd. The aluminium extruded sections conforming to IS designation 63400- WP alloy having following chemical and mechanical properties as per IS 733 and IS: 1285 have been used.

a) Chemical Properties :

	Copper (Max.)%	Magne-sium %	Silicone %	Iron (Max.)%	Magnese (Max.)%	Zinc (Max.)%	Titanium (Max.)%	Chromium (Max.)%
Specified	0.1	0.4- 0.9	0.3-0.7	0.6	0.3	0.2	0.2	0.1
Average Value	0.071	0.57	0.46	0.36	0.09	0.06	0.006	0.011

(Note ; The remainder is of course Aluminium)

b) Mechanical Properties :

	Tensile Strength (Min.) (N/Sqmm)	0.2% Proof stress (Min.) (N/Sqmm)	Elongation (Min.) (Gauge Length 50 mm)
Specified	185	156	7 mm
Average Value Achieved	222.04	199.81	9.35 mm

c) *Powder Coating of Aluminium Sections* : The uniformity of colour, durability & adhesion of coating with aluminium sections etc. depend upon the quality of powder, pretreatment of aluminium sections and process of powder coating. Pure polyester powder of make Berger, Nerocoat or Jenson & Nicholson was specified in the agreement. Perma coat polyester powder of Berger was used. The powder coating has been done by using electrostatic powder spray method and extruded aluminium sections were pretreated before powder coating. The thickness of the finished polyester powder coating was specified to be minimum 50 micron and not more than 120 micron at any point.

2.11 Hermetically Sealed Double Glass Unit

Hermetically sealed double glass unit comprising two sheets of float glass panes separated by hollow anodized aluminium spacer, hermetically sealed using primary and secondary sealants have been used for glazing of windows. The hollow alluminium spacer has been filled with Naftomal 3A or equivalent dessicant which absorbs water molecules. The desiccant used was 35gm per running metre length of aluminium spacer. BUTYL (NAFTOTHERM BU) has been used as primary sealant and silicone sealant of Dow Corning 793 as secondary sealant.

The agency got prepared double glass units from M/s Gold Plus Glass Ltd. one of the following specialized agencies approved for double glazed hermetically sealed glass units as per terms of the agreement.

a) M/s Alkarma

b) M/s Atul Glass Industries Ltd.

c) M/s Gurind India Pvt. Ltd.

d) M/s Gold Plus Glass Ltd.

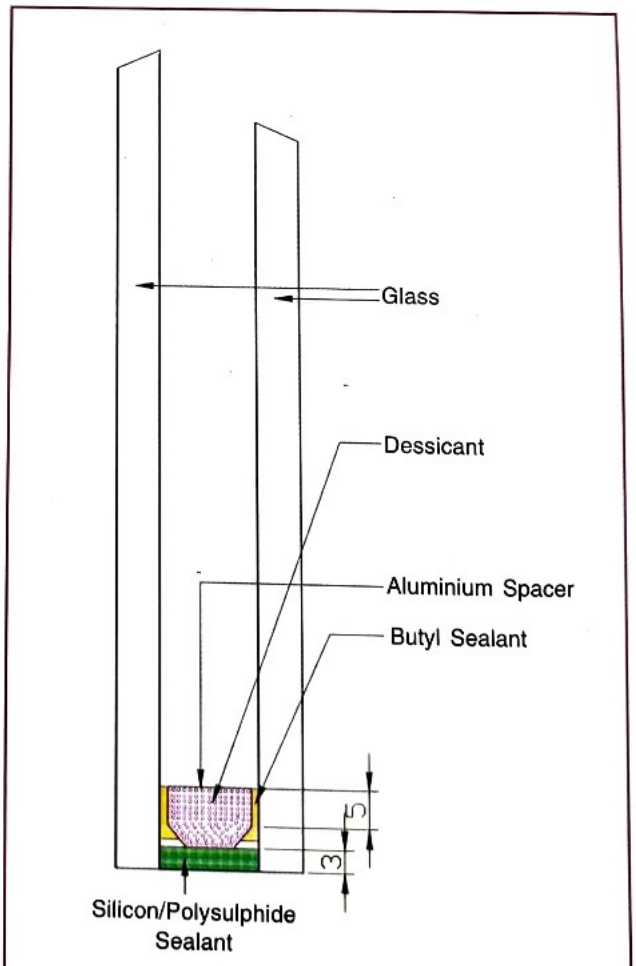


Fig 10.1 : Hermetically Sealed (Double Glazed Unit)

2.12 Float Glass

The clear float glass manufactured by Gujrat Guardian Limited have been used. The glass used is clear, flat, transparent and free from cracks. The tolerance of ± 0.3 mm was allowed in thickness. As far as glazed doors are concerned 6mm thick heat strengthened float glass were used to minimize the breakages. Since no IS Code was available for float glass at the time of

framing of specifications, Japanese Code JIS R 3202 was referred for allowable defects in float glass and following defeciencies were permissible

Sl. No.	Defects	Central	Outer	Remarks
1.	Gaseous inclusion, maximum size mm	3.0	6.0	Separated by at least 30cm
2.	Opaque gaseous inclusion maximum size mm	3.0	6.0	Separated by at least 60cm
3.	Knots, dirts and stones maximum size mm	1.0	1.0	Separated by at least 60cm
4.	Scratches,Rubs and Crush	Faint	Light	Separated by at least 60cm
5.	Bow percent, maximum	0.5	0.5	
6.	Reams Strings and lines	Light	Light	
7.	Waviness	Nil	Nil	
8.	Sulphur stains	Nil	Nil	
9.	Corner breakage and chip	Not more than nominal thickness of float glass		

In addition to above, the cluster of defects mentioned under Sl. No. 1,2 & 3 of table above was also allowed in the combinations shown in the following table.

Sl. No	Quality Of Float Glass	Central Area	Outer Area
1.	A	One cluster of maximum three defects comprising only one from (3) and two from either (1) or (2) or one each from (1) and (2) in an optional circle of 30cm dia.	One cluster of maximum five defects of any type mentioned in (1), (2) and (3) but the presence of stone should not be more than one in optional circle of 30cm dia.

NOTE : Area enclosed by an ellipse or circle whose major and minor axes or diameter do not exceed ½ the length and width of the outside of float glass was considered central area and the remaining area as the outer area.

2.13 EPDM-Gaskets

The glass unit was fixed to aluminium frame using aluminium snap beading and EPDM gasket as per approved shop drawing. The EPDM gaskets were of size and profile as shown in drawings and so as to render the glazings of doors, windows & ventilators air and water tight. The EPDM gasket meeting the following requirements was used.

Sl. No	Description	Standard Followed	Specification Required
1.	Tensile strength Kgf/Sqcm	ASTM – D 412	70 Minimum
2.	Elongation at break %	ASTM – D 412	250 Minimum
3.	Modulus 100% Kgf/Sqcm	ASTM – D 412	22 Minimum
4.	Compression set % at 70°C, 22 Hrs.	ASTM – D 395	50 Maximum
5.	Ozone resistance	ASTM – D 1149	No Visible cracks

2.14 Fittings for Aluminium Doors/ Windows

a) The stainless steel friction stays of AISI-304 grade of make 'Ebco' have been used.

b) The powder coated lockable handle of make TITON TF-200LN/201LN (TITON HARDWARE LTD. UK) have been used.

c) The heavy duty double action hydraulic floor spring of make DORMA B.T.S. 75 V & B.T.S. 80 V (Germany) suitable for door leaf of weight 100Kg have been used. The top cover plate is of stainless steel.

d) The tubular handle bar of aluminium with polyester powder coating of minimum 50 micron have been used. The outer dia of tube is 32mm & thickness is 3mm.

e) The tower bolts of aluminium with polyester powder coating of minimum 50 micron have been used.

3.0 FABRICATION AND FIXING OF WOODEN DOORS

3.1 Fabrication

Timber sawn to sizes after kiln seasoning were brought to site & further fabrication was done at site workshop. Different members of frame/shutter were finished to sizes and were shown by the agency to the Junior Engineer/Assistant Engineer specially authorized for the purpose. These were checked for different requirements of specification & initialed as a token of acceptance. After approval these members were assembled & fixed with necessary glue/bamboo pins etc. for preparation of frame / shutters.

3.2 Fixing

The sal wood rough ground of specified size was fixed in the slots cut in the column, wall etc. The sal wood was painted with bitumen on the surface which was to come in contact with stone work/RCC etc. The rough ground was fixed to the column/wall surface with 3 nos 10mm dia stainless steel dash-fastener for each member

The door frames were then fixed to the rough ground with screws & embedded in floor at the bottom & made in plumb. The fabricated door shutter was then fixed with 4 nos MS powder coated hinges with the frame. Minor adjustment in width/height required as per site conditions were made to make the shutter functional. After

checking functioning, the shutters were removed from the hinges for French spirit polishing and melamine finish so that polishing by melamine finish could be conveniently applied on all edges including top & bottom.

4.0 FABRICATION AND FIXING OF ALUMINIUM DOORS & WINDOWS

4.1 Shop Drawings

The contractor prepared and submitted shop drawings for each type of doors/ windows/ventilators by using suitable sections based on architectural drawings, adequate to meet the requirement/specifications. The shop drawings showed the details of fittings and joints. Before start of the work, all the shop drawings were approved by Engineer-in-Charge.

4.2 Fabrication

Individual door/windows/ventilators etc. were fabricated as per the actual sizes of the opening left at site. For smaller windows the mitred joints were corner crimped and for bigger windows and door the mitred joints were fixed with self tapping stainless steel screws using extruded aluminium cleats of required length and profile. The provision was made for replacing damaged/broken glass panes without removing or damaging any member of exterior finishing material.

4.3 Fixing

The holes in concrete/masonry/wood/any other members for fixing anchor bolts/ fasteners/screws were drilled with an appropriate electric drill. The stainless steel anchor fasteners were of grade AISI 304 of make Canco. The salwood backing was fixed, wherever required.

Openable windows/doors/ventilators etc. were placed in correct final position in the opening and fixed to sal wood backing using stainless steel screws of required size at spacings not more than 250mm centre to centre. In order to ensure that the window frames cover the minimum area of the openings, the vertical members of frames in fixed windows have been fixed with sal wood backing in the grooves cut in the stone mullions and are not visible.

Aluminium sections in contact with stone masonry, brick work, concrete, plaster or dissimilar metal, were coated with an insulation lacquer, to ensure that electrochemical corrosion is avoided. Insulation material was trimmed off to a clean flush line on completion.

The gap between aluminium section and RCC/ Stone masonry has been filled with silicone sealant Winsil 20 of GE Silicone. All joints and glazing pockets were cleaned by removing all foreign matter and contaminants such as grease, oil, dust, water frost, surface dirt, old sealants or glazing compounds and protective coatings. Area adjacent to joints were masked to ensure neat sealant lines.

Backer rod of appropriate size was installed and silicone sealant was applied in a continuous operation using a positive pressure adequate to properly fill and seal the joint. The silicone sealant was tooled with light pressure to spread the sealant against backing material and the joint surfaces before a skin forms. Masking tape was removed

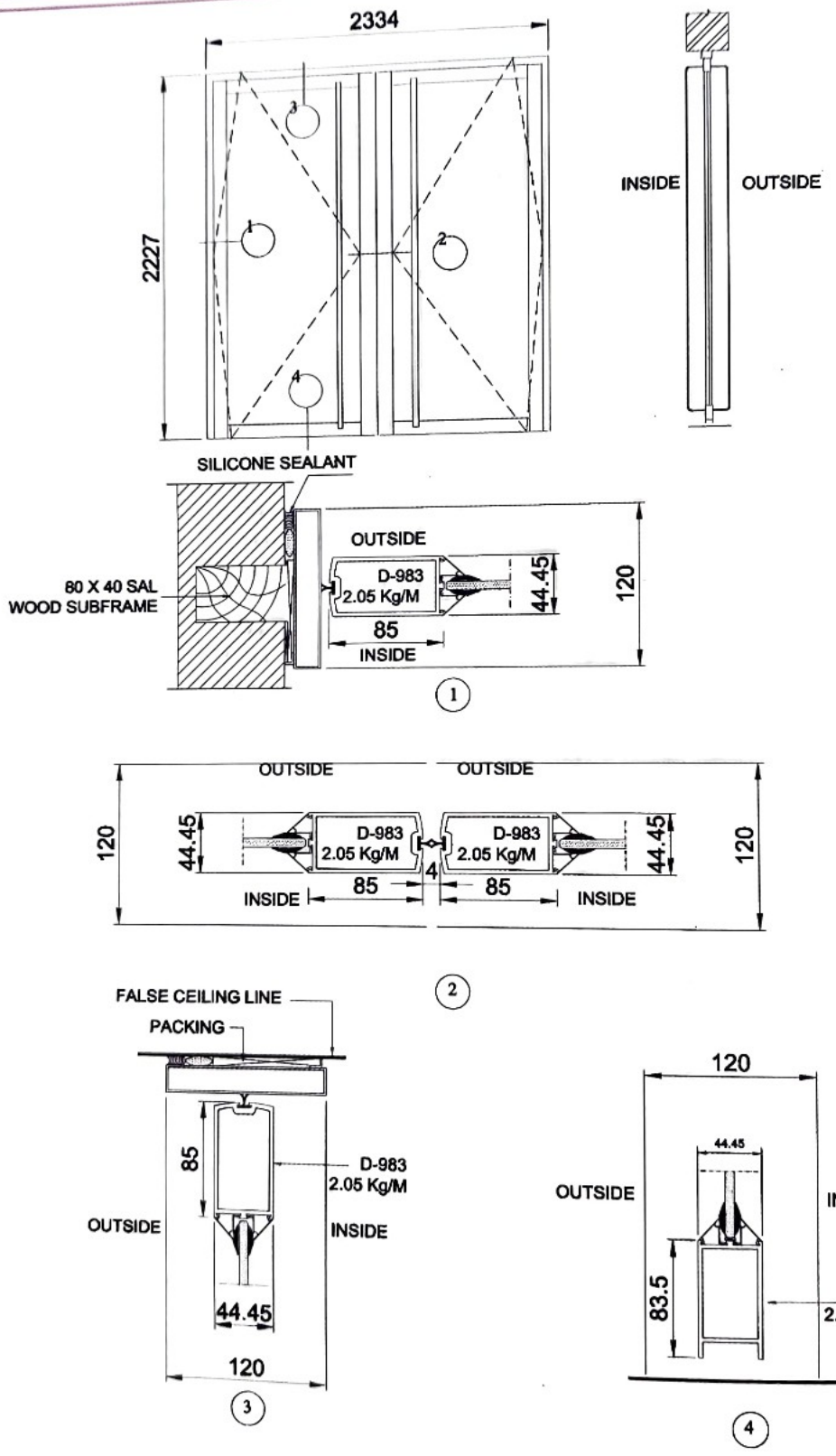


Fig 10.2 : Details for Alumium Doors

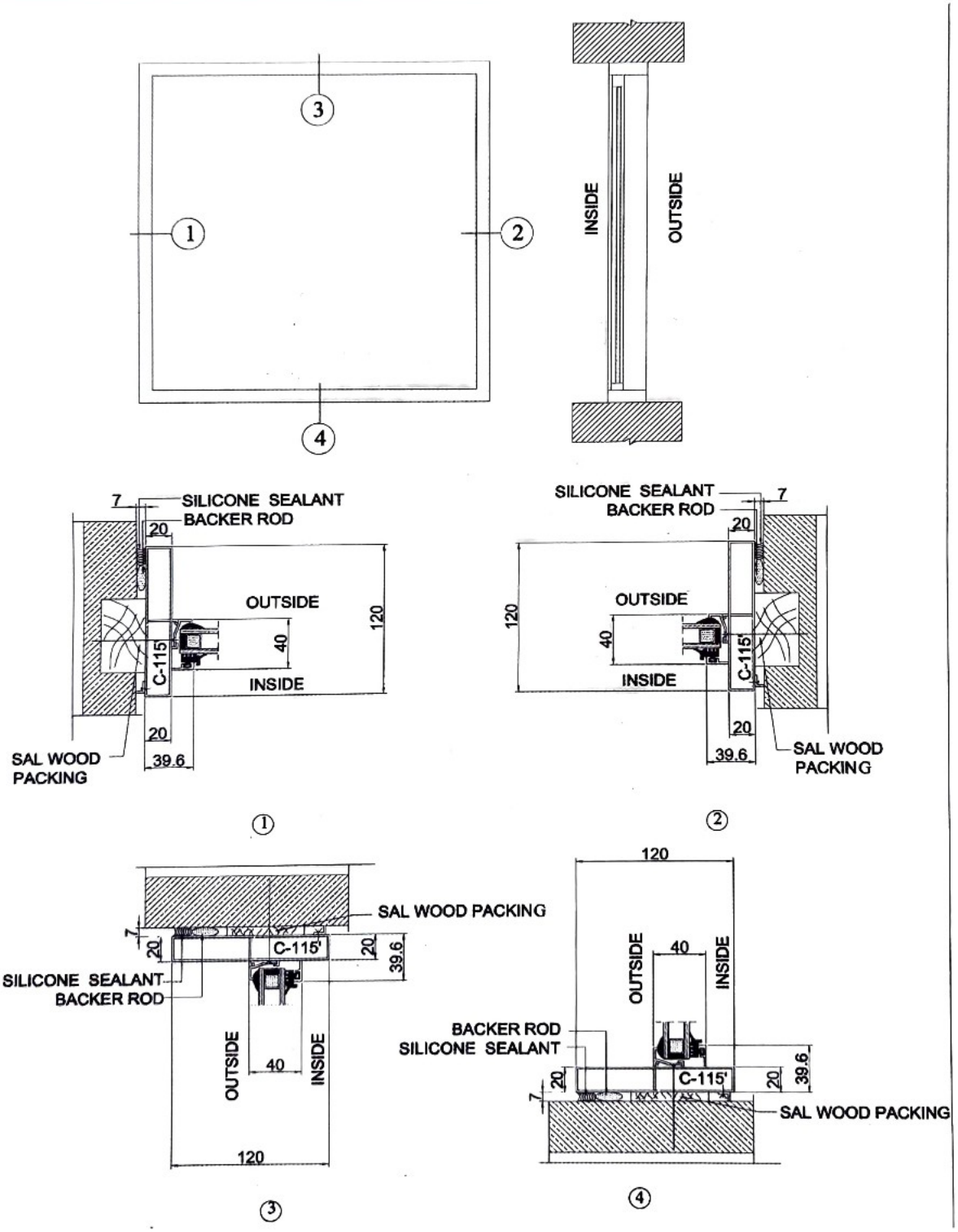


Fig 10.3 : Details for Alumium fixed Windows

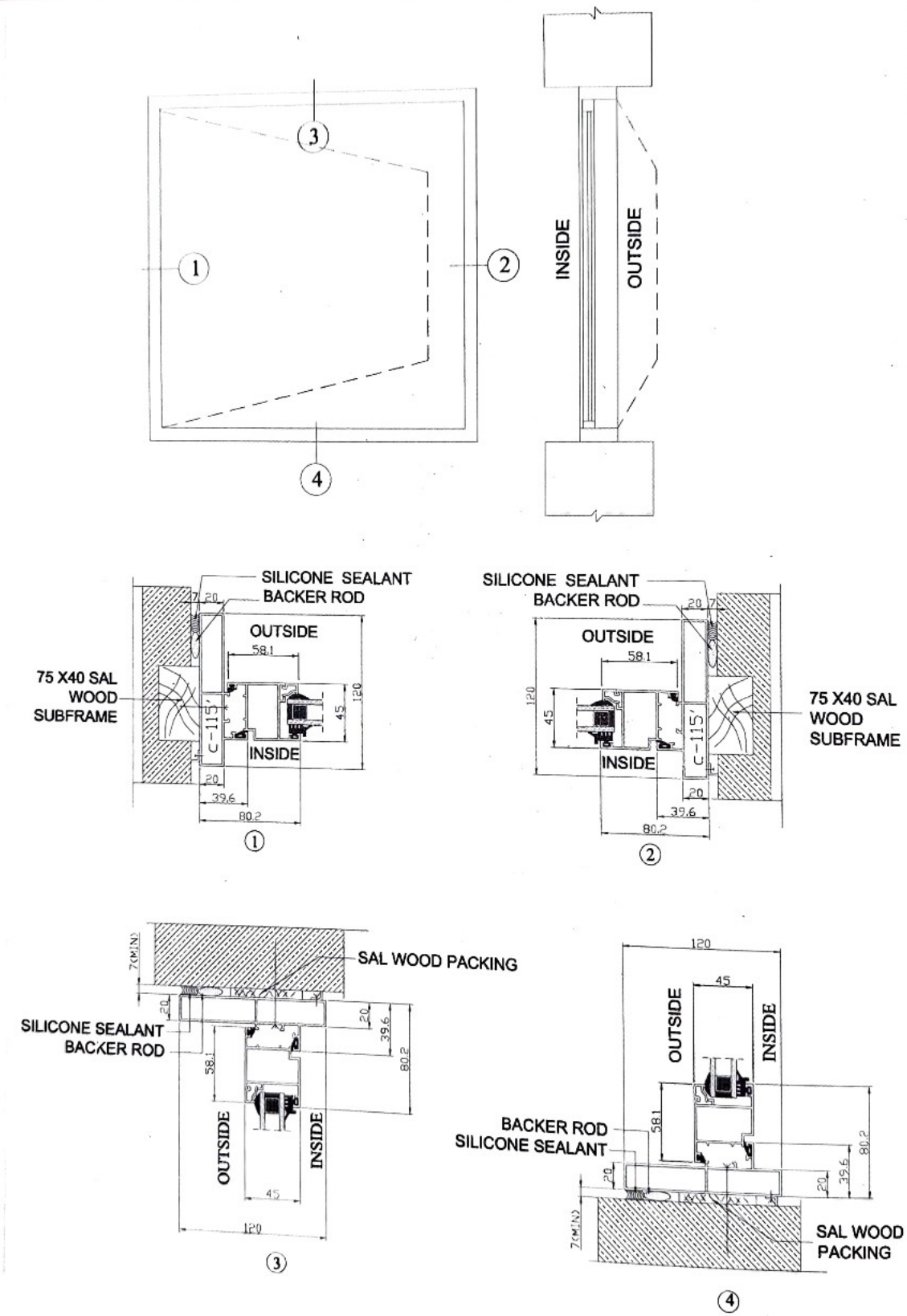


Fig 10.4 : Details for Aluminium Openable Windows

as soon as the silicone joint was tooled. A tolerance of ± 3mm was allowed in the width of silicone joints. The minimum depth of the joints at throat was 6mm.

5.0 WORK DONE

The details of various type of wooden and Aluminium shutters and fittings provided are as below:

Sl.No.	Type	Location	Nos	Fittings provided
	A) Wooden Doors			
1.	Panelled wooden shutters			
a)	50mm thick with 19mm thick panels	Banquet Hall	1	Decorative handle (wooden), Dead bolt & flush bolt
b)	38mm thick with 19mm thick panels	AHU, Machine Room & Blower Room	92	MS Tower Bolt Stainless Steel Door stopper Mortice latch & lock with lever handle.
c)	38mm thick with 19mm thick panels and 12mm thick louvers	Toilets	62	Mortice latch & lock with 'D' type handle one side operated by key, Door Stopper, Hydraulic door closer
2.	38mm thick fully glazed shutter with 5mm float glass			
a)	For FHC	FHC	88	One dead bolt lock one side operated and 'D' type handle
b)	For Computer Centre	Computer Centre	1	One dead bolt lock one side operated and 'D' type handle
3.	45mm thick battened and framed wooden shutter with core of 19mm thick commercial board & 13mm thick battens on both sides.			
a)	Single leaf	Offices etc.	295	Mortice latch & lock with a pair of D-type pull handle, Door stopper, Door closer
4.	38mm thick battened and braced wooden shutter	Parking Shaft Room, Security Rooms	15	Mortice latch & lock with a pair of D-type pull handle, Door stopper, Door closer
5.	107mm thick with 12mm thick wooden battens on both sides with core of 75mm thick mineral wool covered with 3.5mm thick commercial ply on both sides	Auditorium Mini Auditorium AVM: First Basement	22	Decorative Wooden handle, Door stoppers, Dead bolt

Sl.No.	Type	Location	Nos	Fittings provided
6.	45mm thick battened & framed wooden shutter with 13mm wooden battens on both faces with core of 19mm thick bison board (For making fire proof)			
a)	Double leaf	EDB	89	Aluminium tower bolt, Mortice latch & lock with D-type handle
b)	Single leaf	EDB	75	Mortice latch & lock with D-type handle
7.	25mm thick Pre-laminated Particle board shutters	WCs & Janitor	177	Thumb Turn latch in WCs & Dead bolt in Janitors with Stainless Steel handle
8.	Fire Check Doors	As per requirement of compartmentation	136	Details available in compartmentation
		Total	**1053**	
B)	Aluminium Doors/Windows			
1.	Doors	All main entry at GF, Courtyards	47	Tower Bolt, Handle Lock & Floor spring.
2.	Fixed Windows	Rooms & Corridors	1781	Nil
3.	Openable Windows	Rooms & Corridors	1209	Stay, Handle

COMPARTMENTATION – FIRE SAFETY MEASURES

1.0 GENERAL

Provisions have been made in the building for various fire safety measures such as automatic fire detection/ alarm system, automatic sprinkler system, automatic public address system, automatic exhaust system etc. As per National Building Code in case of large area of buildings, the building is to be divided into smaller compartments for fire safety provisions. The compartmentation of building is required in view of following:

a) The design of fire safety measures is economical

b) Only a particular compartment & not the entire building is disturbed in case of fire.

c) The fire, smoke, gases & fumes do not travel from one portion of the building to another.

The building has been divided into 32 fire compartments. Effective compartmentation has been achieved by making provisions in the building as discussed in following paras.

2.0 FIRE CHECK DOORS

The various compartments of the building communicate with each other at each floor level. The entry from one compartment to another needed to be closed with provision of a door. The Fire Rated Doors generally being manufactured were not matching with the aesthetics of the building. After prolonged consultations and discussions, the Chief Fire Officer, Delhi Fire Service vide his letter dated February 21, 2000 and dated May 22, 2000 agreed for provision of 70mm thick Burma teak wood doors as fire check doors. Accordingly provisions have been made for following Burma teak wood fire check doors in the building.

Sl. No	Type of Door	Second Basement	First Basement	Ground Floor	First Floor	Total
1.	75mm thick battened & framed shutters					
a)	Double leaf in corridors	13	11	NIL	NIL	24
b)	Single leaf in staircase	13	10	10	10	43
c)	Double leaf in other areas	16	7	NIL	NIL	23
d)	Single leaf in other areas	3	6	NIL	NIL	9
2.	75mm thick panelled shutters with 50mm thick panelling					
a)	Double leaf in corridors	NIL	NIL	9	13	22
b)	Double leaf in other areas	NIL	NIL	8	7	15
	Total in nos.	45	34	27	30	136

The specifications for wood have been taken as first class Burma teak wood. The thickness for most of the members of shutters used is 75mm. Arranging wood to meet the above specifications was a tedious job for 75mm thick shutters. Even after rejection of 30-40% members of door frames/shutters, the requirement of specification could not be achieved. As the timber was being imported from Burma the lead time for procurement was considerable. At the same time we were working towards a very tight target for completion of the building. We could not close our eyes to these constraints and simply go on rejecting the timber brought to site. So a conscious decision was taken to lower some aspects of the specification for fire check doors, without compromising on the fire rating or the aesthetic appearance of the finished shutters. The relaxation in specifications with reference to agreement provisions were permitted with reduction in rate.

2.1 Fittings

The following provisions were made in fire check doors:

a) Single Leaf Shutters: All single leaf shutters have been provided with door closer-one number, dead bolt-one number, D-type pull handle-one pair & intumescent seal.

b) Double Leaf Shutters: All double leaf shutters have been provided with door closer – 2 nos, door coordinator-one number, sunk slide flush bolt- 2 nos (top & bottom), intumescent seal, dead bolt-one number, decorative handles-2 pairs in GF & FF and 2 pairs 'D' type pull handle at Ist and 2nd basement. In corridor doors in addition to above fittings, electro-magnets have also been provided.

2.2 Special Fittings

The details of special fittings are discussed as below.

a) *Electro-Magnets :* Electro-magnets have been provided in the corridor doors which, in the normal mode, holds the shutter leaves in open position. (The corridor doors are supposed to be kept in open position for easy movement except in case of fire.) Provision has been made for passing of current of 24 Volt DC at current of 5mA which magnetizes the electro-magnet and holds the shutter leaves in open position. In case of fire in a particular compartment, the electric circuit of electro magnet gets switched off by sensing fire through fire detection system, the electro-magnets of the FCDs of that compartment get demagnetized and the doors get closed to prevent the spread of fire into other compartments. The electro-magnet EM-500 of DORMA company from Germany have been used.

b) *Door Coordinator with Door Closers :* Door coordinator with 2 nos. door closers have been provided for double leaf shutters. The provision of door coordinator ensures the movement of shutter leaves in such a way that passive leaf first comes into close position & then the active leaf starts moving to close the door effectively. The door coordinator G-93 GSR with door closers TS-93B/TS-93G from Dorma Company of Germany have been used.



Door with Electro-Magnet

c) *Heat-Activated Intumescent Seal :* The basic principles of good sealing require a continuous seal. Lorient make intumescent fire seal has been provided for preventing passage of fire & hot smoke through the top & sides of doors. These seals consist of a strips of intumescent material enclosed in rigid PVC. These can provide 60 minutes fire resistance. Intumescent material used in these seals is Palusol, a sodium silicate based material. When exposed to fire, it remains stable at temperatures in the region of 1000 °C. Palusol is activated at temperature of 100-150°C and expands 5 to 10 times forming a rigid foam with a high level of thermal insulation. A firm seal is effected but not so firm as to impede the activities of the fire fighting personnel. Therefore, the activation of the seals will in no way compromise the escape of occupants.

d) *Box Type Door Closers :* The box type door closers with Cam-Action TS-93B/TS-93G of Dorma Company from Germany have been used for all single leaf fire check doors.

GENERAL : The provision was also made for panic latches in the agreement which was dropped at execution stage in consultation with Chief Fire Officer and Consulting Architect since the doors with panic latch can be opened only from the side on which latch is provided and is locked from the other side. Alternatively dead bolts with handles have been provided.

3.0 FIRE BARRIERS

After providing fire check doors, the space between lintel level & ceiling level still provided free access from one compartment to other & defeated the very purpose of compartmentation. To overcome this, the space above lintel level was sealed with fire barriers as below:

3.1 Calcium Silicate Board

The system as per manufacturers specification of Promat Company have been provided. The system provides for 9mm thick Calcium Silicate board of density 995Kg/cum fixed on GI frame providing a 2-hour fire rating. This has been used for closing space above Fire Check Door Lintels where clear space (without services) is available.

3.2 Mineral Wool Coated with Fire Resistant Paint

The system has been used for closing the space above lintel level of fire check

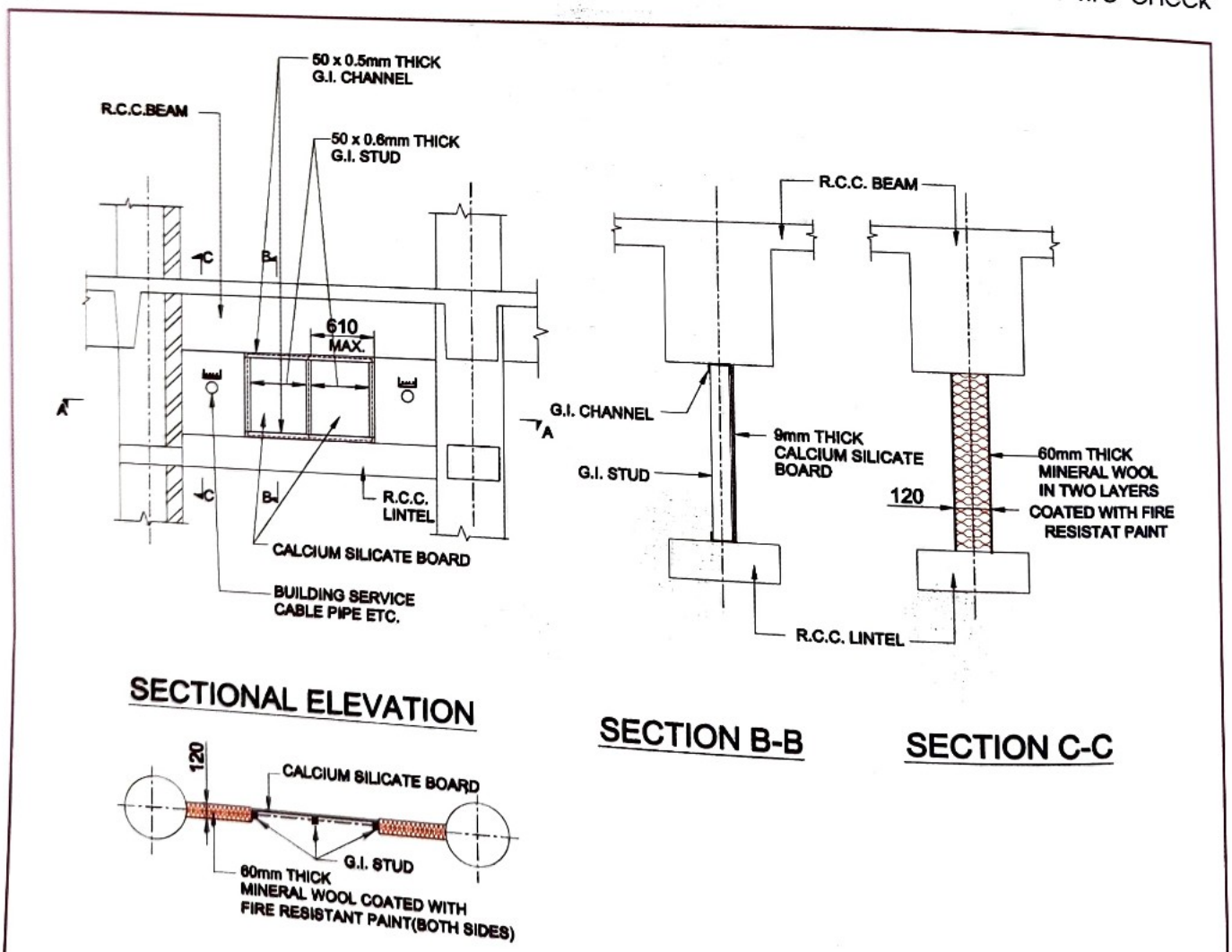


Fig 11.1 : Fire Barriers

doors & other areas through which pipes, cables, cable tray etc. for various services are passing and the openings available are irregular in shape & size. The system consists of providing two layers of mineral wool 60mm thick each having density of 121kg/cum. Though as per agreement, minimum prescribed density of mineral wool was 140 kg/cum, but the density of wool used was 121kg/cum as per test report received from Shriram Institute for Industrial Research. As the result obtained was within ± 15% tolerance permitted in IS:8183-1993, the mineral wool was accepted with cost adjustment. The mineral wool is coated with fire resistant paint of Promat Company as per manufacturers specification and has a fire rating of four hours. The material having higher fire rating have been used in this area since a lot of electrical services are passing through this area.

4.0 QUITE-EASILY-DONE WALLS

The internal walls at many locations in the building were provided upto lintel level only. The walls were left at lintel level initially to avoid breakage for passing of various services such as AC duct, cable tray etc. After completion of these services this space was required to be sealed for effective compartmentation. At completion stage it was not desirable to construct brick wall with cement mortar. To overcome this problem QED walls were erected above lintel level. QED wall consists of 100mm thick gypsum block available in size of 666mmx500mm manufactured by M/S IDL Industries (India) Ltd. These blocks can be joined with QED bonding plaster which require no water-curing. These blocks have density of 900kg/cum, average compressive strength of 9.3kg/sqcm. (against the minimum specified value of 5.0kg/sqcm for non-load bearing gypsum blocks as per IS:2849-1983) and fire resistance rating of 3 hours.

5.0 SEALING OF EDB CUT-OUTS

The FCDs, the fire barrier & QED walls constructed above lintel level fulfilled the requirement of compartmentation. However, the cut-outs in EDBs which were the communicating path from one floor to another also needed treatment for effective fire compartmentation. These cutouts were sealed with 2 layers of 60mm thick mineral wool of density 121kg/cum coated with fire resistant paint of Promat Company. Two nos PVC pipes were left in each EDB and temporarily sealed with fire barrier to meet the requirement of future insertion of cables etc., through these pipes. There were few locations in EDBs where mineral wool barrier was not feasible due to space constraints. Fire resistant pillow of different sizes manufactured by M/S Promat Company were used for such irregular & smaller openings. These pillows are designed to provide 3 hour fire rating.

6.0 AIR HANDLING UNIT DOORS

As per provision in agreement 38mm thick wooden panelled shutters with 19mm thick panels were provided. However, subsequently it was felt necessary that doors for AHUs should not only be fire resistant for one hour rating but should also have good acoustics. The AHU doors have been made sound-proof & fire resistant in the following manner.

Plain A.C. sheet 6 mm thick was fixed on the shutter towards AHU side. A frame work of first class Burma teak wood was provided over the asbestos sheet and covered with aluminium perforated sheet. 40mm thick mineral wool of density 48kg/cum wrapped in markeen was placed into the gap. This proved to be an appropriate solution for converting existing shutters into acoustically treated fire-proof shutters without sacrificing the aesthetics.

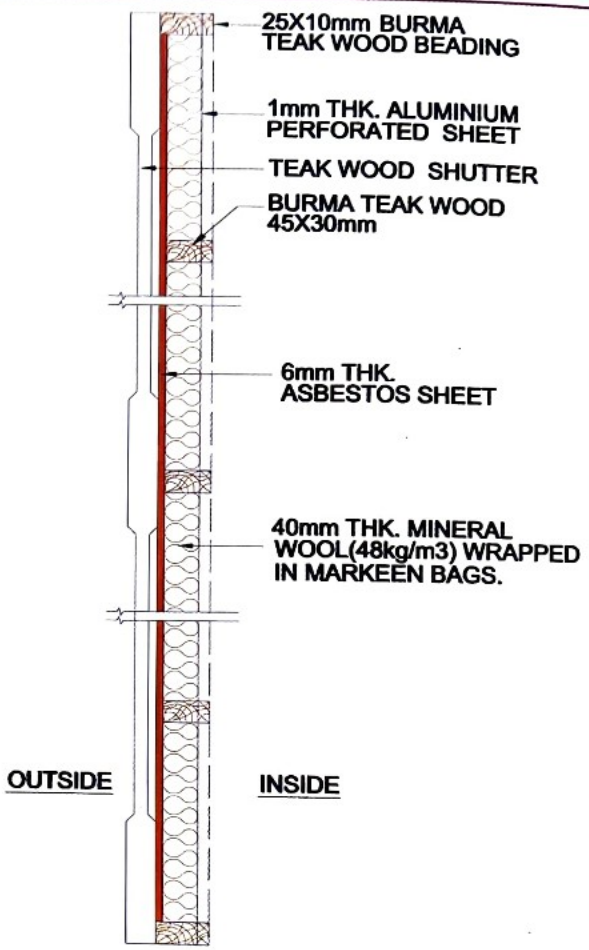


Fig 11.2 : Details of AHU Doors

7.0 PORTABLE FIRE EXTINGUISHERS

As per Chief Fire Officer's approval to building plans, portable fire extinguishers were to be provided in accordance with IS:2190 for fighting localized fires. Accordingly, following types of extinguishers have been provided in the building.

a) CO_2 type fire extinguishers of 4.5kg capacity for AHUs, Pantries, Kitchenettes, blower room, control room & computer center etc. Total number of such fire extinguishers are 143 nos.

b) ABC type fire extinguishers of 5kg. capacity in the corridors, basements & other locations have been provided, where powder type extinguishers were feasible. Total number of such extinguishers in the building are 211 nos.

8.0 FIRE RESISTANT TREATMENT ON STRUCTURAL STEEL TRUSSES-AUDITORIUM

The Chief Fire Officer, Delhi Fire Services during inspection on April 2, 2002 desired that structural steel trusses provided in the Auditorium dome should also be protected with fire resistant protective material. The structural steel when exposed to fire, loses its strength and properties at temperature of 550°C and above. Hence it was felt necessary that structural steel trusses of auditorium dome should be provided with fire-resistant coating to avoid initial damage. As on April 2, 2002 the work for false ceiling for auditorium dome was complete and it was not feasible to provide fire resistant coating on unexposed surfaces. The matter was again discussed with Chief Fire Officer, who desired that wherever feasible fire coating should be done which will substantially serve the purpose.

8.1 Material Selection

The alternative materials of following agencies dealing in this field were discussed.

a) Navair International Limited: The firm is dealing in fire retardant paint for steel members with the brand name Viper.

b) Newkem Engineers Pvt. Ltd., Mumbai: The firm is dealing in fire retardant paint for steel structure with brand name CAFCO.

c) Global Fire Protection Co. : The firm is dealing in passive fire protection material & paint with brand name PROMA PAINT.

d) LLOYD Insulation (India) Pvt. Ltd.: The firm is dealing in ceramic fibre blankets with the brand name SUPERCERA.

e) Agni Safety (I) Pvt. Ltd. : The firm is dealing in ceramic fibre blankets with the brand name "Fire Master Ceramic Blanket".

8.2 Provision in Agreement

The matter was again discussed with Chief Fire Officer who agreed that either fire resistance coating or ceramic blanket duly tested by CBRI, Roorkee for conformity of one hour fire rating may be used. Accordingly the tenders were invited with both the alternatives. M/S Agni Safety (I) Pvt. Ltd. had quoted the lowest rate for ceramic fibre blankets. The work was awarded to M/S Agni Safety (I) Pvt. Ltd.

8.3 Material Used

M/s Agni Safety (I) Pvt. Ltd is working in the field of passive fire protection in association with Murugappa Morgan Thermal Ceramics Ltd.with brand name: Fire Master Ceramic Blanket. MMTCI is a subsidiary of the Ceramic Division of Morgan Crucible Co. plc U.K. Fire Master blanket is an asbestos-free, alumino-silicate fibre made from blends of high purity alumina & silica and has zero flame spread, zero smoke development and zero fuel contribution characteristics. The Fire Master blanket was already tested in CBRI, Roorkee for 50mm thick for 2 hours fire rating as per ASTME-119, BS:476 Part 20 & IS:3809-1995 as per certificate available with company. However the material has been got tested for 37mm thick Fire Master blanket through CBRI Roorkee and passes for one hour fire rating.



Ceramic Blanket Testing
CBRI, Roorkee



Truss wrapped with Blankets

8.4 Procedure For Application

The provision in the agreement was made for minimum 25mm thick ceramic blanket, however, 37mm thick fire resistant blanket comprising of two layers (25mm + 12mm) has been provided for fire rating of one hour. The surface of all the steel members of the structure was cleaned thoroughly. First layer of 25mm thick blanket was wrapped with 25mm overlap and adjacent blanket was wrapped in similar way. The joints between two blankets have been compressed and the first layer of blanket has been secured in position with the help of GI tie wire. Second layer of blanket of same grade 12mm thick has been wrapped over the first layer. Joints have been staggered by 300mm in second layer with respect to first layer joints. Blanket of second layer have been secured with the help of 19mm wide carbon steel tape. The top layer has been covered with GI wire mesh and secured with steel tie wire.

9.0 SUMMARY

75mm thick Burma teak wood shutters, fire barriers comprising of calcium silicate board and mineral wool coated with fire resistant paint above lintel level at door locations, QED walls above lintel level for other walls and fire pillows & barrier in EDBs taken together provide complete & effective fire compartmentation as designed and conceived for the prestigious Parliament Library Building. The provision of portable fire extinguishers at various locations in the building and ceramic fire blanket on exposed surface of structural steel truss of auditorium dome further add to the fire safety of the building.

FLOORING

1.0 TYPES OF FLOORING

The total flooring area of the building is 57529sqm including parking, basements, service area, AHUs, Terrace etc. The functional use of building varies from location to location - like stack area for books, reading area, lecture rooms for training, office rooms, committee rooms, banquet hall, auditorium, museum, service area, parking etc. The type of flooring in various areas have been selected according to utility and importance of the area. The change in flooring pattern was also necessitated to break the monotony. The following types of flooring in various combinations have been used.

Sl. No.	Type of Flooring	Location	Architectural consideration	Total quantity in Sqm
1.	Cement concrete 40mm thick	Auditorium Seating Tiers	Covered with carpet	898
2.	Cement concrete with hardonite 52mm thick	Machine Rooms, AHUs,Service area	Movement & placement of Heavy Machinery	4890
3.	Kota stone with mosaic strips	Second Basement, Office Rooms, Library (FB,GF & FF)	Mosaic strip pattern given to match floor trunking strips	26737
4.	White marble, kota, & jaisalmer	Corridors (FB, FF) except focal area, MPs reading Area, (GF & FF) Canteen, BPST Coffee Room	VIP Area involving occasional use by dignitaries	3090
5.	White marble & Jaisalmer	Auditorium Foyer, (GF & FF) AVM(GF & FF)	VIP Area involving occasional use by dignitaries.	2952
6.	Udaipur pink with white marble	Banquet Hall	VIP Area	298
7.	Granite (Polished & Flame finish)		VIP movement area & focal Area	
a)	Grey Granite	Corridor (GF) Staircases,Focal Area Toilets (GF & FF)		3049
b)	Almond Granite	Focal Area FB		326

Sl. No.	Type of Flooring	Location	Architectural consideration	Total quantity in Sqm
c)	Pink Granite	Focal Area GF & VIP entrance		1659
d)	Sinduri Red Granite	Focal Area FF		334
8.	Red sand stone	Terrace/Open Courtyard.	To match Parliament House	4460
9.	Ceramic tiles	Photolab at First basement	Use of chemicals	330
10.	Rangoli patterns	BPST, VIP, AV, Service Entrance at GF & Focal at SB	VIP Area	225
11.	Precast chequered tile	Parking & space below Auditorium	Space for Parking, Storage	8007
12.	Burma Teak wood	Auditorium stage, Stage of BPST/FF, AV (GF & FF) Committee Rooms.	Stage Area	274

2.0 MATERIALS USED

The special materials used which are not specified in CPWD Specifications are classified as below:

2.1 Marble

a) *Banswara/Andhi Marble :* White marble with brown & grey streaks/shades and brown & green spots available at Banswara/Andhi, Rajasthan. Stones with through cracks on both faces was not accepted. However, in stone pieces upto a width of 150mm, the total length of superficial cracks not exceeding the length of such stone pieces & for stone pieces beyond 150mm width, the total length of superficial cracks not exceeding double the length of such pieces was accepted. The length of each crack, if any was measured as straight line between its two ends.

b) *Udaipur Green Marble :* Dark Green marble with dark green patterns available at Udaipur, Rajasthan.

c) *Udaipur Pink Marble :* Pink marble with blackish & white streaks available at Udaipur, Rajasthan.

d) *Jaisalmer Yellow Marble :* GoldenYellow marble available at Jaisalmer.

2.2 Granite

a) *Light Grey Granite :* Light grey granite with black & white spots available at Sadarhally (near Bangalore), Karnataka.

b) *Pink Granite* : Light pink granite with black, chocolate & white spots available at Bangalore, Karnataka.

c) *Almond Granite* : Light brown granite with black, chocolate & white spots available at Pali (Distt.),Rajasthan

d) *Sinduri Red Granite* : Sinduri Red Granite with black, chocolate & white spots available at Jodhpur, Rajasthan

The granite of following finishes have been used.

i. Mirror Polished : In general machine mirror polished granite have been used.

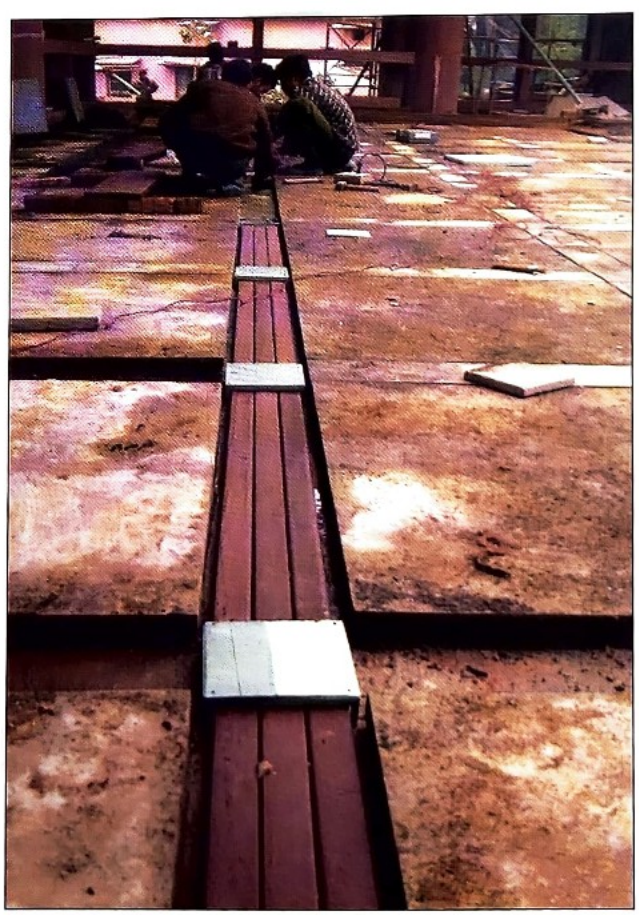
ii. Flame–Finished : The mirror polished granite is very slippery, hence as anti skidding measures flame-finished granite have been used in combination with mirror polished granite. This also helps in reducing the glare and breaking the monotonous look since these are used in long corridors and large common areas. The flame-finished granite has been prepared before fixing at site by flaming the top surface of granite with the help of acetylene torch to the required temperature to make the surface rough.

2.3 Precast Chequered Hardonite Cement Concrete Tiles

Hardonite cement concrete heavy duty tiles conforming to IS:13801 have been used. The tiles used were 25mm thick with 8mm thick metallic concrete hardener top-layer with 1 part cement: 1.5 part metallic hardener (70% Carborundum and 30% White Quartzite) and 17mm thick under layer of 1 part grey cement: 1.5 parts stone dust. As per terms of the agreement contractor was to submit the certificate from the manufacturer regarding the composition as above.

3.0 FLOOR TRUNKING

Except for the auditorium, video conference room & computer training centre, nowhere else in this building, carpets have been used. A large number of cables/wires for electricity, computers, telephone & other services pass over the floor at various locations. In order to avoid loose wires on the floor, provision of floor



Floor Trunking

trunking has been made in various areas of building except for second basement where mobile closed stacks have been provided. The floor junction boxes have been provided at regular intervals for facilitating laying and maintenance of wiring system. The junction boxes have been covered with stainless steel plates. The floor trunking has been very useful for accommodating various cables/wires.

The following experiences during execution are placed on record for further improvement in future.

a) The location of floor junction boxes was decided before final decision on location of furniture. This severely curtailed the choice of the users, to make even minor changes in the furniture layout.

b) The floor trunking was terminated in important service areas such as AHUs, EDB shafts etc. which should be avoided. These boxes had to be sealed subsequently to prevent the flow of condensation water from AHU into EDB shaft.

c) Great difficulty was faced in providing stainless steel cover plates on pre-fixed floor junction boxes specially in kota stone flooring area with mosaic strips. The size of stainless steel plate had to be finally changed to include width of strips.

4.0 SLOPE IN FLOORING

The building is planned to be cleaned regularly by dry/wet mopping. In view of provisions of floor trunking, washing of floor is not planned and no drainage system has been provided for sweeping out water from washing of floors. Accordingly, the slope of flooring in the building has been kept as dead slope (except of course, for toilets, kitchen & Pantries).

5.0 BURMA TEAK WOOD FLOORING

First class Burma teak wood flooring 75mm thick has been provided on stage in Auditorium, BPST, FF Committee room, AV, Mini Auditorium at FF, Press & Public Relation room in AV block at GF. The total area of wooden stage flooring is 274sqm.

First class Burma teak wood flooring consists of planks of size 1250mm x 150mm nailed over 75mmx50mm chemically treated sal wood frame work fixed with L-shaped mild steel flat 40mm x 5mm clamp & dash fastners both ways @ 625mm centre to centre on RCC slab to provide rigidity to flooring. Glass wool insulation 50mm thick of density 48kg/cum wrapped

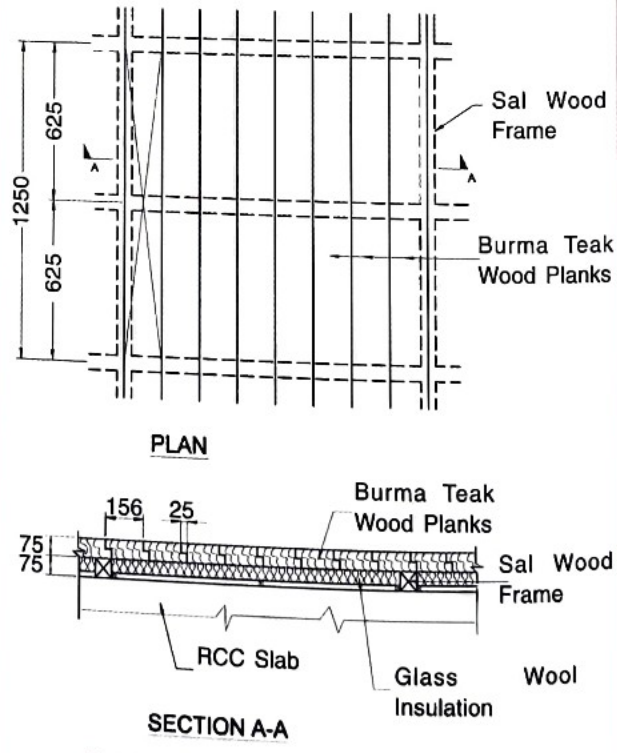


Fig 12.1 : Wooden Stage Floor



Auditorium Stage – Burma Teak Wood Flooring

in hession cloth, supported on 25mm x 25mm chemically treated sal wood frame have been provided. All unexposed wood work has been treated with wood primer. In the Auditorium stage 24 number of electrical junction boxes have been provided on the floor and entire conduiting has been done under the floor for various electrical services e.g. light & sound etc. The top surface of the flooring was finished with mechanical fine sander to get smooth surface, then surface was cleaned and finished with French spirit polish and melamine coating.

6.0 LAYING TYPICAL FLOORING PATTERNS

6.1 Kota Stone Flooring with Mosaic Strips

Kota stone flooring in rectangular pattern with mosaic strips of 12.5mm width have been used. The width of mosaic strip being very less it was difficult to maintain uniform width & straight line, however, efforts have been made to do the work with great precision. The mosaic strips near floor junction boxes is having unsupported length & being very thin could not be retained at number of places. Moreover hardness of kota stone & marble chips flooring being different, the mosaic strips have been damaged at some locations during process of grinding & polishing. The use of STONE STRIPS IN PLACE OF MOSAIC STRIPS would have given better results.

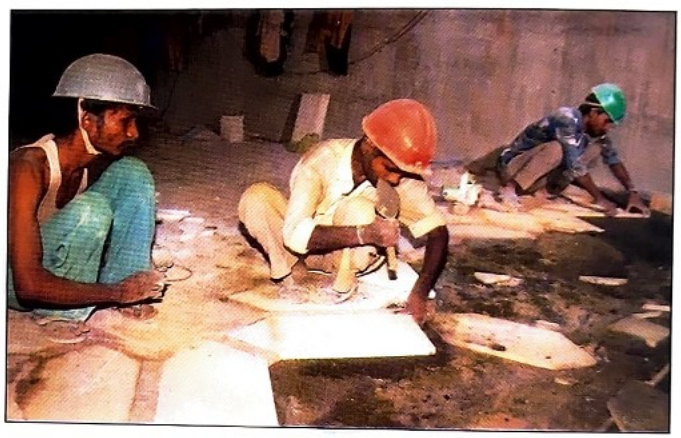
Kota stone of brown & grey colours have been used initially in the work. The quantity of kota stone flooring being very large (27,585sqm) it was impossible to get all stones of the same matching shade. The Consulting Architect was however of the view that the stones should be used in their natural shades available and there should be no conscious attempt to match the shades. Accordingly, stones with varying shades were used. The kota stone of brown shade of good quality is generally not available and brown strips of kota stone had to be changed to grey strips for subsequent work due to non availability of good quality of brown kota stone.

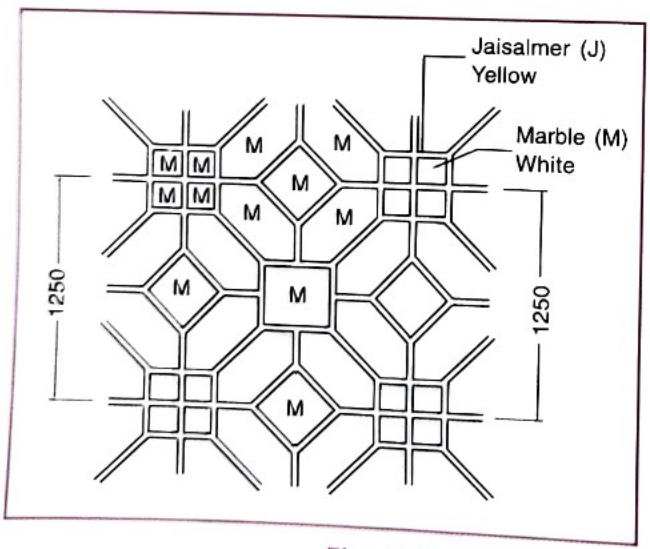
However much one may select the kota stone, the surface after grinding presents some patches and spots which were not visible before grinding. While a large number of such stones were replaced after grinding, from practical considerations we had to permit some percentage of such stones. It is adviseable not to specify such huge quantities of kota stone flooring as the quarries are not always able to produce perfect quality of kota stones all the time.

6.2 Stone Flooring Patterns

The intricate flooring patterns for auditorium foyer, banquet hall and rangoli patterns for focal area/second basement, main entrances i.e. VIP, BPST, MPs entry (AV Block) and Reception (service block) have been provided.

The following sets of sketches and photographs show the kind of intricate pattern that were developed in the flooring of the various areas.





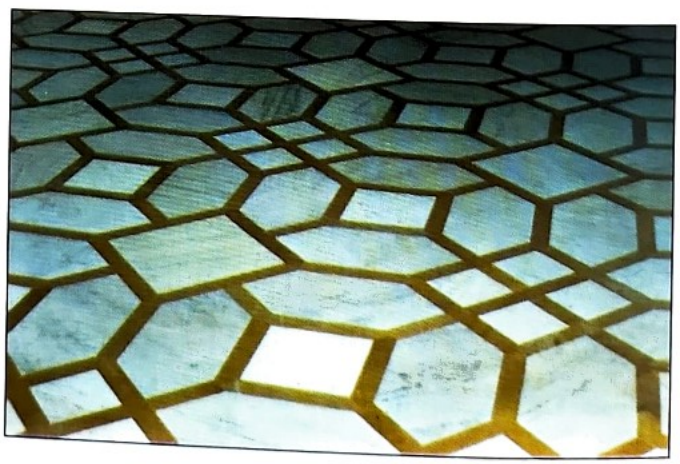
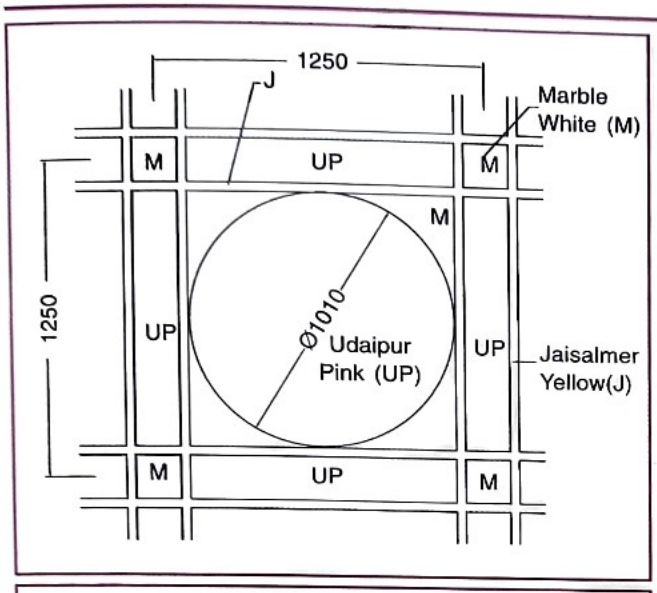
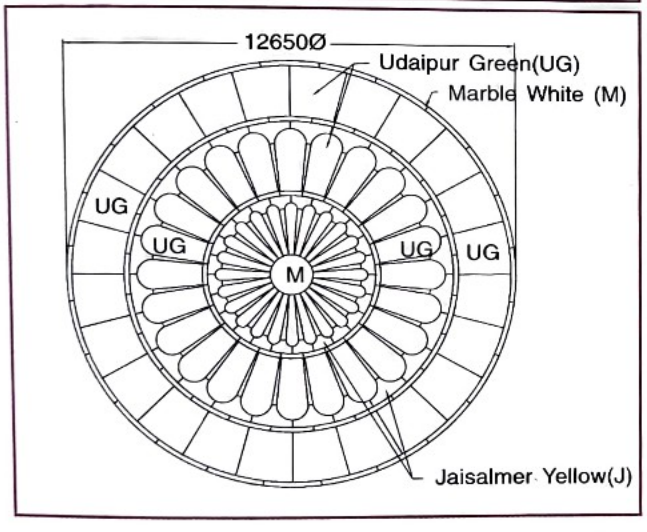


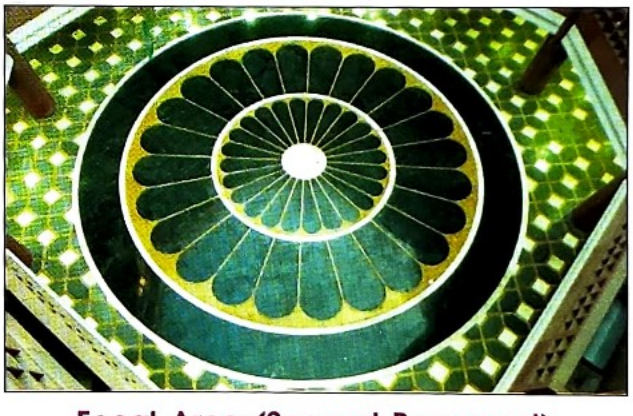
Fig 12.2 : Flooring Pattern - Auditorium Foyer



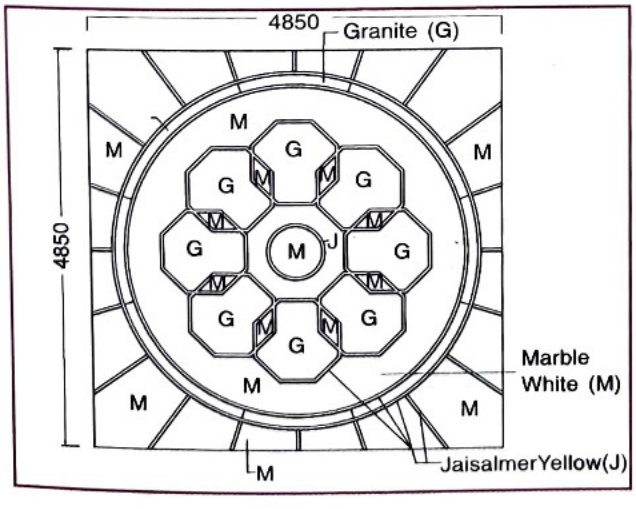


Banquet Hall





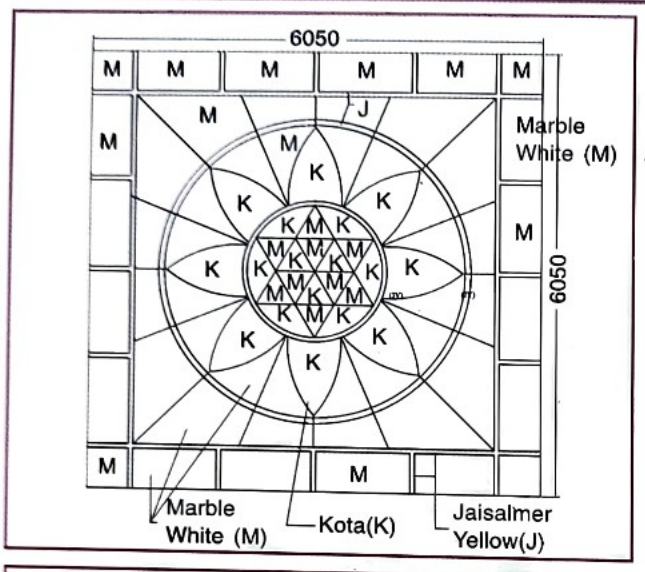
Focal Area (Second Basement)





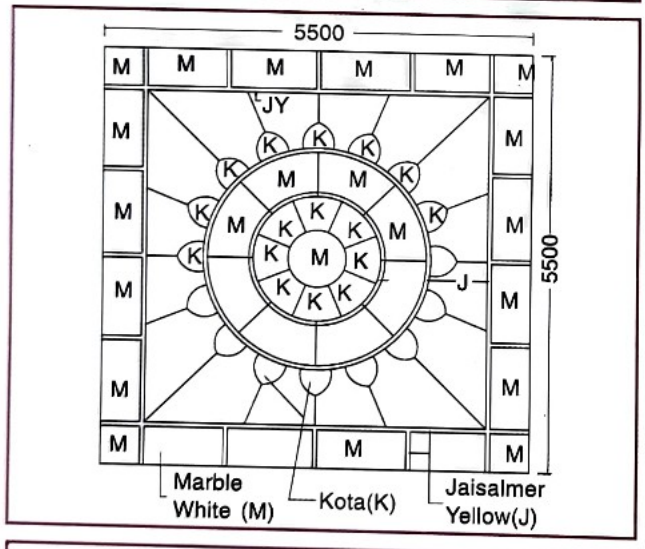
V.I.P. Entry (Ground Floor)

Fig 12.3 : Flooring Patterns



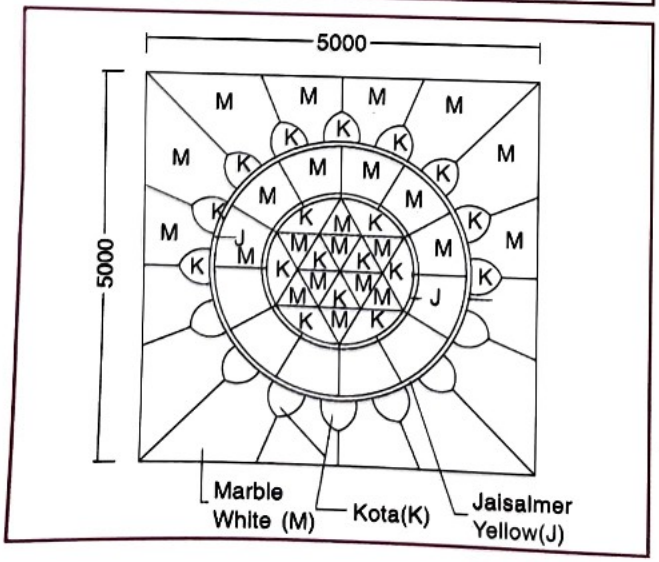


B.P.S.T. (Ground Floor)





MP's Entry (AV Ground Floor)





Public Reception (Ground Floor)

Fig 12.4 : Flooring Patterns

RAILING

1.0 TYPES OF RAILING

There are number of cutouts, staircases etc. for which following types of railing of 900mm height have been provided in the building.

Sl. No.	Details of Railing	Location	Quantity
1.	Stainless steel railing with hand rail of 41.27mm dia (OD) tube & baluster and middle rail of stainless steel tube 25.4mm dia (OD)	BPST, Library first basement glasswell area and I & J block cutout area below domes at first floor	142m
2.	Stainless steel railing with 60mm x 75mm first class Burma teak wood hand rail & baluster and middle rail of stainless steel tube of 25.4mm dia (OD)	Auditorium foyer area staircase and N type staircase in 5m wide corridor between VIP block & Auditorium	297m
3.	Mild steel powder coated railing with tube of 40mm dia (nominal bore) as hand rail and 25mm dia (nominal bore) as baluster and middle rails	Terrace, Parking and Toilet shaft.	276m
4.	Railing with 60mm x 75mm Burma teak hand rail, mild steel powder coated tubes of 25mm(nominal bore) as baluster and Burma teak batten of 200mm x 35mm size as middle rails.	In all staircases other than N-Type staircase.	497m
5.	Red sand stone railing 200mm wide	2.5m wide corridors in first basement, 5m corridor from VIP block to Auditorium, cut-outs below VIP dome at first floor, Library dome at ground & first floor, AVM dome at first floor and focal dome at all floors.	653m

2.0 STAINLESS STEEL/ MILD STEEL RAILING

The fixing procedure was the same in all types of railing. Base plate of size 60mm x 60mm x 6mm was welded to insert plate of size 80mm x 80mm x 6mm placed during the casting of RCC, 12mm dia cold twisted bar duly painted with red oxide zinc chromate primer was welded to base plate which were fixed @ 600mm centre to

centre spacing (though there was provision of 16mm dia cold twisted bars in agreement but encasing of 16mm dia bar in 25.4/25mm (OD) tube was not feasible, hence due to technical reasons 12mm dia cold twisted bar was provided). The CTD bar was encased within 25.4mm dia stainless steel tube/25mm dia powder coated mild steel tube. This tube has been welded to M.S. base plate and one nut was welded at the top of tube to fix the mild steel flat 40mm x 4mm with bolt to the nut, for fixing the wooden hand rail. The Burma teak hand rail was fixed with screws on mild steel flat, otherwise 40mm dia stainless steel tube/ Powder coated mild steel tube hand rail was directly welded to balusters. Junctions & Joints of stainless steel tube/mild steel powder coated tube were ground and finished smooth. A shoe of stainless steel/brass was placed at the bottom of baluster to give an aesthetic look & to conceal gap between tube and floor finish. Burma teak wood hand rail/middle rail was finished with French spirit polish and melamine coating.

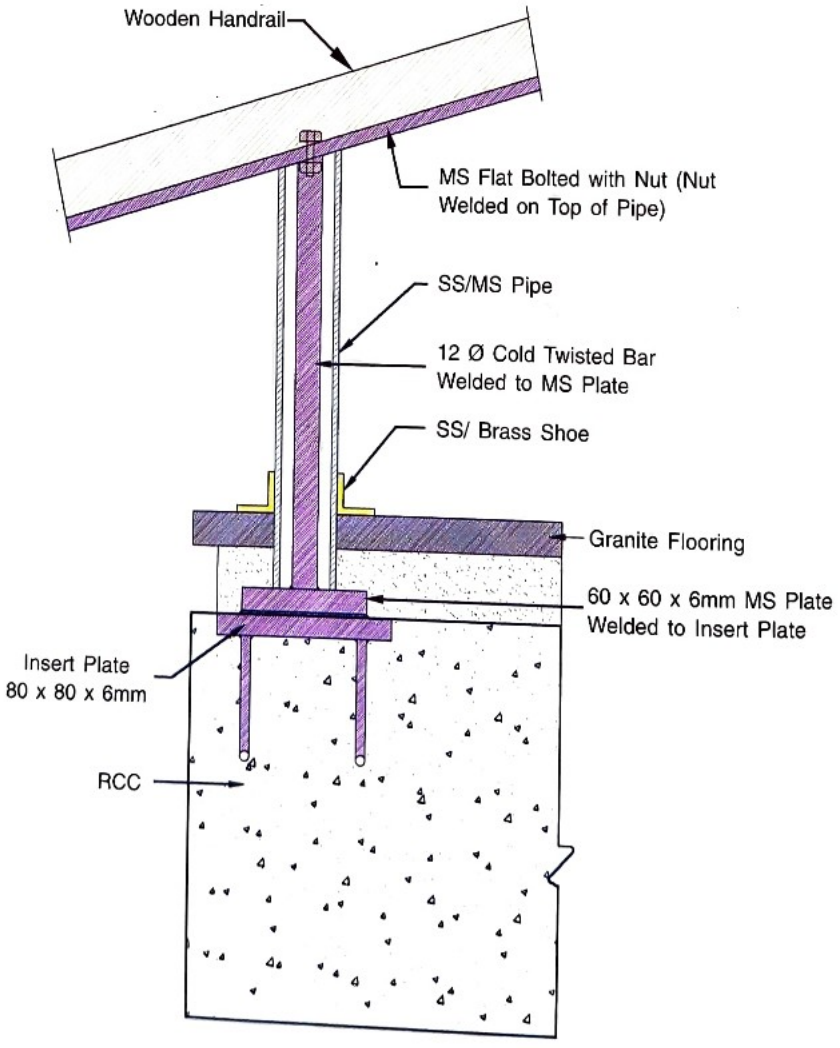


Fig 13.1 : Fixing Arrangement of Railing

3.0 RED SAND STONE RAILING

This consists of 200mm x 150mm size red sand stone blocks placed horizontally one at top & one at bottom & 5nos placed vertically in between & one at each end in a 5m long module, 200mm x 50mm thick members fixed horizontally in middle and also placed vertically @ 300mm center to center. These blocks have tongue & groove arrangement and fixed with araldite. Bottom member has been fixed with the RCC beam underneath with 8mm dia stainless steel pins @ 2 nos per stone. Top members have also been fixed with the vertical members with tongue and groove arrangement. Stainless steel pins have also been provided between two top members to give rigidity to the railing. The sand stone railing has been given fine chisel finishing.



Stainless Steel Railing in Core Block



Sand Stone Railing in Progress – Focal Area



Finished View Sand Stone Railing – Focal Area

DOMES – STRUCTURAL SYSTEM

1.0 BACKGROUND

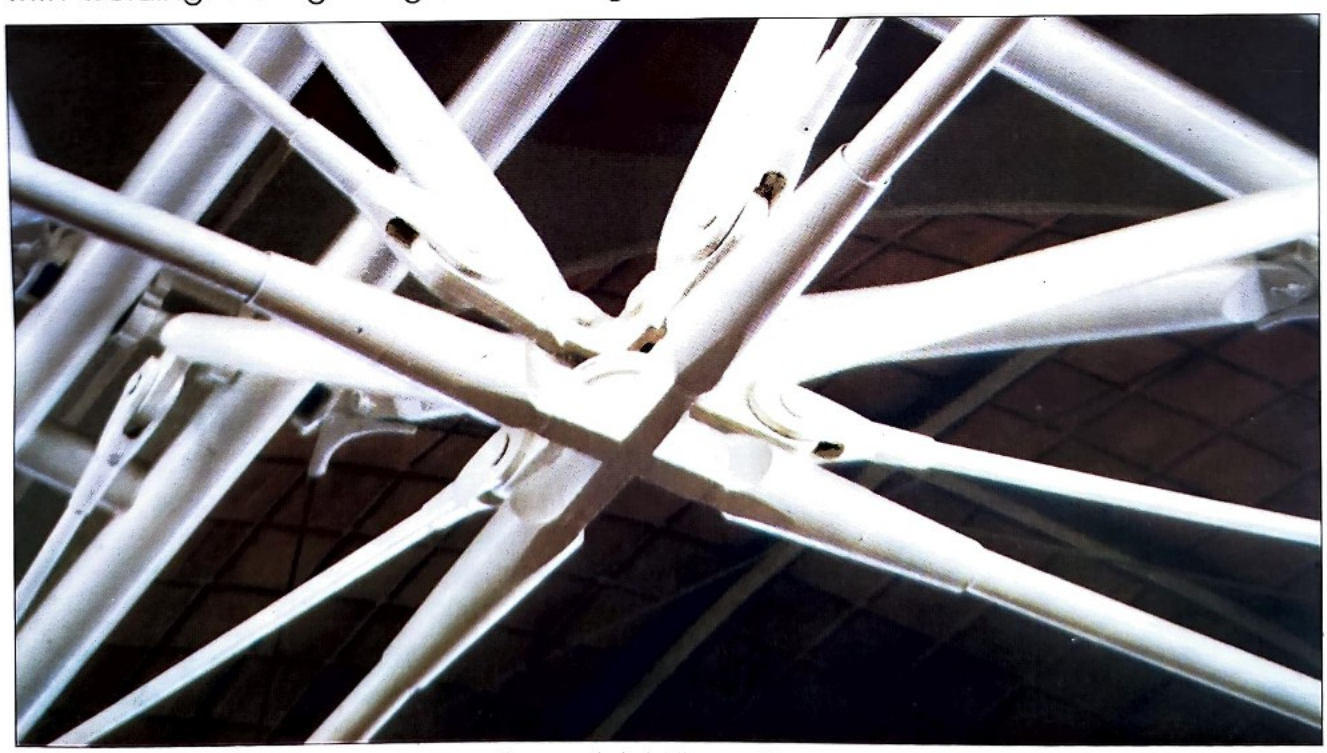
Twelve domes at roof level of diameter/spans varying from 14m to 35m having varying geometry have been provided. The domes are categorized into totally opaque domes, opaque domes with sky lights and transparent domes. Except for Auditorium dome the structure for other domes are visible from inside the building and therefore stainless steel structure for VIP & Focal dome, carbon steel structure for Core, BPST, AV, Services, Library & Museum and normal structural steel for Auditorium dome have been used. The main feature of the domes are concrete bubbles, cast joints & connection details between various members.

1.1 Concrete Bubbles

The bubble geometry was finalized as a spherical shell having circular base of diameter of approximately 5m with a pitch of 1:6 (1 rise :6 span) having square/ hexagonal /octagonal rib patterns. Structural Engineering Research Centre (SERC), Chennai were entrusted with the work of development of bubbles including the suitability of the material for the bubbles. SERC, Chennai suggested use of High Performance Fibre Reinforced Concrete (HP- FRC) of grade M50 for the bubbles.

1.2 Jointing of Structural Members

Initially the jointing of structural steel tubular members were planned to be done with welding. During design & detailing of tubular structural system of domes it was



Flower Joint Library Dome

found that at top joints as many as 6 tubes in case of hexagonal patterns & 8 tubes in square pattern domes were meeting at single point. Also in the bottom chord, at a number of locations 12 members meet at one point. The behaviour of such critical welded joints was very uncertain. Moreover extensive overhead in situ welding would have resulted in poor quality of welding. Therefore on the advice of Welding Research Institute, Trichy, the idea of welding of the joints was given up as large extent of welding at the joints would have caused uncontrollable distortion of the members resulting in distortion of the geometry of the domes. Instead cast-steel joints were adopted which reduced the welding to the minimum.

1.3 Detailed Engineering

M/s RFR, Paris carried out the detailed engineering of domes which consists of joint detailing, connection details between steel ring beam & dome structure, connection of bubbles with steel dome structure and support system of the steel ring beam on the existing RCC columns. M/s RFR, Paris also recommended use of cast steel joints.

2.0 GEOMETRY & SHAPE

A number of alternative geometry and shapes were tried out by the Consultant Architect before finalizing the geometry of the domes structure The final geometry & shape adopted after discussion with Consulting Architect are as follows :

Sl. No.	Dome Identification	Span(m) approx.	Rise	Geometry	Material for structure	Cladding
1.	Auditorium	30	Nil	Space Lattice box Truss direct tension/ compression structure	Structural steel	HP-FRC Bubbles Cladded with sand stone & granite
2	Core-1 Core-2 Core-3 Core-4	14	2.3m at a pitch of 1:6 (1rise: 6 span)	Single layer, Twin Tube Hexagonals, compression structure	Carbon Steel	HP-FRC Bubble cladded with sand stone & granite
3.	VIP	16	2.5m at a pitch of 1:6 (1rise: 6 span)	Single Layer, Twin Tube Octagonals and squares, compression structure.	Stainless steel	HP-FRC* Bubbles cladded with sandstone & granite for Octagonals & Glass sheets for squares
4.	BPST AV Services	22	1.0m	Double layered, upper chord twin tube Octagonals and squares & bottom chord consisting of rods and connected with diagonals and props.	Carbon Steel	HP-FRC Bubbles cladded with sand stone and granite.

5.	Museum Library	22.5x35 /25x35	0.5m	Double layered, upper chord twin tube Octagonals and squares & bottom chord consisting of rods and connected with diagonals and props.	Carbon steel	HP-FRC Bubbles cladded with sand stone and granite & central square portion with Glass blocks.
6.	Focal Dome	25	4.2m	Pagoda shaped space Truss of petals consisting of purlins & rafters connected with ladder & stabilized with tension ties system. Each petal is a triangular portion of surfaceof revolution similar to that of a rugby ball.	Stainless steel	Glass sheet cladding.

3.0 DESIGN FEATURES

Three Dimensional AUTOCAD Computer modelling was carried out based on the concept that for the domes circular in plan every point of upper chord of the dome structure lies on the spherical surface and for Library & Museum dome, every point of upper chord of dome structure lies on a cylindrical surface. The exact coordinates of the joints were than extracted from 3D AUTO-CAD Model for each Dome. From the coordinates, STAAD-III modelling was prepared and preliminary sizes of various members were selected for each dome for analysis & design. STAAD-III Version-22 was used for analysis. Optimum sizes of the various members of the dome structure were finalized by trial & error method. The basic design data considered are as below

a) Dead load equivalent to the weight of 138mm thick concrete screed to account for the weight of concrete bubbles, water proofing, bed mortar, sandstone cladding & thermal insulations was considered in addition to the self weight of the steel structure.

b) Live load of 0.75kN/sqm was considered for all the domes except Auditorium dome for which live load of 1.5kN/sqm was considered (being an accessible flat roof).

c) The seismic coefficients for Seismic Zone –IV with importance factor 1.5 was considered for earthquake load.

d) Temperature variation of +30^{0}C was considered for the calculation of temperature load. The coefficient of thermal expansion for high carbon steel and stainless steel were considered as 1.2 x 10^{-5} & 1.7 x 10^{-5} respectively.

e) The dead load & live loads on the surface of the dome were converted into joint load and applied in vertical direction on the joint/ nodes of octagonal/hexagonal patterns of the domes where bubbles would rest. Similarly dead load & part of the live load converted into earthquake load by applying earthquake coefficients has been applied in the horizontal directions on the joints/nodes of octagonal/ hexagonal patterns of the domes. The temperature load is longitudinal load hence members have been assigned temperature load indicating temperature variation as 30°C in the STAAD-III input data.

f) Size of different members resisting compression and combined forces (compression + bending) were checked with reference to the slenderness aspect and members were also checked with respect to permissible stresses as per IS: 800-1984.

g) The stability of dome especially single layered structure like Core domes & VIP dome is very sensitive to correctness of geometry. The stability aspect for rigid jointed single layered domes i.e. Core domes & VIP dome were studied & checked according to the empirical formulae suggested in the following literatures :

   i. "Stability of structure" by Mehdi Farshd Published By Elsevier Science B. V. Amsterdam.

   ii. "Analysis Design & construction of Braced Domes" by Z.S. Makowski Granada Technical Books Granada Publisher Ltd. London.

However, for BPST, AV, Services, Library, Museum and Auditorium domes, deflections were checked as per IS: 800-1984 i.e. maximum deflection not to exceed 1/325 of span.

4.0 STRUCTURAL SYSTEM

The structural system for the dome consists of tubular arc type trusses shaped to form skeletal dome roof arranged in hexagonal/octogonal and square pattern and supported through ring beam and bearings on RCC columns. The octagonal or hexagonal patterns formed by the steel frame are filled up by placing pre-cast concrete bubbles. Thus the structural system is of composite construction.

4.1 Dome Structure

The parallel carbon steel/stainless steel twin tubes of 139.7mm outer dia and 8mm thickness have been welded at both ends to cast end connectors. The tubes of 114.3mm outer dia and 6.3mm thickness cross-connect the parallel twin tubes at intermediate locations to form vierendeel elements. The dome structure is made by jointing high carbon steel/stainless steel vierendeel elements/tubes/rods with high carbon steel/stainless steel castings. High strength carbon steel/stainless steel friction grip bolts were used to connect various cast steel members. These bolts provide rigidity to the structure as the shear force is resisted by friction between the abutting surfaces of two castings. Stainless steel/high carbon steel shims have been used for minor adjustment of connecting cast members. The shims have also been used for minor

angular geometrical adjustment to achieve the desired geometry by placing extra shims between top rows of bolts.

4.2 Connection Details

The tubular structure is connected to high carbon steel/stainless steel ring beam of 457mm outer dia & 12mm thickness by articulated pin joints to allow rotation at these joints. The ring beam is finally supported on RCC columns through 65mm thick reinforced neoprene bearing for circular domes in such a way that radial movements are allowed at bearing support to allow expansion & contraction due to temperature variation. For domes polygonal in plan, linear movements in selected supports are permitted in 2 perpendicular directions.

4.3 Placing Concrete Bubbles

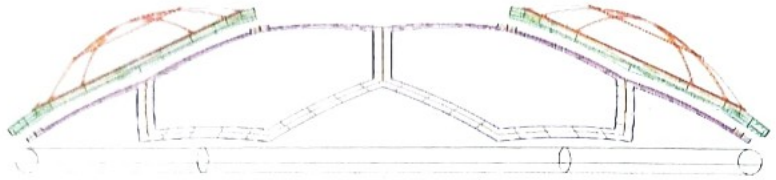
The concrete bubbles are placed over the steel structure. Each bubble has three types of supports i.e. free, sliding & fixed. Free support allows movement in all directions whereas sliding support allows sliding in one direction only. Fixed support holds the bubble and does not allow any sliding. Fixity is achieved by fixing the projecting bolt of the cast support into the sleeve provided at support point in the bubble concrete. Each bubble has one sliding, one fixed and rest free supports.

5.0 AUDITORIUM DOME

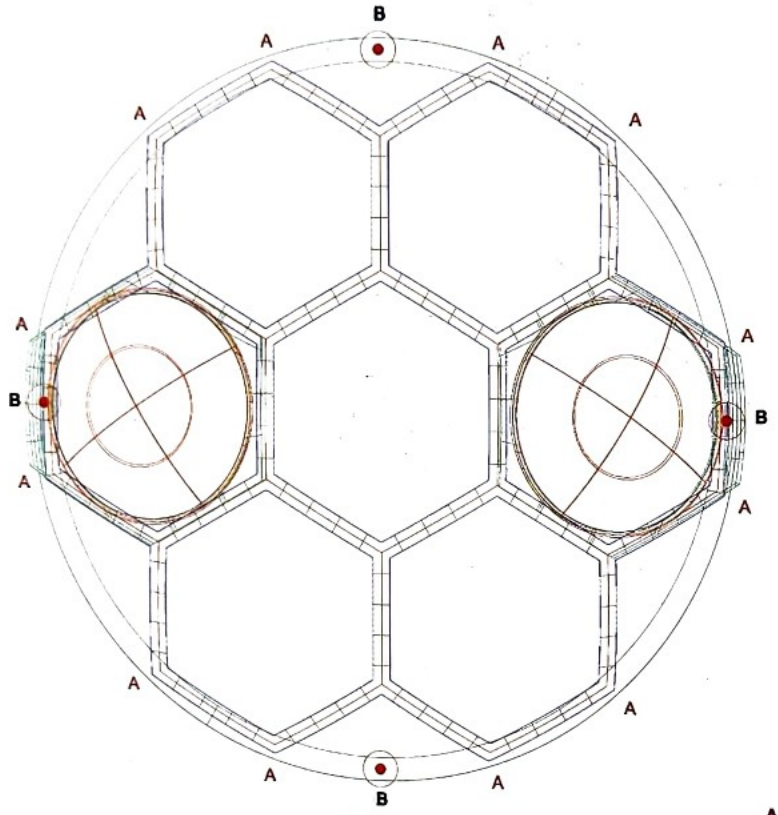
The structure of auditorium dome is a box lattice made of twin truss construction spanning in two directions. The box lattice truss is also braced at top and bottom to form an octagonal pattern. The structural tubes of 139.7mm outer dia have been vertically welded at octagonal points to receive the cast bubble supports. The structural tubes of varying length have been used to achieve slope in the finished roof levels. Suitable camber has been provided while erecting the truss to take care of sagging due to dead loads. The ends of the trusses are supported on RCC ring beam through 33mm thick reinforced neoprene bearings and supports have been considered as roller support for design. Secondary structural system have been fabricated in the shape of inverted bubbles to receive the false ceiling. The spacing and depth of the trusses were finalized to fulfill architectural & structural requirements with provision of cat walk.

6.0 CORE DOMES

These are single layered structural frame work, lying on a spherical surface of 12.239m radius of curvature. In plan the frame work resembles a circle, inscribed with hexagons forming a honey comb. The twin tube vierendeel elements when bolted to Y shaped cast steel joints by high-strength carbon steel friction-grip bolts forms hexagonal pattern structural grid. Each core dome has seven full hexagons. The central hexagon is a true hexagon and the peripheral six hexagons are slightly distorted to match the spherical surface. The structure is connected to high carbon steel circular ring beam through articulated pin joint at 12 locations to allow the rotation at these



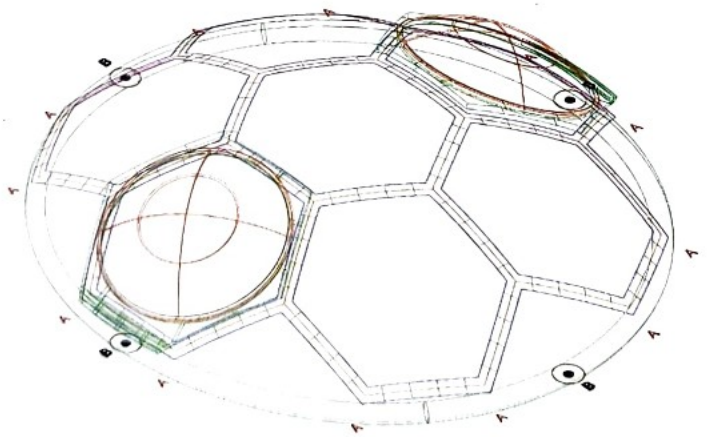
ELEVATION



PLAN

A - Structure- Ring Beam Support

B - Column Support



ISOMETRIC VIEW

Fig 14.1 : Structural System – Core Dome

joints. The ring beam is itself supported on 4 circular RCC columns. Supports for the cast bubbles have been provided at hexagonal nodes. (Fig 14.1)

7.0 VIP DOME

The structure is a single layered grid lying on spherical surface of 13.488m radius of curvature. In plan the frame work resembles a circle inscribed with a system of octagons and squares. The twin tube vierendeel elements when connected to Y shaped cast stainless steel hub using high strength stainless steel friction grip bolts form the octagonal & square patterns. There are nine full octagons out of which 5 octagons are symmetrical and four other are distorted to match the spherical surface. The structure is connected to circular stainless steel ring beam through articulated pin joint at 16 locations to allow the rotation at these joints. The ring beam is supported on 8 circular RCC columns. The cast bubbles supports have been provided at octagonal nodes. (Fig 14.2)

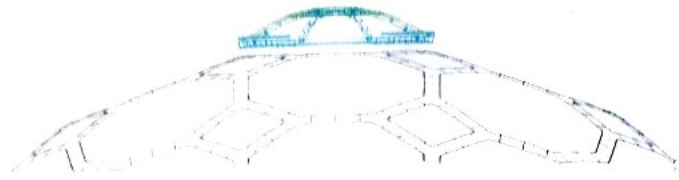
8.0 BPST, AV & SERVICES DOMES

The structure is double layered grid with top layer lying on a spherical surface of 63.22m radius of curvature. This is a two layered frame work. In plan the top chord resembles a circle inscribed with a system of octagons and squares. The dome is made with a series of trusses spanning in two directions at right angles to each other. Each truss consists of top chords of carbon steel twin tubes & bottom chord of solid steel rod. Tubular props have been provided to connect the bottom chords & top chords of the trusses in right angle directions to form inverted pyramids. Diagonals of solid rod have also been provided. The twin tube top chord vierendeel elements have been jointed to square shaped cast steel hubs through high strength carbon steel friction grip bolts.

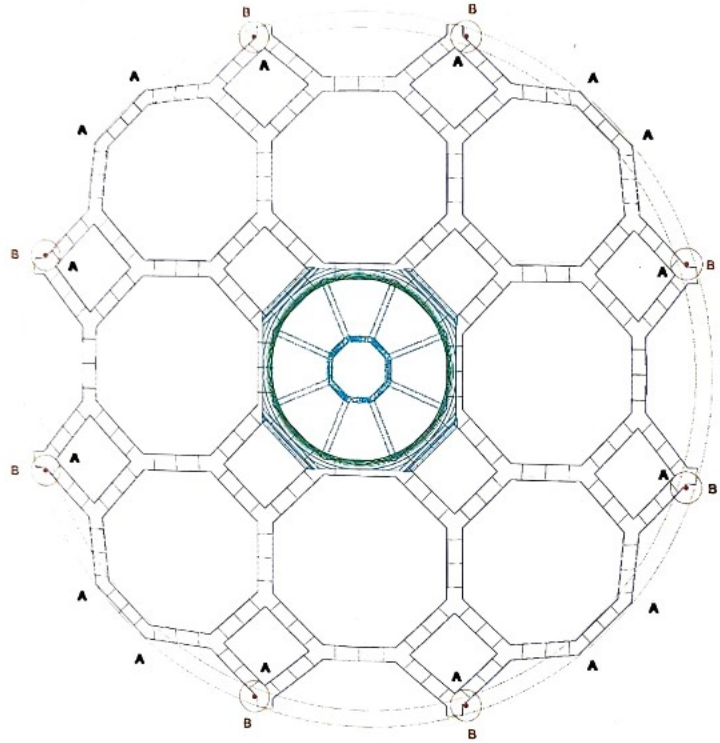
The bottom chord of truss assemblies are solid high strength carbon steel bars of dia 60mm manufactured by Mc Calls Special Products, UK Limited U.K. The tie bars run between bottom nodes and edge beam connections. Structural continuity is ensured by articulated nodes in to which the bars are fitted. The bottom nodes consist of a cast steel cross node to which cast steel end connectors are welded at angles according to truss geometry.

The cross nodes are mounted on to cast steel hubs incorporating a spherical bearing. This articulated assembly allows the bottom chord cross nodes to align correctly without inducing local bending moments in to the assembly. When fully assembled and tensioned the forces act to maintain the cross nodes in position on the spherical bearing. As a safety measure, a four piece collar security clip is fitted around the neck of the spherical bearing. The spherical bearing is centered on the node system points and forms the cast steel hub. This component incorporates double lugs to receive, in the typical case, four diagonal pyramid strut terminations which are assembled by pins.

The props of 88.9mm outer dia 4.85mm thick have been connected to cast steel connecting elements through cast steel strut termination to form inverted pyramids. The



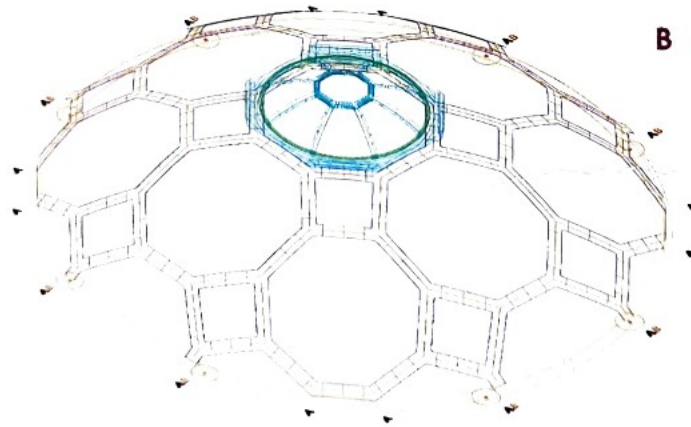
ELEVATION



PLAN

A - Structure- Ring Beam Support

B - Column Support

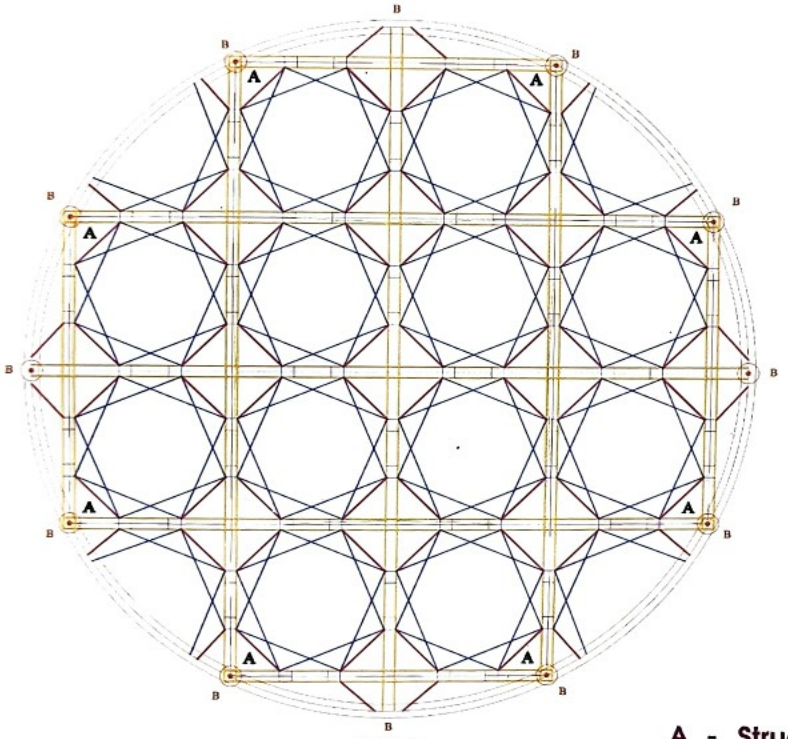


ISOMETRIC VIEW

Fig 14.2 : Structural System – VIP Dome



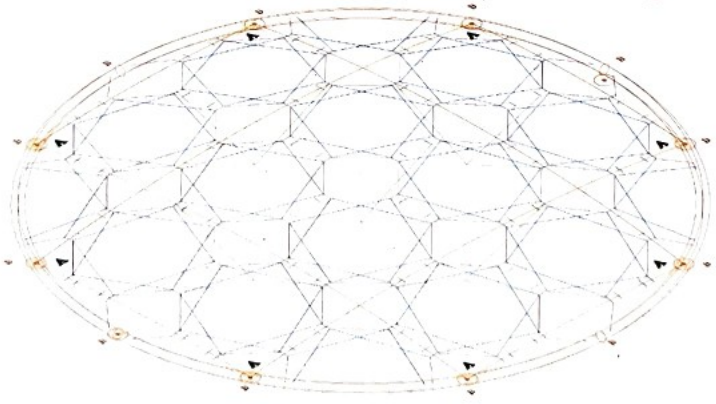
ELEVATION



PLAN

A - Structure- Ring Beam Support

B - Column Support



ISOMETRIC VIEW

Fig 14.3 : Structural System BPST, AV & Service Dome

diagonal tie bars of 34mm dia have also been connected to cast steel strut termination through pin arrangement

The top chord vierendeel assemblies at the perimeter are modified to provide lugs for bottom chord connectors. The top chord end assemblies are then connected to ring beam by means of pins through cast pin connection. This structure is primarily a flexural structure, the top chords resisting large bending moments and compressive forces and the diagonals & bottom chords resisting large tensile force. (Fig 14.3)

9.0 LIBRARY & MUSEUM DOMES

The structure is double layered grid with top layer lying on a cylindrical surface with radius of curvature as 156.5m In plan the top layer resembles an irregular hexagon inlaid with patterns of octagons and squares, made up of twin tubes. This structure is primarily a flexural structure, the top chord resisting large bending moment and compressive forces and the diagonal & bottom chord layer resisting large tensile forces. (Fig 14.4)

The structural-system for Library and Museum domes is similar to structural system for BPST Dome except following :

a) The ring beam forms a polygon having 6 sides.

b) The end pieces of tubes of twin tube vierendeel elements are cast steel tubes of 139.7mm outer dia and 25mm thickness (higher thickness to account for the fact that loading from bubbles on these end pieces is not on a node but directly on the tube).

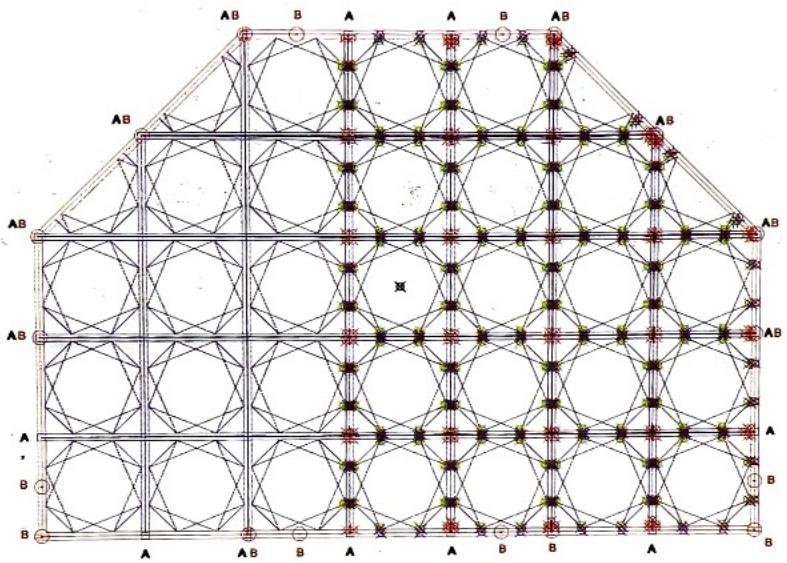
c) For library and museum domes, sliding support condition for two columns in each of the two perpendicular direction of trapezoidal plan on opposite ends and free support condition for all other columns have been provided to allow movement of the dome structure to absorb thermal variation. The sliding support permits sliding in one direction and holds the structure in the perpendicular direction by means of stopper plates. Thus sliding in one direction takes place due to horizontal forces through all the supports except the two sliding supports which are oriented in perpendicular direction, the structure is held by them in position resulting in transfer of entire earthquake forces through these two supports to the column.

10.0 FOCAL DOME

The focal dome exhibits a unique geometry and design of structure in order to satisfy the architectural criteria of visual lightness and transparency. The design of this dome was done by the non-linear analysis software package known as Fablon. The Focal dome is a doubly curved stainless steel-and-glass cupola, octagonal in plan, spanning 25m with a rise of 4.2m from springing level to apex of the dome. The dome structure is formed by four mutually supporting stainless steel frames called petals connected through pins to straight ladder purlins. The four petals are also connected



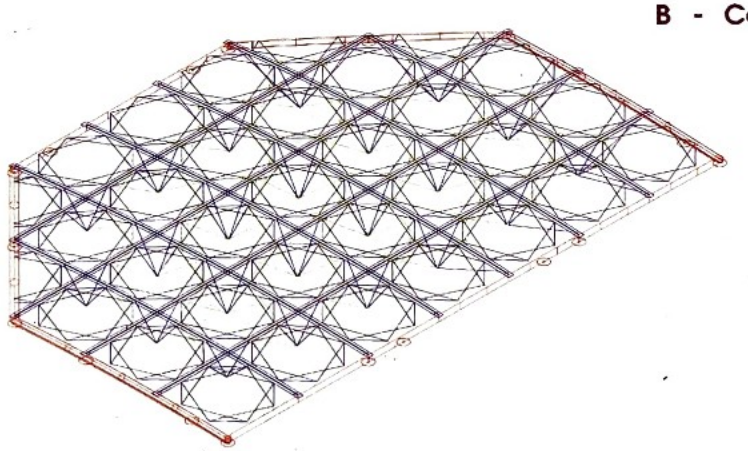
ELEVATION



PLAN

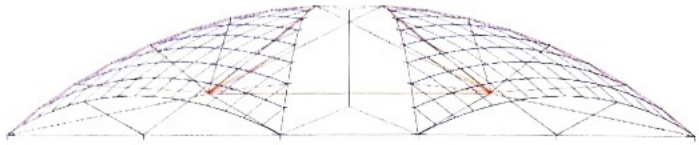
A - Structure- Ring Beam Support

B - Column Support

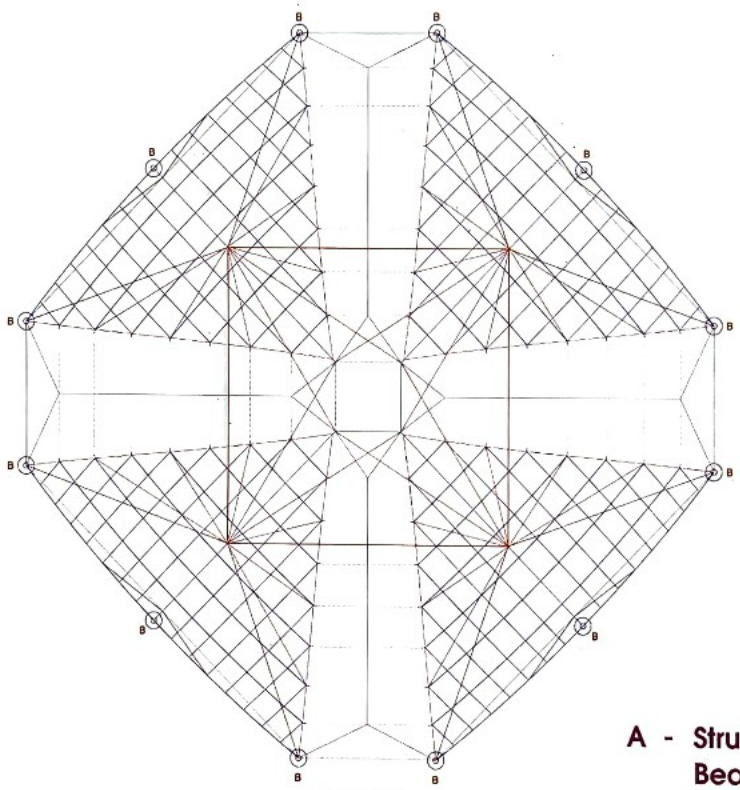


ISOMETRIC VIEW

Fig 14.4 : Structural System Library & Museum Domes



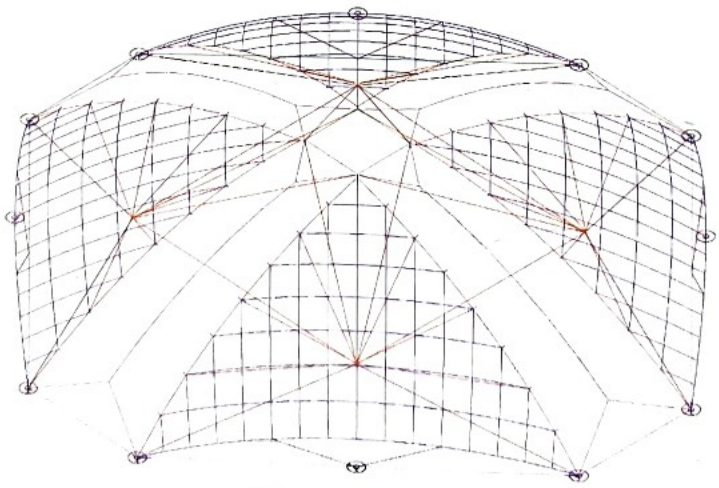
ELEVATION



PLAN

A - Structure- Ring Beam Support

B - Column Support



ISOMETRIC VIEW

Fig 14.5 : Structural System – Focal Dome

to the apex square ring beam by pins. The focal dome structure, thus consisting of petals, ladder purlins and apex ring beam is stabilised by a system of tension ties.

10.1 Petals

Each petal is a grid of stainless steel tubes of 101.6mm outer dia and 10mm thickness. The radial elements called petal rafters are straight following a faceted geometry and circumferential elements called petal purlins are curved. The petal rafters form the support for glazing system which spans between petal purlins and glazing supports are made by T sections welded to the petal rafters.

10.2 Ladder Purlins

Ladders are elements which connect adjacent petals to each other. The adjacent petal edge profiles are connected to each other at grid intersections by welded T section. These T sections form concentric circumferential load transfer bars which contribute to the overall stability of the dome.

10.3 Apex Ring Beam

Each petal is connected to the square shaped apex ring beam of trapezoidal section fabricated from 20mm thick stainless steel plate. The ring beam is formed by



Tension Tie System – Focal Dome

assembling the four trapezoidal tubes to cast stainless steel corner brackets which incorporate fixing lugs to connect the petals and tension ties.

10.4 Tension Tie System

The overall stability is ensured by high strength stainless steel rods. The primary network consists of upper ties of 25mm dia stainless steel rods connecting the apex ring beam to the primary tie nodes (flying nodes) and 40mm dia rods connecting these nodes back to edge support points. The secondary system consisting of fan-shaped arrangement of ties and the square ring tie assembly ensures stability of the petals against buckling under uplift and asymetrical loading. The secondary ties connect the grid intersection points along each side of the petals to the flying nodes assembly of primary ring tie system. The ties linking each of these four nodes form a square in the horizontal plane. This ring tie assembly consists of 40mm dia high strength stainless steel rods. Further tensioning system of tie bars connecting points on the arched perimeter petal ring beam to the intermediate column positions provide rigidity of the petals against buckling.

10.5 Ring Beam

Horizontal petal ring beams of 193.7mm outer dia & 16mm thickness and ladder ring beam of 139.7mm outer dia and 12.5mm thickness run along the perimeter between supports to ensure that vertical loads are transmitted to the concrete structure. They are connected by pinned connections to the cast steel corner nodes of the petals.

10.6 Bearing Supports

The support points to the concrete substructure are located at the corners of the octagon in plan. All supports are sliding arranged in such a way that for each petal one support is sliding & other is free support. The vertical loads are transferred through 40mm thick reinforced neoprene bearings and uplift is resisted by four nos articulated strut assemblies provided at every support.

HIGH PERFORMANCE FIBRE REINFORCED CONCRETE – PRECAST CONCRETE BUBBLES

1.0 HIGH PERFORMANCE FIBRE REINFORCED CONCRETE

The basic requirement of material for concrete bubbles was

a) high strength to keep the bubble thickness to the minimum so as to reduce the dead load on the structure

b) durability

c) impermeability and

d) ease in construction.

The SERC, Chennai was consulted on the selection of suitable material for these bubbles. The alternatives considered were Ferro cement, Polymer-Impregnated Concrete Composite and Fibre –Reinforced HPC.

The desired characteristics viz. high strength, durability and impermeability with protection to embedded steel reinforcement against corrosion was considered feasible by use of high-performance fibre-reinforced concrete. In HPC the water-cement ratio is reduced considerably using chemical admixture and microstructure of cement concrete is improved vastly by using mineral admixtures such as Ground Granulated Blast Furnace Slag (GGBFS), Condensed Silica Fume (CSF) and fly ash. Hence HPC was considered to be the best material of construction in place of polymer impregnated ferro cement/cement concrete. Addition of steel fibres to HPC mix enhances the mechanical properties of the concrete such as resistance to shrinkage, tensile/flexural strength, toughness and ductility. Use of stainless steel fibres was considered but given up due to the following reasons;

i. due to the possibility of galvanic corrosion, it would have meant that all other skin reinforcement for the bubbles should also be of stainless steel. This would have been a costly proposition.

ii. since the HP concrete with very low permeability (and further water proofed and cladded from top) was being used, stainless steel fibres and skin reinforcement would have been superfluous.

2.0 FACTORS GOVERNING DURABILITY IN HIGH PERFORMANCE CONCRETE

Durability of cement concrete is governed mainly by its permeability characteristics. The rate and quantity of diffusion (entry) of aggressive elements into the cement concrete, which depend on the permeability characteristics of concrete, determine the type and rate of deterioration of cement concrete. The permeability characteristics of cement concrete in turn, depend upon porosity (quantity of pore volume), pore size distribution & shape of grains and their sizes.

The basic aim of high performance mix design is to reduce/eliminate the quantum

of various types of pores to the extent possible as mentioned below.

a) *Capillary Pores* : These can be eliminated completely by adopting water- cement ratio less than 0.38.

b) *Sedimentation Pores* : These can be controlled by avoiding or reducing bleeding in cement concrete mix by use of finer filler materials (of grain sizes smaller than that of cement) and by converting the calcium hydroxide produced during the cement hydration into stronger/denser C-S-H products.

c) *Entrained Air Bubbles* : These can be controlled by avoiding admixtures which tend to entrain excessive air & by use of proper vibrating method during fresh concrete placement.

d) *Entrapped Air Voids* : These can be avoided by employing suitable/effective compacting techniques & by adopting proper concreting sequences.

e) *Honey Combs* : These can be avoided by designing cohesive/non-segregating mix.

f) *Defects* : These can be avoided by correct reinforcement detailing and by adopting suitable curing regime.

g) *Gel Pores* : These can not be reduced being an intrinsic characteristics of the products of cement hydration.

3.0 CRITERIA OF SELECTION OF INGREDIENTS OF HP-FRC MIX

Design of a concrete mix, considering the above mentioned points, make the diffusion of aggressive elements, such as CO_2, Oxygen, Chloride ions, Sulphate ion, etc., into concrete very difficult and hence, the structure is rendered highly durable. This was achieved by adopting following measures in the present mix design.

3.1 Water-Cement Ratio

Water cement ratio of 0.35 was selected for design.

3.2 Superplasticiser

When the water cement ratio becomes low, workability of cement concrete mix needs to be augmented by use of a suitable superplasticizer (SP). The super plasticiser of naphthalene formaldehyde condensate base was found to be adequate for imparting the desired workability to the concrete mix. Actual dosage varies from 0.5% to 2.0% by weight of cement and depends upon the ambient temperature/humidity conditions at the time of casting, type of cement, mix proportion, characteristics of aggregate system and filler used in the mix. The quantity of superplasticizer was decided by trial & error method by testing slump & 7 days compressive strength with varying dosages of superplasticizers.

3.3 Cement

Cement matrix is the most porous material among the ingredients of concrete. It

undergoes changes (shrinkage/expansion) due to moisture movement. Cement matrix is most prone to attack by aggressive elements, such as, sulphates, nitrates, and carbon-di-oxide. Cement hydration, being an exothermic reaction, generates considerable amount of heat and hence, a slower rate of cement hydration is generally preferred.

From the above considerations, it is necessary to reduce the cement content as much as possible. This was achieved by replacing part of the cement by the use of mineral admixtures, such as Ground Granulated Blast Furnace Slag and Condensed Silica Fume. Both these materials, being pozzolonic in nature, utilize two of the products of cement hydration, viz., Calcium hydroxide and heat. Thus, the ill-effects of excessive heat of hydration and weaker calcium hydroxide are reduced and controlled. Cement conforming to 53 grade was used.

3.4 Size of Aggregates

The bubble thickness being 40mm, aggregate of maximum size of 10mm was selected so that uniform concrete mix across the thickness of the bubbles can be ensured.

3.5 Sand

With water-cement ratio of 0.35, the cementitious content (such as, cement, GGBFS and CSF) was quite substantial. The reduction/elimination of finer fraction of sand was done by using coarse sand to reduce the water demand of the concrete mix and thereby workability of the concrete was enhanced. Coarse sand used was as per IS 383 : 1970 in respect of deleterious material. The fineness modulus was between 2.6 and 3.0; maximum size of particles was less than 4.75mm and minimum size was more than 300 micron.

3.6 Ground Granulated Blast Furnace Slag (GGBFS)

As per ACI committee 226, upto 40% replacement of cement by Ground Granulated Blast Furnace Slag the compressive strength of cement concrete is even higher than the strength of cement concrete without GGBFS. In the HP-FRC used for precast bubble units, 35% of cement was replaced by GGBFS and 5% by Condensed Silica Fumes (CSF). GGBFS conforming to BS: 6999-1992 was used. The advantages of using GGBFS in cement concrete are:

a) Reduced heat of hydration (when GGBFS replaces equal amount of cement on mass basis)

b) Reduction in permeability of concrete due to reduction in pore size (The pore structure gets refined through the reaction of GGBFS with the $Ca(OH)_2$ and alkalis released during the hydration).

c) Lowering of chloride diffusion rates (hence, better protection for embedded steel reinforcement against corrosion).

d) Reduction in expansion due to alkali-silica reaction (aggregates having reactive silica can be used without any danger of expansive cracks in concrete). However, aggregates having reactive silica was not used here to ensure durability of concrete.

3.7 Condensed Silica Fume (CSF)

The CSF is very fine powder and is a highly active pozzolonic material due to a very high content of SiO_2. The CSF starts reacting with $Ca(OH)_2$ of hydrated cement in the early ages itself and therefore, the strength of concrete with CSF is higher than those of concrete without CSF. To overcome the possible slower gain of strength before 7-days due to use of GGBFS, CSF was used as an additional mineral admixture. The CSF also contributes to pour size reduction and pore structure refinement of cement concrete.

3.8 Steel Fibres

Steel fibres were added further to improve the shrinkage resistance characteristics of fresh concrete and to improve the tensile strength of hardened concrete so that the possibility of micro cracking in concrete is minimized, besides imparting toughness (energy absorption capacity) and ductility to concrete. Dramix steel fibres of Type ZP 30/05 conforming to AS-10-05, imported and supplied by Tata Special Steel Ltd., Mumbai were used. The Dramix fibres have following chemical composition and mechanical properties.

a) Chemical Composition

Carbon	Magnese	Silicone	Phosphorus	Sulpher
0.10% max.	0.6% max.	0.30% max.	0.035% max.	0.035% max.

b) Mechanical properties

Diameter	Tensile Strength	Length
0.49 – 0.61mm	1200 – 1470 N/sqmm	27 – 33mm

3.9 General

Due to use of GGBFS and CSF, the cohesiveness of the fresh concrete was very high. Bleeding was very much reduced with proper compaction and curing. The different kinds of pores listed earlier are either very much reduced or eliminated altogether. Hence the concrete is highly durable and the service life of the structure is likely to be very high.

4.0 MIX PROPORTIONS OF HP-FRC

The ingredients of high performance fibre reinforced cement concrete used for dome units casting by weight were in the proportions of (0.60 Cement: 0.35 Ground Granulated Blast Furnace Slag: 0.05 Condensed Silica Fume): 1.6 Sand: 1.9 Coarse Aggregates: 0.35 Water: 0.01 to 0.02 Superplasticiser. Steel fibres used were 0.8% by volume of concrete. The HP-FRC mix had a characterstic compressive strength of 50N/sqmm at 28 days.

5.0 FORM WORK/MOULD OF PRECAST BUBBLES

The precast HP-FRC bubbles have very intricate geometry having two different curvatures. The curvature of the edge band of the bubble (which would ultimately be seated on the bubble supports) corresponds to the geometrical surface of the dome i.e. the surface enveloping the top layer of steel structures. (These are-planar in Auditorium dome, cylindrical in Library & Museum domes and spherical in other domes). On these edge bands the raised portion of the bubbles in the shape of segment of a sphere of radius approximately 4.0m and spans approximately 4.5m are superimposed. The presence of ribs in different patterns further complicate the form work.

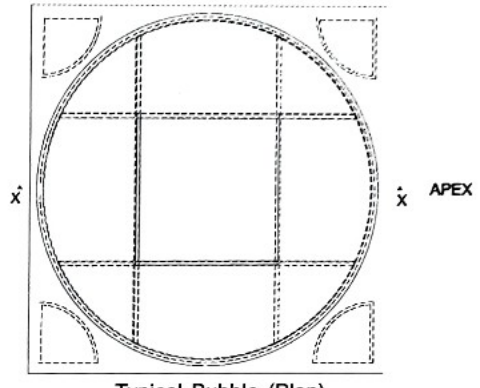


Fig 15.1 : HP-FRC Bubble Library Dome



Mould for Precast Bubble of Library Dome

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The dimensional accuracy required for the precast bubbles was ±5mm over a span of 4500mm. Any bubble having dimensional variation beyond 5mm would not fit on the structure as the support points are already permanently fixed on the structure in the form of cast bubble supports.

First, the edge profile of bubbles mould was correctly made using 10mm thick mild steel plates, angles and channels and checked for dimensional accuracy, then the spherical segment was fixed over the edge profile. The ribs were then welded and the top plate was cut to form rib profile. The bubble geometry was then further checked using levelling instrument and any minor variation was corrected by grinding or cutting and welding. The demoulding arrangement was then made using mild steel channel and jacks. In all 161 full bubbles and 91 part bubbles have been cast. The total quantity of HP-FRC for concrete bubbles is 341cum.

6.0 REINFORCEMENT

The reinforcement cage was prepared and placed in position on the mould.



Reinforcement Placing for Precast Bubble

7.0 CONCRETING

The pan type mixer of capacity 200 litres was specially fabricated to suit the mixing requirement of HP-FRC. The pan type mixer had aggregate batching hopper with four compartments and water batching tank of 50 litres capacity. The mixer was operating with 10HP electric geared motor.

The ingredients to be added in small quantities such as condensed silica fumes, superplasticers and steel fibres required for one batch of concrete mix were pre-weighed and kept in separate packets to be added during batching operation. The remaining four ingredients were placed in following fixed sequence in four compartments of aggregate batching hopper.

a) Coarse Aggregate

b) Sand

c) Cement

d) Ground Granulated Blast Furnace Slag.

The cumulative weights of ingredients after addition of each ingredient was automatically appearing



Pan Type Mixer



Concreting in Progress

on LCD of electronic panel and various ingredients were added in a pre determined sequence as above to ensure addition of pre-fixed quantity for each ingredients. The pre-weighed packet of condensed Silica Fumes, Superplasticiser & Steel Fibres was added, the required quantity of water was added from water batching tank with automatic cut off and after mixing, the mix was ready for use.

Concrete placed on the formwork of the bubble unit was compacted using needle vibrator. As soon as top surface of the concrete becomes hard, the curing was started by covering top surface of concrete and keeping the same wet by using sprinklers. The curing was done for 28 days. Lifting of the cast dome unit from its mould was done using lifting arrangement, containing steel frame and jacks after 72 hours of completion of casting. The bubbles were tied with steel rope by 8/6 number hooks provided in bubbles during casting and then lifted by jack arrangement.

8.0 CASTING OF CHAJJAS WITH HP-FRC MIX

The chhajja for various domes with HP-FRC mix was to be cast. The radius of curvature varied from dome to dome. The total length of chhajja to be casted was approximately 660m. In-situ casting of chhajja after erection of bubbles would have taken significant time. The casting of chhajja was therefore divided into segments and 140 nos precast units were made ready before erection of bubbles was complete which helped in early completion of work. While preparing precast units of chhajja the reinforcement bars were extended on either side and provision was made for erection of precast units at their appointed locations and in-situ casting of approximately 0.70m length between two consecutive units to achieve continuity & structural stability. The total quantity for HP-FRC used for chajja was 60cum.

The support system for chhajja consist of two stainless steel channels 100mm x 50mm of thickness 10mm placed back to back at spacing of approximately 2400mm centre to centre. These vertical channels were welded to stainless steel plates 200mm x 200mm x 20mm thick fixed in R.C.C. ring beam during concreting. Stainless steel plates of size 200mm x 200mm x 20mm thick were also fixed in the chhajja units exactly at the position of vertical supports. The precast chhajja units were fixed to the stainless steel channel supports by welding the stainless steel channels to the stainless steel insert plates. After fixing the precast chhajja elements, the extended reinforcement bars were lapped/welded and in-situ portion of chhajja was cast.

MATERIAL FOR DOMES

1.0 STRUCTURAL STEEL

Since there was no restriction on member sizes in Auditorium dome (as the members were in any case to be covered by the false ceiling) ordinary M.S. channels, angles, tees and plates were used to fabricate the trusses of Auditorium dome. M.S. tubes and flats were used to fabricate secondary structure to support the inverted bubble shaped false ceiling. Structural steel conforming to IS 2062 having following mechanical & chemical properties was used

a) Mechanical Properties

Minimum Yield strength	Minimum Tensile strength	Minimum Elongation
250 N/sqmm	410 N/sqmm	23%

b) Chemical Properties

Carbon (Max)	Magnese (Max)	Phosphorus (Max)	Sulphate (Max)
0.23%	1.50%	0.05%	0.05%

2.0 CARBON STEEL

In the case of all other domes, the structures are visible from inside the building and are prominent architectural features. Thus, in the case of Core- 4 nos., BPST, AV, Services, Library & Museum domes in order to make the structure sleek it was decided to use high-strength carbon steel tubes, plates castings etc. High strength carbon steel of following grades having mechanical & chemical properties as mentioned below have been used.

Sl. No	Properties \ Carbon Steel Grade	API – 5LX 52	SAILMA 350	340-570W (For Castings)
a)	**Mechanical properties**			
1.	Minimum Yield strength (N/sqmm)	359	350	340
2.	Ultimate tensile strength (N/sqmm)	455	490-610	570
3.	Elongation (Minimum)	33.5%	20%	15%
b)	**Chemical Properties**			
1.	Carbon (Max)	0.31%	0.25%	0.25%
2.	Magnese (Max)	1.35%	1.5%	1.5%
3.	Phosphorus (Max)	0.4%	0.055%	0.04%
4.	Sulphur (Max)	0.05%	0.05%	0.035%
5.	Silicone (Max)	–	0.4%	0.60%

2.1 Carbon Steel Tubes

As per IS:1161-1979 highest grade carbon steel structural tube is Yst-310 grade. However at the time of execution it was found that the carbon steel tubes of Yst-310 grade conforming to IS:1161-1979 were not being manufactured in India. Carbon steel seamless tubes of American Petroleum Institute API-5LX52 grade having better mechanical properties were allowed to be used for work as an alternative for Yst-310 grade as per provision in agreement.

2.2 Carbon Steel Plates

The plates for bearing support system, making lugs for high strength bottom chord rods and other such structural components were also stipulated to be of high strength carbon steel plates so that mechanical properties of plates are compatible with the mechanical properties of tubes, castings etc. SAILMA-350 plates manufactured by SAIL having mechanical properties compatible with mechanical properties of carbon steel tubes and castings have been used. Though SAILMA-350 plates have higher carbon content than mild steel they are still weldable.

2.3 Carbon Steel Ring Beams

In order to keep the sizes of ring beams as small as possible, high strength carbon steel pipes were required. The pipes of 457.5mm diameter and 12.5mm thickness having strength approximately 350N/sqmm were not available, hence it was decided to fabricate the ring beams using SAILMA-350 carbon steel plates. Circular pipes of length approximately 2.1m were fabricated by bending the plates and welding longitudinally under controlled conditions in the workshop. The ring beam pieces (of 2.1m lengths) were then bent to required curvature. The bent pieces were then stress relieved in electrical furnace to eliminate the internal stresses. The bent ring beam pieces were then welded at site in bigger segments (approximately 6.3m) and erected at their final positions. These bigger pieces were then finally welded in situ after checking the alignment.

2.4 High Strength Carbon Steel Rods and End Connectors

The diagonal struts and bottom chord tension members of the dome structures in double layered domes i.e. BPST, AV, Services, Library and Museum domes were carrying working loads as high as 60t. Using hollow carbon steel tubes for bottom tie members was not found feasible because the sizes of tubes for such high loads would have been in the range of 150mm dia which was totally unacceptable to the consultant Architect. Therefore high strength solid carbon steel rods with reverse thread to facilitate the length adjustment along with end connection system manufactured by Mc Calls Special Product Limited U.K. having following properties were selected.

Minimum Yield Stress @0.2%	460 N/sqmm
Minimum Ultimate Tensile Strength	610 N/sqmm
Minimum Elogation	19%

The carbon steel end connectors along with necessary pins, nuts and bolts compatible with the rods in strength and chemical composition were used.

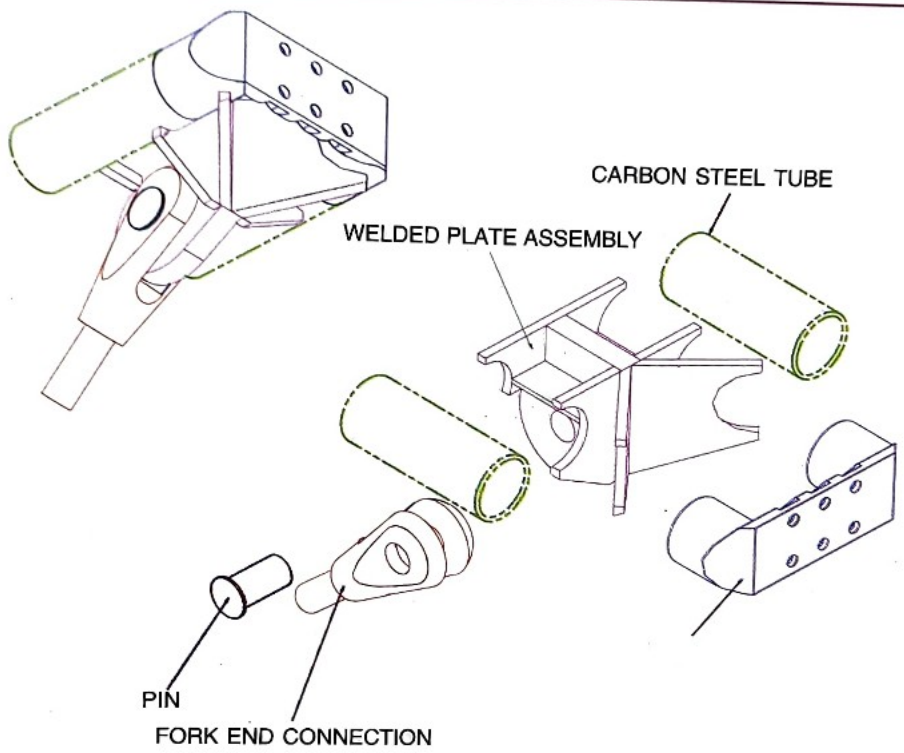


Fig 16.1 : Fork End Connection

2.5 Carbon Steel Castings

In order to match the strength of the high-strength carbon steel tubes, plates etc., castings of grade 340-570W conforming to IS:1030-1998 were selected. These castings have the advantage of being weldable and of high strength.

2.6 Carbon Steel High Strength Friction Grip Bolts (HSFG)

The high strength friction grip bolts, of size M22 and property class 10.9 conforming to IS:1367 Part 3 or ISO 898/1 were used. The high strength structural nuts were of same size as HSFG bolts and conform to property class 10 of IS:1367 part 6 or ISO 898/2. The hardened tempered washers conforming to IS: 6649 of hardness HRC 35-45 were used. The high strength friction grip bolts, nuts and washers were of make "Unbrako" manufactured by Processing Fasteners Ltd. Mumbai and Sundaram Fasteners Limited Chennai.

3.0 STAINLESS STEEL

The stainless steel was decided to be used for focal dome and VIP entrance dome from architectural considerations. The stainless steel of following grades having mechanical & chemical properties as mentioned below have been used.

Sl. No	Properties \ Stainless Steel Grade	AISI-304 L	AISI-304	AISI-316	A-744 CF-3
a)	**Mechanical Properties**				
1.	Minimum Yield Strength(N/sqmm)	200	205	550	200
2.	Ultimate tensile strength(N/sqmm)Min.	485	515	700	480
3.	Minimum Elongation	20%	40%	15%	30%
4.	Hardness HB (Max)	—	201	—	—
5.	Notch Impact strength @ 20°C (KCV)	—	—	27 J	28 J
b)	**Chemical Properties**				
1.	Carbon (Max)	0.03%	0.08%	0.08%	0.06%
2.	Silicone (Max)	0.75%	0.75%	0.75%	2%
3.	Magnese (Max)	2.0%	2.0%	2.0%	1.5%
4.	Chromium	18% -20%	18%-20%	16%-18%	17%-21%
5.	Nickel	8%-12%	8%-12%	10%-14%	8%-12%
6.	Phosphorus (Max)	0.045%	0.045%	0.045%	0.04%
7.	Sulphur (Max)	0.03%	0.03%	0.03%	0.04%
8.	Nitrogen (Max)	0.10%	0.1%	0.01%	—
9.	Molybdinum	—	—	2%- 3%	—

3.1 Stainless Steel Tubes

The stainless steel tubes of different diameter & thickness AISI (American Iron and Steel Institutes) 304L grade were used. The tubes for VIP dome having 139.8mm (OD) and 8mm thickness of SAIL were used. Whereas for focal domes tubes were imported from South Africa since these were not available with SAIL. The tubes were finished to a satin finish (classified as 180 grit finish).

3.2 Stainless Steel Plates for Structural Members of VIP & Focal Dome

The stainless steel plates of different thickness of AISI-304L grade having minimum yield strength 200N/sqmm were used, 32mm thick plates were imported from South Africa and plates of lower thicknesses were procured from SAIL. These plates have been used in box sections (focal dome), Tee sections, bearing system, shims etc.

3.3 Stainless Steel Plates, Tees, Angles, Channels

Approximately 50t of stainless steel plates, channels, tees etc. of AISI-304 grade have been used for miscellaneous works of domes. The vertical member consisting of

2 channels 110mm x 50mm of 10mm thickness placed back to back supporting R.C.C. chhajja, channel of size 100mm x 50mm x 5mm for glass brick walls, angles for supporting granite tiles on the dome roof etc. have been fabricated. In fixing arrangement of glass over focal dome, rectangular hollow tubes of size 30mm x 18mm of thickness 2.5mm and channels of size 24mmx10mm of thickness 0.5mm were used.

3.4 Stainless Steel Ring Beam (VIP Dome)

457mm outer dia and 12mm thick ring beam of VIP dome was fabricated by bending 12mm thick stainless steel plates of AISI-304L grade supplied by SAIL. The fabrication, bending and stress relieving were done in the same way as for carbon steel ring beam. All pieces of approximately 6.3m bent to required radius of curvature were erected on column supports. The joints were then sealed with tape and inert Argon gas was filled inside the ring beam to ensure inert atmosphere during welding. The root run was then made using TIG welding methods.

3.5 High Strength Stainless Steel Rods and End Connectors

High strength stainless steel rods and end connector were used in focal dome as stabilizing ties to keep the dia of rods to the minimum. The stainless steel rods and end connectors were of grade AISI-316. The rods were reverse threaded at both ends and were cold drawn to have higher strength. These rods along with end connectors, pins, washers etc. were supplied by Mc Calls Special Products Limited U.K. through their local dealers M/s Usha Martin Ltd. One assembly out of 50 assemblies of stainless steel rods and end connectors including pins washers etc. was load tested at minimum yield strength.

3.6 Stainless Steel Castings

Stainless steel castings have been used in cast joints of VIP and focal domes. Since these castings were to be welded to stainless tubes, the weldable grade stainless

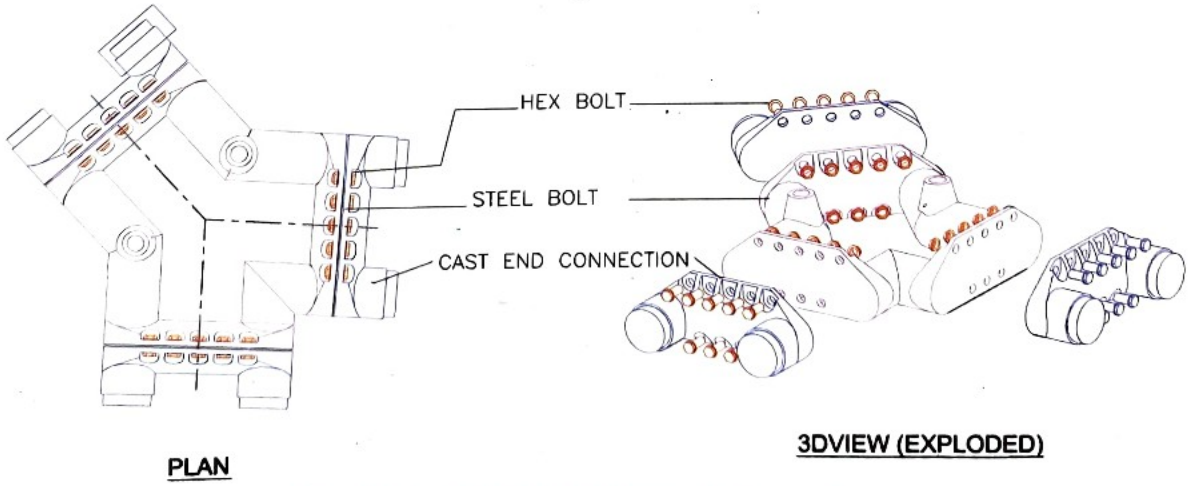


Fig 16.2 : Typical Stainless steel castings

casting have been used. To minimize any contamination of stainless steel during melting, the inside surface of ladle was given a lining of suitable refractory material. The grade of stainless steel casting was decided on the basis of required mechanical strength, weldability and availability of raw material. From the point of view of chemical composition, castings equivalent to AISI-304L would have been most appropriate. Since the castings are made from graded scraps, it was extremely difficult and economically not feasible to make the castings having carbon content lower than 0.03%. Even if the castings are made from graded scraps having lowest carbon content i.e. 0.03% during the process of casting, the carbon content was likely to go up.

Keeping in view the above constraints castings of radiographic quality of grade AISI-304 was selected. The maximum carbon content was restricted to 0.06%. As per ASTM standard the casting grade was A-744 CF-3.

3.7 Stainless Steel High Strength Friction Grip Bolts (HSFG Bolts)

The stainless steel HSFG bolts were not available in India and the same were imported from HAGUE Fasteners, U.K. The HSFG bolts of M22 size and property class 8.8 conforming to IS-1367 have been used. The bolts have the following properties.

Mechanical Properties (As tested)							
0.2% proof stress (Min)	Tensile strength (Min)	Elongation (Min)	Area Reduction	Hardness			
485 N/sqmm	639 N/sqmm	40%	70%	213 HB			
Chemical composition							
C (Max)	Si(Max)	Mn(Max)	Cr	Ni	P(Max)	S(Max)	Mo
0.08%	1.0%	2.0%	16% -18.5%	10% -14%	0.05%	0.03%	2% - 3%

4.0 SELECTION OF AGENCIES FOR CASTINGS

In order to identify agencies capable of making such castings, requirements were published in leading newspapers. About 15 agencies gave their response. The sample was got prepared through M/S R.V.Engineering Ballabhgarh before call of tenders and was shown to the intending tenderers during pre-bid conference. After the work was awarded, M/s Larsen & Toubro Ltd. submitted the detailed profile of M/s R.V. Engineering Ballabhgarh, M/s Hastalloy India (P) Ltd. Vishakhapattinam and M/s Kartik Steels, Ranipet (Tamil Nadu)

The workshops of these three agencies were inspected and it was found that above agencies were capable of producing steel castings for domes. The agencies submitted the sample castings along with the test reports and were then approved for making carbon steel and stainless steel castings for domes. The agencies were allowed to start mass production after inspecting one piece for each type of castings. The carbon steel castings were made by all the three agencies as above while stainless steel castings were made by M/s Kartik Steel, Ranipet (Tamil Nadu).

5.0 PREPARATION OF CASTINGS

The steel castings used for dome structures had large variations in shape and size having very less repetitions. Hence sand mould casting process was found suitable. Following steps were involved in manufacture of castings.

5.1 Preparation of Patterns

Patterns were made for each type of castings from shop drawings. Since a good finished surface was required, good quality of teak wood was used for making patterns. For some castings where number of repetitions were more, aluminium patterns were also made. The dimensions of the patterns were kept higher than the dimensions of the finished casting by 2% to make allowances for shrinkage. The casting surfaces to be machined were given 3 to 4mm machining tolerance. After making the patterns, the dimensions of the patterns were thoroughly checked and the pattern surfaces were painted with two coats of suitable epoxy paints to give smooth surface.

5.2 Preparation of Moulds

In order to achieve good quality castings with uniform surface finish CO_2 process (no-bake process) of moulding was adopted. In preparation of sand moulds, 3% to 5% sodium silicate (binder) was mixed in dry sand (free of clay) and suitable additives such as coal powder, saw wood etc. were also mixed as per requirement. The moulds were then prepared in mould boxes and CO_2 gas was passed through the sand mould for a predetermined duration. Due to chemical reaction of CO_2 gas with sodium the sand mould becomes hard and strong. After hardening of sand mould, the patterns were taken out and the internal surfaces of sand moulds were applied with Ziron coating to make the internal surface smooth. Any minor damages to internal surfaces of moulds were repaired before applying Ziron coating. The gates and risers were made at pre decided locations.

5.3 Melting & Casting

Melting of metal was done in electric induction furnace having appropriate refractory lining on inner surfaces. For carbon steel casting of grade 340-570W of IS: 1030:1998, cold rolled annealed carbon steel sheet scrap was used. While melting 1.2% to 1.5 % magnese was added. A small percentage of chromium was also added during melting to improve the tensile strength of casting. For stainless steel castings, graded scrap of grade AISI-304L was used. To ensure specified chemical composition and mechanical properties, coupon test pieces were taken from every melt for testing.

5.4 Fettling & Heat Treatment

After the castings were cooled in the sand mould, castings were taken out by breaking the moulds and cleaned of sand etc. The attachments such as gates & risers were removed by sawing / flame cutting. Unwanted projections if any were removed and the castings were heat treated in the furnace for about 8-9 hours. The soaking temperature was kept about 900°C.

5.5 Final Finishing

After heat treatment the carbon steel castings were shot blasted to give the surface uniform finish and make the surface free of dirt, dust etc. After shot blasting the surfaces requiring machining were machined and holes wherever required were drilled. In case of stainless steel castings, acid pickling, machining and polishing was done after heat treatment.

In all 6024 Pieces of carbon steel castings and 876 pieces of stainless steel castings have been used in work.

6.0 INSPECTION & TESTING

Para 2.0 of particular specifications of agreement provides for an independent (third party) inspection agency for quality assurance of welding, casting and other tests to be carried out for carbon steel structures and stainless steel structures. In accordance with above provision a testing agency, M/S IRC Engineering Services India Pvt. Ltd. was appointed to carry out tests and another agency M/S CEIL (a sister company of M/s Engineers India Ltd.) was engaged for third party inspection & review of test results for castings, welds etc. The approval of samples, patterns, testing and inspection for stainless steel castings was done in the same way as for carbon steel castings. In addition to the tests carried out for carbon steel castings, notch impact strength test was also done for stainless steel castings.

6.1 Deficiencies in Stainless Steel Castings

The following problems were encountered during inspection of stainless steel castings.

a) Finishing of surface of castings was not proper in some pieces. The surface of castings had black spots.

b) In ultrasonic testing of castings it was found that the signal observed on the screen was not clear with normal probe of 4 MHz frequency.

c) Some castings had hair cracks on the surface.

The above problems were studied and following measures were taken to solve these,

i) The black spots on the surface were because of pits created due to sand inclusions. To reduce the problem the sand moulds were carefully checked and any loose particles / damage to the moulds were repaired.

ii) Because of larger grain sizes of the stainless steel castings the 4 MHz probes were not giving clear signals. The 4 MHz probes were replaced with 0.5 MHz imported probes which gave clear signals and ultrasonic testing was done using 0.5 MHz probes.

iii) The hair cracks were investigated and it was found that the cracks were as deep as 4mm. The cracks on surface were due to non uniform cooling of castings. The entire lot of castings having surface cracks was rejected and the castings were re-done for rejected pieces.

FABRICATION AND ERECTION OF DOME STRUCTURES

1.0 GENERAL

Various components of dome structures were brought to site and the fabrication of structure was done in a well established workshop at site as it was easy to control and supervise the process of fabrication at various stages. Except in case of auditorium dome (where the structure consists of simple trusses forming square grid patterns) the mock up of each type of dome structure was carried out either at ground level or in situ. After complete checking, the structure was dismantled, members finally welded and then erected at site by bolting. The fabrication of various dome structures was carried out in following stages

2.0 FABRICATION AND ERECTION OF AUDITORIUM DOME

2.1 Fabrication of Auditorium Dome

The auditorium structure consists of a system of parallel trusses braced at top and bottom forming box section at spacing of 3.57m centre to centre in both directions. The box sections were fabricated in suitable segments. The central trusses of span approximately 28m were divided in three parts of equal length to make the handling by tower crane easy. Similarly, other trusses were fabricated in suitable lengths. The gusset plates were cut on semi-automatic pug machines. The structural angles were cut on mechanical saw and channel section was cut using manual gas cutting torch. The edges cut were then ground to remove the burned portion of edges. The edge preparation was made as shown in the shop drawings. Various members were marked with suitable identification marks shown in the drawings.

Since all the trusses were identical in shapes and external dimensions, jig was made on the ground in the workshop where gantry was installed to facilitate the handling of trusses. Various members were assembled and tack welded. The dimensions of various components were again checked, edge preparations for welding were inspected and then welding was allowed using approved grade and quality of electrodes. The welding was allowed only by approved welders for which welders identity cards were issued by the Engineer-in-charge. After completion of welding of a particular segment, the truss segment was inspected and was allowed to be erected in position using tower crane.

2.2 Erection of Auditorium Dome Structure

Complete staging using DOKA system was made in entire dome area. Platforms were erected at every nodal points i.e. at every 3.57m centre to centre in both directions. The levels of support platforms were adjusted to the bottom level of trusses. The required camber of 40mm was provided while fixing the level of platform and execution was done as per details below.

a) The truss segment was placed on the platform and supported at the ends on neoprene bearings.

b) The cross segments of the truss were then placed in position and the ends meeting the longitudinal truss were connected temporarily using bolts

c) Segments of next longitudinal trusses were aligned properly, level was rechecked and connected by welding.

d) The cross segments were then placed and ends connected by bolting.

e) The erection of entire longitudinal and cross elements was completed. Horizontal bracing elements were then connected by tack welding.

f) After completion of erection and temporary connection of top and bottom bracing elements, the alignment and levels of entire structure was checked using level machines.

g) Temporary connection of horizontal bracing elements and cross truss segments were then finally welded as per the welding sizes and lengths shown in the shop drawings.

h) Bubble supports were then marked on top chord members using theodolite. The bubble supports were then temporarily connected.

i) The welding was checked using dye penetration method.



Steel Trusses – Auditorium Dome

j) The structure was then properly cleaned using wire brush and emery papers and epoxy primer was applied.

k) After applying the epoxy primer, epoxy paint was applied using brush and allowed to dry for 24 hours.

l) Bubble erection was then started in rows. After completing the erection of bubbles in one row the temporary connection of bubble supports were finally welded before starting the erection of bubbles in next row and the primer and paints damaged during welding were repaired.

m) The erection of bubbles was then completed in rows. The joints between bubbles were sealed using silicone sealant.

3.0 FABRICATION AND ERECTION OF CORE DOMES

3.1 Ring Beam–to–Column Support

The bearing assembly consist of circular anchorage plate, bearing plate, transfer plate, spacer plate and ring beam connection plate. The ring beam-to-column connections are identical in all domes except the position of the stopper plate in the cast transfer plate. The exact shapes and dimensions of different components were

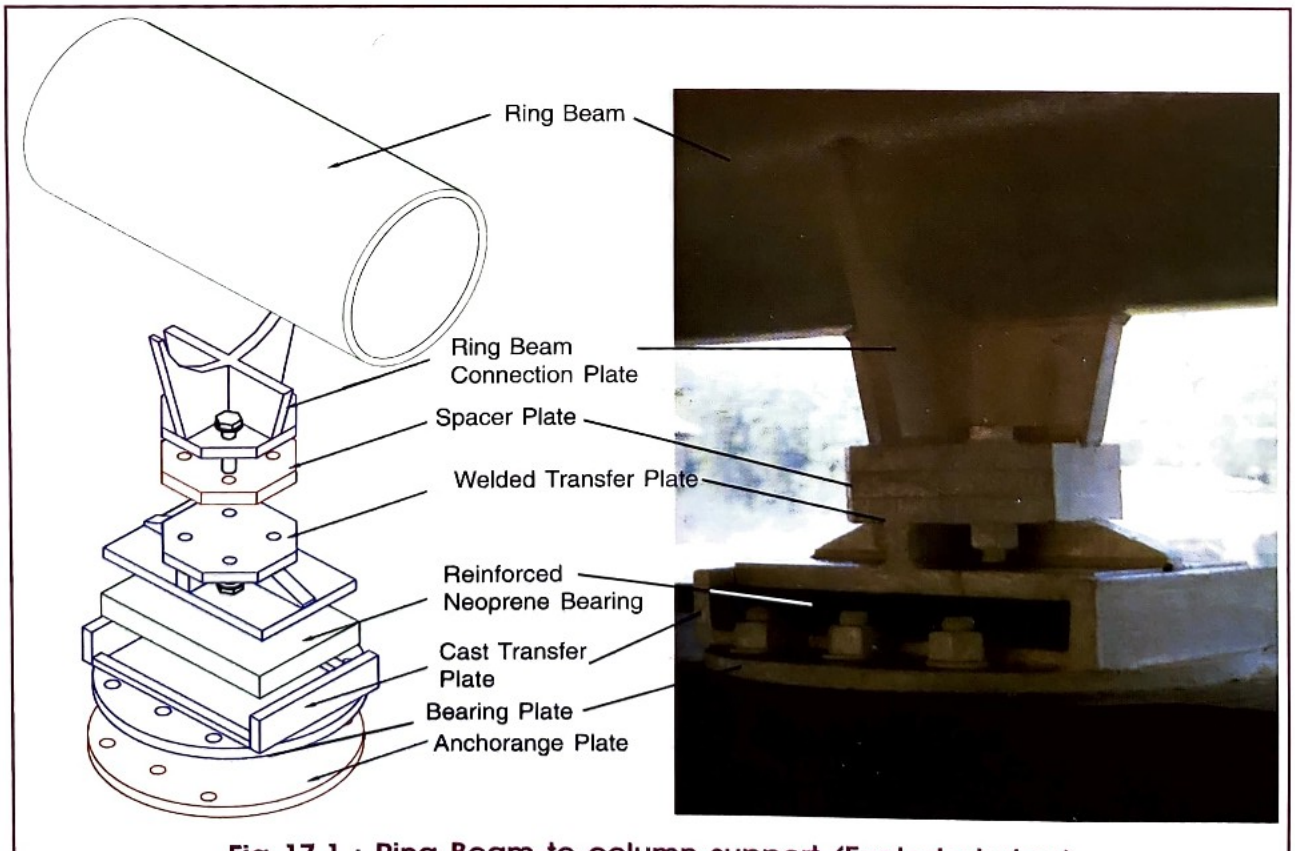


Fig 17.1 : Ring Beam-to-column support (Exploded view)

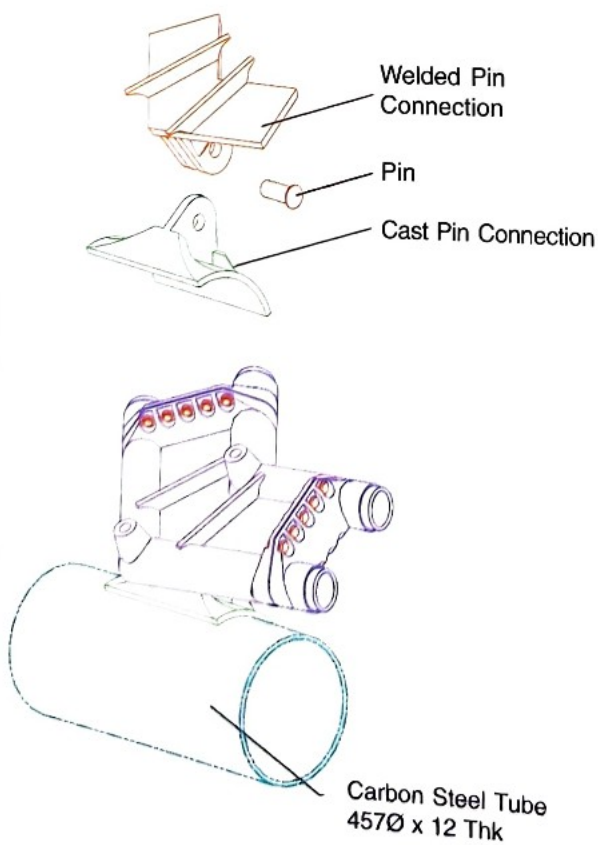
marked on the plates and the component pieces were cut using pug machine. The edges were ground and prepared for welding, 32mm dia holes were drilled in the plates for bolting and various components were assembled by tack welding. The ring beam connection plate assembly was then checked by matching with ring beam and 10mm size continuous fillet welding was done as shown in the shop drawings. The welding was finished by buffing and epoxy primer and paint was applied.

3.2 Ring Beam to Tubular Structure Connection

This connection is made by welding a cast pin connection to ring beam and by welding a corresponding pin connection to the cast hub and joining these two pin connection elements using 50mm dia high strength pin. The welded pin connection to cast hub was fabricated using 30mm & 20mm thick SAILMA 350 plates for carbon steel domes. The cutting of plates, assembly, checking of dimensions and welding was done in the same way as column-to-ring beam connection.

3.3 Tubular Vierendeel Elements

The top chord of dome structure consists of parallel twin tube curved vierendeel elements with cast end connections welded to the tubes at ends. First the tubes were



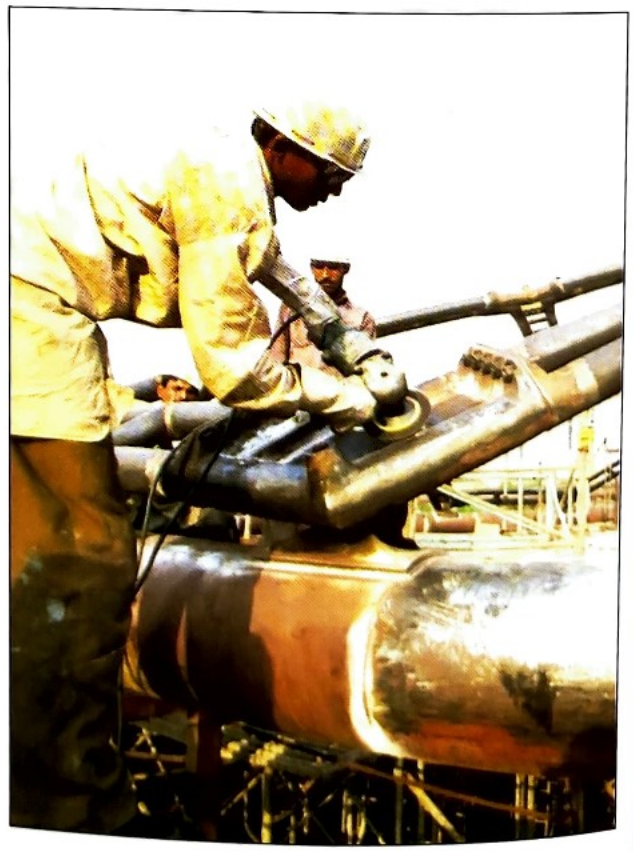


Fig 17.2 : Ring Beam to Structure Connection – Core Dome

bent to the required curvature using bending machine installed at site. Suitable jigs and fixtures were fabricated to give the tubes required curvature. These tubes were initially bent to slightly lower radius of curvatures to allow for some straightening after release of loads. The tubes were then cut to required lengths worked out from three-dimensional co-ordinates. The edges of the tubes were bevelled and identification number was marked on the tubes.

The two parallel tubes were then firmly held at 360mm centre to centre on jigs. The cross tubes were inserted in position and cast end connectors were assembled at ends. The 'V' grooves formed between cast end connection and main twin tubes were checked for its shape and root gap. Various dimensions were then checked and the twin parallel tubes, cross tubes and cast end connectors were connected by tack welding to form Vierendeel Elements. All vierendeel tubular elements were fabricated and identification number were marked.

3.4 Mock up of Core Dome

As per terms of the agreement one of the Core domes and also VIP dome was to be tried first as a mock up at site to verify construction methods and accuracy before fabrication is taken up for other domes. The agreement also provided for pre-assembling of one full truss element of each double layered dome prior to launching fabrication. The mock up of core dome structure was done using the following steps-

a) Timber runners were laid on well prepared and level ground to make an unyielding and level platform.

b) The position of ring beam was marked on the timber runners. The ring beam segments were placed in position and ends were connected by tack welding. The radius of ring beam and levels at every support points were checked accurately within tolerance of ± 2 mm.

c) Staging was erected at every joint position using DOKA staging towers. Steel plates were fixed on top of staging towers at exact height and angle. The position of cast joints were then marked on the steel plates with an accuracy of ± 5mm in tangential direction. The angle cleats were then fixed to support the cast joints in position.

d) The progressive assembly of dome structure was started from Apex working towards perimeter in concentric rings. The gaps between cast end connectors and cast hub if any (within 5mm) were filled up and adjusted using shims of suitable thicknesses. The joints were tightened using temporary assembly bolts.

e) The cast pin connections to ring beam were then fixed to ring beam termporarily using tack welding.

f) After all elements of dome structure were assembled the geometry of the structure i.e. the position and levels of various joints were again checked.

g) The position of various bubble supports were then checked using templates for various types of bubbles. Any deviation found was corrected.

h) Match marks were made on all joints of mock up assembly clearly indicating the number of shims used in the joints.

i) Vierendeel elements i.e. the pipe and end connectors assemblies were dismantled one by one from the cast hubs and were taken down for welding in the site workshop. A special jig was made to enable the two parallel tube along with the end connector to rotate while welding was in progress to ensure the best welding position i.e. under hand welding.

j) The welds were dressed and finished to match the welds with pipes and casting.

k) All joints of the ring beam except site erection joints were then welded.

3.5 Erection (in Situ) of Core Dome Structure

Following sequence have been adopted for erection of Core dome structure.

a) Anchorage plates were fixed on levelled columns, high strength grout slurry was applied on top of columns to ensure perfect contact between anchorage plates and columns.

b) Bearing plates and transfer plates were then placed in position over the anchorage plates leaving approximately 40mm gap between bearing plates and anchorage plates for accurate levelling. The levels of bearing plates were checked and corrected within tolerance of ± 2mm.

c) The gap between anchorage plates and bearing plates were grouted using high strength grout. The grout was allowed to set and strengthen for 24 hours. The bearing plates and anchorage plates were tightened to the columns by anchor bolts already embedded in the R.C.C. columns during casting of columns.

d) Ring beam segments were then positioned and assembled on the sliding supports as explained in para 3.1. Complete assembly of ring beam and column support was checked and corrected within tolerance of ± 2mm.

e) The staging for joint supports was erected and the position of the joints were fixed using steel plates and angle cleats.

f) The position, elevation & direction of various joint supports were thoroughly checked and adjusted.

g) The progressive assembly of dome structure was then started from perimeter working towards apex in concentric rings by fixing HSFG bolts and shims.



Core Dome Structure

h) After completing the entire assembly as per the required geometry, the position and level of various joints were again checked and any minor deviation was corrected using shims.

i) The HSFG bolts were then tightened to the required torque in a symmetrical manner starting from perimeter to apex.

j) The site joint welding of ring beam was completed.

k) The staging supports were released and dismantled. The deflection of structure was checked and epoxy painting was done. After painting the structure was ready for bubble erection.

4.0 FABRICATION AND ERECTION OF BPST, AV, SERVICES, LIBRARY & MUSEUM DOMES

4.1 Ring Beam-to-Column Support

The ring beam-to-column connections are identical to Core domes in case of BPST, AV & Services domes. However for Library & Museum domes, the stopper plate in cast transfer plate is provided in such a way that linear movements in selected supports are permitted in two perpendicular directions, other details remaining the same.

4.2 Ring Beam to Tubular Structure Connection

The fabrication & erection is identical to Core domes.

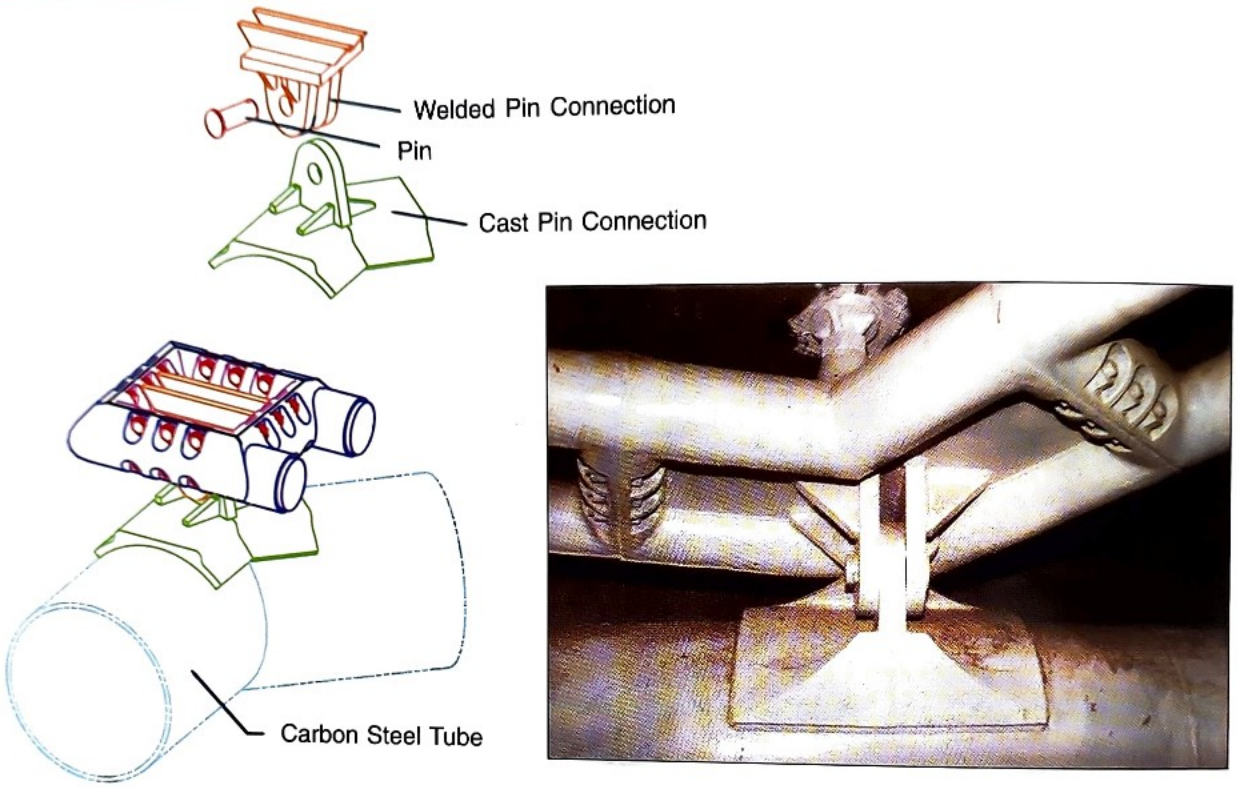


Fig 17.3 : Ring Beam to Structure Connection – Library Dome

4.3 Top Chord Tubular Verendeal Elements

The fabrication is identical to Core domes.

4.4 Mock up and Erection of BPST, AV, Services, Library & Museum Dome Structures

The mock up and erection procedures of these five domes are identical. For these domes the mock up was carried out in situ. Following procedure was adopted for mock up and erection of the dome structures –

a) The steps a) to f) as per erection of core dome structure (para 3.5) were followed.

b) Progressive assembly of top chord elements along centre line in both the directions was made.

c) The bottom chord elements along with the diagonal struts were assembled along the centre line in both directions.

d) The assembly of top and bottom chord members along with the diagonal struts were then completed working from centre lines towards perimeter along four directions.

e) The alignment of the dome structure was checked accurately and any deviation found was corrected within tolerance of ± 2mm. The gaps between cast hubs and end connectors were filled with shims and the joints were tightened with temporary erection bolts.

f) The position of various bubble supports were checked using templates for various types of bubbles and any deviation in mock up assembly if found was corrected.

g) Match marks were made on all the joints of mock up assembly clearly indicating number of shims used in the joints.

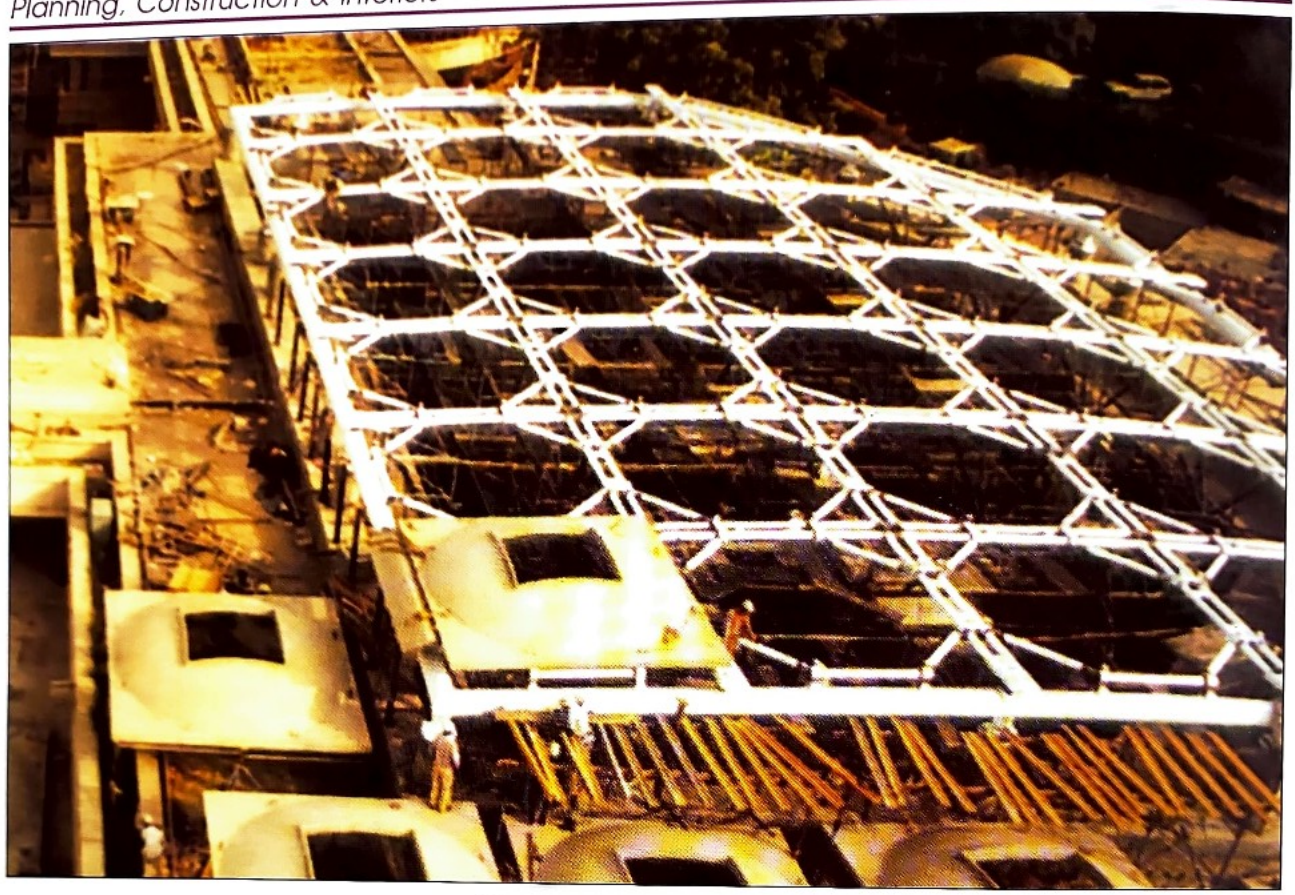
h) The virendeel elements were then dismantled and taken down one by one for welding in site workshop and re-erected in position.

i) After completing the welding and erection of top chord elements, the diagonal struts were also dismantled, taken down for welding and re-erected in position one by one in same sequence as top chord members.

j) After completing the welding and erection of diagonal members, the end connectors of tie rods were welded in situ to the bottom chord cast cross nodes.



BPST Dome Structure



Library Dome Structure

k) After completing the welding and erection of bottom chord elements, the casting support to ring beam was welded to the ring beam in position. Then ring beam site erection joints were welded.

l) All the welded joints were dressed and finished. The welding of bottom chord end connectors to cast cross nodes were stress relieved.

m) Non-destructive testing of welding was carried out and any defect if found was repaired and again tested.

n) Temporary erection bolts were then replaced by HSFG bolts. The HSFG bolts were tightened to required torque.

o) The supports were released, deflection was checked at various points and epoxy painting was done.

4.5 Stress Relieving of Welded Joints

The welded joints between Macalloy end connectors and bottom cast cross nodes were very thick i.e. 40mm. In order to remove the internal stresses in the weld zone, these joints were stress relieved. The following stress relieving cycle was adopted.

Loading temperature:	:	300 ^{0}C
Heating rate	:	200 ^{0}C per hour (max)

Soaking temperature	:	620 ± 25°C
Soaking time	:	1 hour 35 minutes
Cooling rate	:	200 °C per hour (max)
Unloading temperature	:	300 °C

The stress relieving procedure was submitted by M/s Larsen & Toubro. The procedure was checked and approved by M/s CEIL i.e. third party inspection agency. 4mm thick wires covered with insulating beads were wrapped around the welded joints. The entire joint was then wrapped with glass wool insulating materials. After starting the current, the temperature was observed on the temperature monitor and the electric current was controlled through control panel to get appropriate rate of heating & cooling. The total heating, soaking and cooling cycle of approximately 6 hours was adopted. The entire stress relieving cycle was recorded on graph sheet (temperature vs. time) attached to the temperature recorder. After stress relieving operation was over, the hardness of weld zone was tested.

5.0 FABRICATION & ERECTION OF VIP DOME

The mock up and erection of VIP dome was done in the same way as the Core



VIP Dome Structure

dome except that in place of epoxy painting, polishing of stainless steel structure was done before starting the erection of bubbles. Fabrication of various elements was done in the same way as in case of core dome except that following additional precautions were taken :

a) The stainless steel plates were cut using plasma cutting.

b) All grinding and cutting tools used for stainless steel elements were kept separately from grinding/cutting tools of carbon steel to avoid any contamination of stainless steel.

c) The plates, tubes, castings were polished to dull satin finish and were kept in separate sheds over wooden platform or over polythelene sheets to avoid any contact with carbon steel.

d) Although jigs and fixtures used for fabrication of stainless steel elements were made of carbon steel, the contact surfaces of carbon steel jigs and fixtures with stainless steel elements were lined with stainless steel sheets to prevent the contact of stainless steel elements with carbon steel.

6.0 FABRICATION & ERECTION OF FOCAL DOME STRUCTURE

Focal dome structure consists of petals, ladder purlins, top ring beam, peripheral ring beam, stabilizing ties and supporting systems.

6.1 Fabrication of Petals

The four identical petals form the main component of the focal dome structure and are fabricated out of 101.6mm outer dia, 10mm thick tubes. The petal edge beam members are formed by continuous tubes 114.3mm outer dia and 10mm thickness.

The geometry of petals is a doubly curved surface matching with the surface of revolution of arc of diameter 20801mm moving along a chord length of 9729mm. The petal structure is in the form of tubular grids having curved purlins of different radius of curvatures placed parallel to each other at spacing of 1250mm centre to centre. The petal rafters form segments of arc of dia 20801mm and then connect the petal purlins at spacing of approximately 900mm. Apex end of triangular petal is connected to the apex ring beam and bottom ends are connected to the bearing support assembly.

The shape of individual petal is a spherical triangle of sides 14m and weight approximately 7t so it was not possible to fabricate petals in a workshop, transport it to site and erect it on the terrace. To ease the problem of carriage and erection, the petals were fabricated on the terrace itself in one piece and then every petal was cut into three pieces for erection.

Curved lengths of petal purlins were first worked out from three dimensional computer modeling and the tubes of 101.6mm outer dia and 10mm thick were then cut to the required length of purlins keeping sufficient margin for edge preparation for welding. The tubes were then bent to required curvatures and the lengths of petal

purlins were checked and the ends of tubes were ground to required shape to fit closely on the petal edge beam. All the segments of the petal rafters were of same size and had identical length of approximately 1250mm. Rafter segments were cut to exact length and ends were cut to the circular shape to fit closely on the petal purlins.

The geometry of the petal was set on the terrace using grid of M.S. channels and angles as base supports. Vertical angles were then welded to the base grid. Petal perimeter profile was first fixed in its exact position on the vertical M.S. angles and tack welded to the stainless steel lining on M.S. angle supports. One row of petal rafters was placed and tack welded to the petal perimeter profile. The next petal purlin was laid and next row of petal rafters were connected by tack welding. In this way all the petal purlins and rafter elements were assembled. The petal edge beam tubes were then fixed from both sides and tack welded to petal purlins and petal rafters. After assembling the petal purlins, rafters, perimeter profiles and edge beams the geometry was checked and any discrepancy found during checking were corrected. After checking and correcting the petal geometry, petal apex casting was fixed by tack welding. The cast node was then checked by placing the circular ends of cast nodes (meant for connecting petal edge beam and petal perimeter profile) in the ends of petal edge beam and petal perimeter. After checking the entire petal assembly, the required root gap at welding locations were checked.

Holding the various components of the petals firmly in assembled position, the welding was started using tungsten-innert gas (TIG) method of welding. Initially root run



Fabrication of Petals

was welded at all welded joints and after cleaning and checking the root runs, further welding was done starting from three corners simultaneously to avoid distortion.

6.2 Fabrication of Ladder Purlins

The petals are connected to each other by ladder purlins through 36mm dia pins. Lugs made out of 15mm thick plates were welded to the petal edge beam to connect the ladder purlins. The ladder purlins were fabricated in the shape of T using 25mm thick stainless steel plates. The flange of the ladder purlins are 25mmx90mm whereas the web are 125mmx25mm. The lengths of the ladder purlins were taken from three dimensional computer modeling and the plates for flanges and web were cut using plasma cutting machine. The edges were then ground straight. The corners of the web plates were ground at top to make V groove at the junction of web and flange plates. The web and flange plates were then welded together using TIG welding. To avoid distortions, the web and flange plates were held together tightly using jigs and fixtures. The location of holes for pins were then marked at the ends and then 38mm dia holes were accurately made.



Petal Connection with Apex Ring Beam

6.3 Fabrication of Apex Ring Beam

The apex ring beam has hollow trapezoidal section and was fabricated out of stainless steel plates. The four pieces of apex ring beam of section having top width 150mm, bottom width 100mm and height 235mm were fabricated using 25mm thick /12 mm thick plates. The ends were bevelled to make V groove with the cast steel corner brackets. The four pieces of apex ring beam were then assembled with cast stainless steel corner brackets and tack welded. The dimensions were then checked to make the apex ring beam perfectly square and joints were welded using TIG welding.

6.4 Focal Dome Structure to Column Support

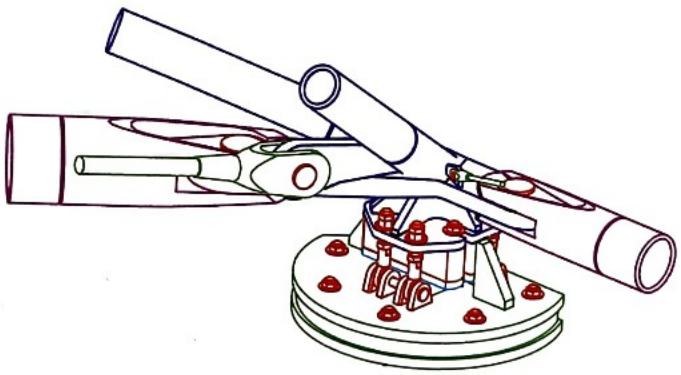
Focal dome structure to column support system of focal dome consist of stainless steel anchor plates, welded base plate, 33mm thick reinforced neoprene bearing, spacer plate and cast stainless steel node. The anchor plate and welded



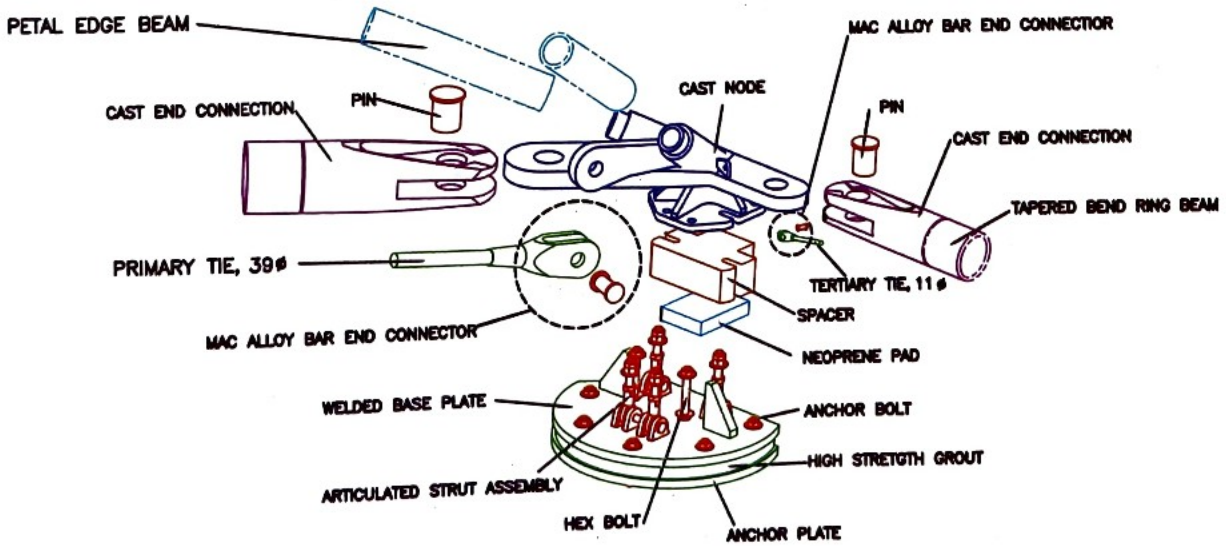
Focal Dome Structure to Column Support

base plates have been bolted to the columns (with 40mm high strength grout between two plates as levelling course) with stainless steel anchor bolts. The reinforced neoprene bearing is placed between base plate & spacer plate bolted to the cast stainless steel node. The petal edge beam and the petal perimeter ends are welded to the cast node whereas the ring beam is connected to the cast stainless steel node by 65mm dia pins.

Since the entire focal dome is covered with glass units only and the structure is very light, there is chance of the focal dome lifting up due to heavy winds. To resist the uplift force the focal dome structure is held down to supporting RCC columns using articulated strut assembly which allows limited lateral movement of the structure on the neoprene bearing in all the directions, but holds it firmly down against uplift.



3D VIEW (ASSEMBLED)



3D VIEW (EXPLODED)

Fig 17.4 : Focal Dome Structure to Column Support

The articulated strut assembly is connected to the base plate with 20mm dia pin passing through two parallel stainless steel plates welded to base plate. The base of articulated strut assembly has truncated spherical ball with hole for 20mm dia pins. This spherical bolt allows the limited movement of strut in all direction except vertical. The top end of strut assembly has 20mm dia bolt, nut with spherical base and check nut. The spherical nut & check nuts are tightened over the base of cast node in such a way that the spherical nut does not press against base of cast node to allow lateral movement while resisting uplift.

6.5 Erection of Focal Dome

After the fabrication of petals, column support, ring beams, ladder purlins etc. were completed. The erection of focal dome structure was done in following sequence.

a) The steps a) to c) as per erection of Core dome structure (para 3.5) were followed.

b) The peripheral ring beams were assembled and positioned over the bearing plates with in tolerance of ± 2mm.

c) The apex ring beam was erected and fixed on scaffolding at exact position and level within tolerance of ± 2mm.



Focal Dome Structure

d) The petals were cut in three pieces at pre decided locations for ease of handling. The cast stainless steel sleeves with collars were then welded to the petal purlin tubes on one side. The petals were erected on firm scaffolding. The geometrical accuracy was checked and various components of petals were adjusted within permissible tolerance.

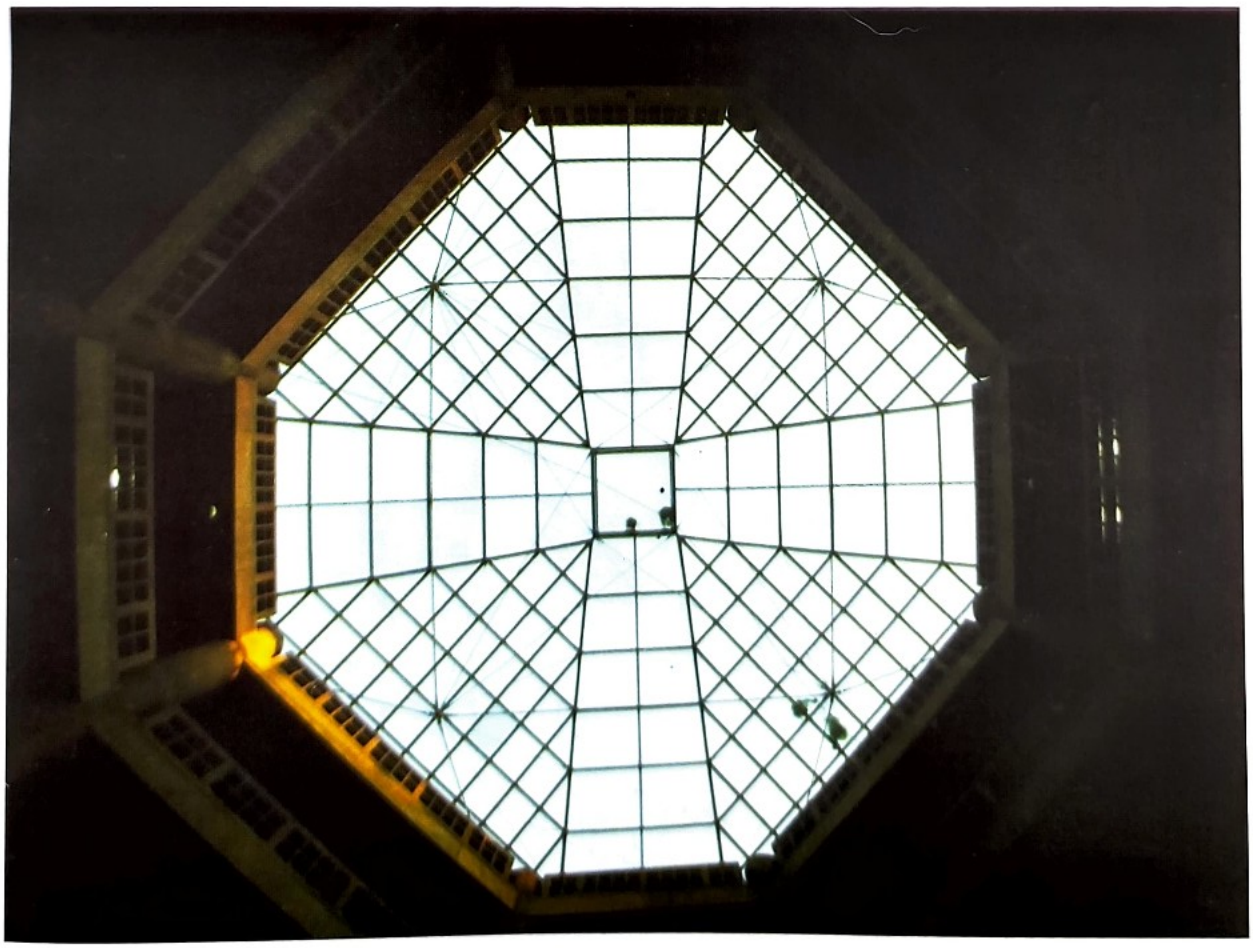
e) The petals were connected to apex ring beam and column supports by pin arrangement. The site welding of the 3 pieces of petals was done in position starting from both the sides symmetrically to avoid any distortion in the petal structure.

f) The tension tie system was positioned and connected using pins/bolts at end connector location and flying nodes.

g) Ladder purlins were connected to the petals using pins.

h) After the entire structure was completely assembled and checked for geometry and dimensional accuracy, the sliding supports were released.

i) The other supports were released and deflection was checked.



Focal Dome

j) The glazing support system consisting of tees, rectangular tubes, angles etc. were fixed to the structure and glazing was started. The glazing panels were positioned progressively starting from perimeter working towards apex.

k) The tension tie system was re-adjusted after fixing of glazing panels was complete.

l) The waterproofing i.e. filling the gaps between glazing panels with structural silicone was started after all glazing panels were correctly positioned, checked and adjusted.

7.0 WELDING

Different types of materials such as high strength carbon steel tubes/plates, stainless steel tubes/plates and carbon steel/stainless steel castings have been used. Since different combination of materials were used, special precautions were required in selection of welding consumables and processes to ensure the compatibility of different types of materials with the welding consumables. Following procedure was adopted-

a) After selection of electrode for a particular combination of welding, the detailing was done in accordance with IS: 9595–1998 showing clearly the welding process, base metal, position of welding, joint detailing, post weld heat treatment, type of electrodes etc.

b) The welding procedure was approved after discussion with CEIL i.e. the third party inspection agency.

c) The details of experienced welders were submitted by M/s Larson & Toubro for different types and position of welding.

d) A test piece was welded by welders as per the approved welding procedure.

e) The test pieces were inspected by the CPWD Engineers and CEIL jointly and the test pieces were got tested by radiography and mechanical destruction testing method.

f) The welders whose test pieces passed the requisite tests were approved and welder's identity cards were issued.

g) All welders were tested for radiographic quality welding in 6G position (over head the most difficult position)

h) After approval of welders and welding processes the welding was allowed.

7.1 Welding Process

Since different types of materials were involved in the welded joints, two welding processes were used depending upon materials used.

a) *Shielded Metal Arc Welding* : Shielded metal arc welding process was used for all carbon steel welded joints using appropriate welding electrodes. DC current was

used for welding. Shielded metal arc welding process was also used in filler runs for welding of stainless steel.

b) *Gas Shielded Tungston Arc Welding (GTAW) or TIG Welding :* In stainless steel welding the root runs being very important were welded using GTAW welding method (Argon gas 99.99% pure was used as shielding gas and non consumable Tungston electrodes were used to create Arc).

The edges cut using flame cutting/plasma cutting methods were ground to remove brittle material and hardness was tested. The root gaps and groove angles were checked before starting the welding operation. All electrodes were preheated and were kept in the oven to ensure moisture free electrodes. After root run was over, the welding was cleaned using wire brush and was inspected before starting subsequent runs.

Special precaution was taken for welding of cast steel bottom node to the end connectors of high strength rods. This was 40mmx100mm butt weld and hence the parent metals were preheated and welding done from both the sides in alternate passes to avoid the distortion. Further to remove any internal stresses, stress relieving was done, since this joint is subjected to high tensile load continuously. All such joints were subjected to radiographic examination

8.0 POLISHING OF STAINLESS STEEL STRUCTURE

The structure of focal and VIP domes consist of various stainless steel members. The high strength tie rods and end connectors were brought at site in prepolished condition and hence were not polished at site. The tubes were also machine polished in factory but the polishing on tubes got damaged at some locations during fabrication and erection. The plates too were polished in workshops but during welding the polishing got damaged and the plate assemblies were again polished at site. The castings in semi polished condition and ring beam segments in unpolished condition were brought at site.

After fabrication and erection of structure the polishing of structure was done at site. The polishing of stainless steel structure proved to be very tedious job because of very intricate shapes of castings and large area of welding. The polishing was done as mentioned below.

a) The welding locations were first ground using grinders. Needle shape grinders were used to grind the tube to tube welding whereas disc grinders were used to grind the welding where welds were required to be made flat at locations such as end connector to tube welding. The ground surfaces of weldings were then made smooth by using buffing wheels. After buffing, the polishing was done using polishing wheels of different grades (120 grit to 180 grit) in successions. Where polishing using machines was not possible, the polishing was done using emery paper of 180 grit.

b) All stainless steel castings were polished using hand polishing tools to match 180 grit polish of stainless steel tubes. The nitches in the casting made for bolts were ground smooth using needle shaped grinding on buffing tools. The manual polishing gives very irregular patterns and hence it was found extremely difficult to match the polish on casting with 180 grit polish of stainless steel tubes. It would have been easier to match the polished surfaces of castings and tubes if mirror polish had been adopted as the finish on stainless steel surfaces.

c) After polishing the entire surface was cleaned using alcohol based thinner and wiped dry with clean dry cloths. Lacquer was applied on entire stainless steel surface using brush.

9.0 WORK DONE

The following quantities of carbon steel & stainless steel have been used, in the dome structures

a) Structural Steel : 129t

b) Stainless steel : 70t

c) High Carbon Steel : 368t

GLASS WORK

1.0 GLASS BLOCKS

1.1 Selection of Glass Blocks

The glass block manufacturing factories at Ferozabad (UP) were visited and samples were collected and it was found that glass blocks generally available in the country have the following deficiencies.

a) The glass blocks had a number of visual defects such as inclusion of impurities, air bubbles, non-uniform appearance, scratches on surface etc.

b) The glass blocks are manufactured in coal furnaces without any control on temperature, hence proper annealing of glass blocks is not done due to which internal stresses are developed. The glass blocks are prone to spontaneous breaking due to internal stresses.

c) The hollow glass blocks are made in two parts and later on joined using adhesive and there is chance of separation of the two pieces at joints.

In view of above deficiencies, it was decided to use imported glass blocks. Hollow glass block of following make having transmittance properties as mentioned below of 190mm x 190mm x 80mm size were used depending upon location.

Sl. No.	Sample Description	Location	Light transmittance %		
			Ultra violet	Visible	Infrared
1.	Fidenza 19T/Satin	Sky lights for Library & Museum Domes	55.8	85.76	42.92
2.	Fidenza Vetroarredo 3190 DSC	Light well along periphery of building	60.03	70.22	32.29
3.	Solaris 198 white light diffusing	Glass Block walls for Domes	62.1	82.76	45.60

1.2 Glass Block Panels as SkyLights for Domes

Horizontal reinforced precast glass block panels of size 1.7m x 1.7m have been provided as sky lights on the cutouts of precast fibre reinforced concrete bubbles of library & museum domes to allow diffused sunlight from top of the domes. The glass blocks are frosted from inside.

The design of glass block panels was done on the basis of the guidelines given by manufacturer. The thickness of RCC ribs between glass blocks was taken 25mm and two layers of 8mm dia MS bars were provided in both directions at spacing of 215mm centre to centre, concrete of mix 1:1:2 (1 cement : 1 coarse sand : 2 graded stone

aggregate 10mm down grade) was used. The size of edge beam was kept 150mm x 80mm and 4nos of 8mm dia MS bars were provided in the edge beam. The sample of glass block panel was cast and tested for 250kg/sqm load. The Following procedure was adopted for construction of precast glass block panels.

a) The wooden form work matching the curved shape of glass block panel was made and wooden beading of size 25mm x 10mm were fixed on the form work at a spacing of 215mm centre to centre.

b) The glass blocks were placed on the wooden form work between the wooden beadings. The reinforcement cage was laid in the gap between the glass blocks.

c) Concrete of grade 1:1:2 (1 cement :

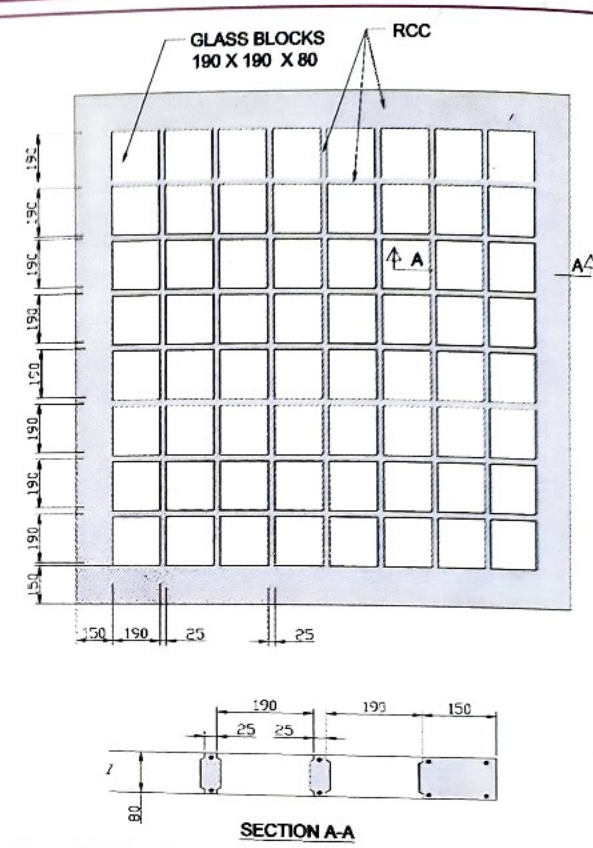
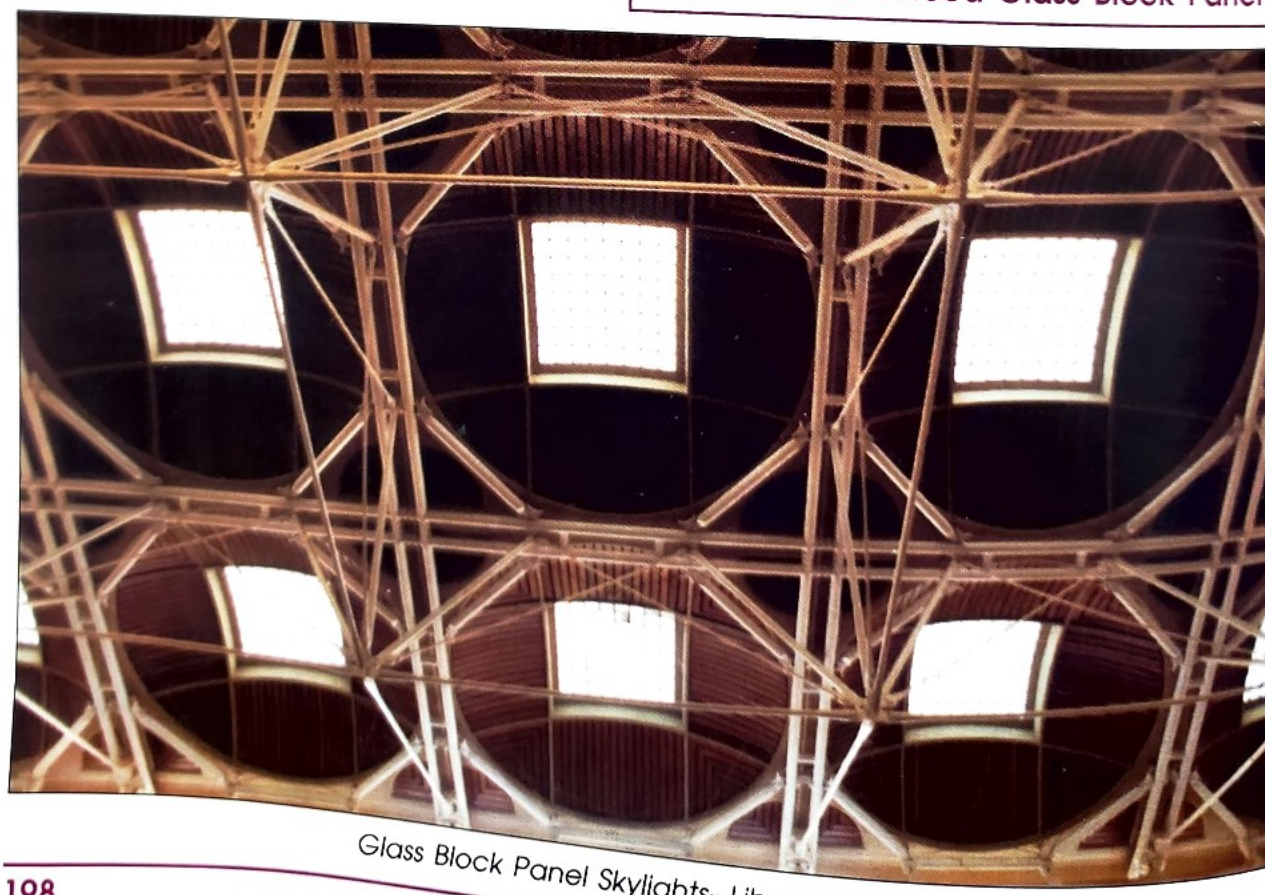


Fig 18.1 : Reinforced Glass Block Panel



Glass Block Panel Skylights- Library Dome

1 coarse sand : 2 graded stone aggregate 10mm down grade) admixed with conbex 100 non shrink compound was laid and compacted using steel rods. The concrete was finished keeping the ribs 10mm below for water proofing mortar.

d) The concrete was allowed to cure for two days. The top portion of RCC joints were cleaned and the joints were filled with cement mortar 1:2 (1 cement : 2 sand) admixed with water proofing compound after applying a coat of tapecrete slurry over cleaned joints. The glass block panels were allowed to cure for total seven days.

e) After seven days curing the panels were removed from the form work and the 10mm deep joints at ribs location on the bottom side were finished with water proofing mortar in the same way as the top joints explained above.

f) After finishing the bottom joints the panels were cured for another seven days by covering the precast panels with wet gunny bags.

g) After curing the panels were placed in position & water proofing of joint was done.

1.3 Glass Block Light Well

The building has been provided with two basements. Unlike normal buildings in this case even the 2nd basement is an "active" floor having functional areas like library stacks. Keeping in view the comfort conditions of occupants and to avoid sick-building syndrome, it was felt necessary that some natural light should reach the two basements. Glass block panels in combination with granite strips have been provided all along outer periphery of the building and periphery of courtyards to act as light wells.

However, though the glass blocks helped in admitting natural light upto basement level, these have resulted in intercommunicating spaces between the two basements, thereby disturbing our scheme for fire compartmentation. Hence water curtains have been provided with the help of continuous sprinklers to have effective fire fighting arrangements.

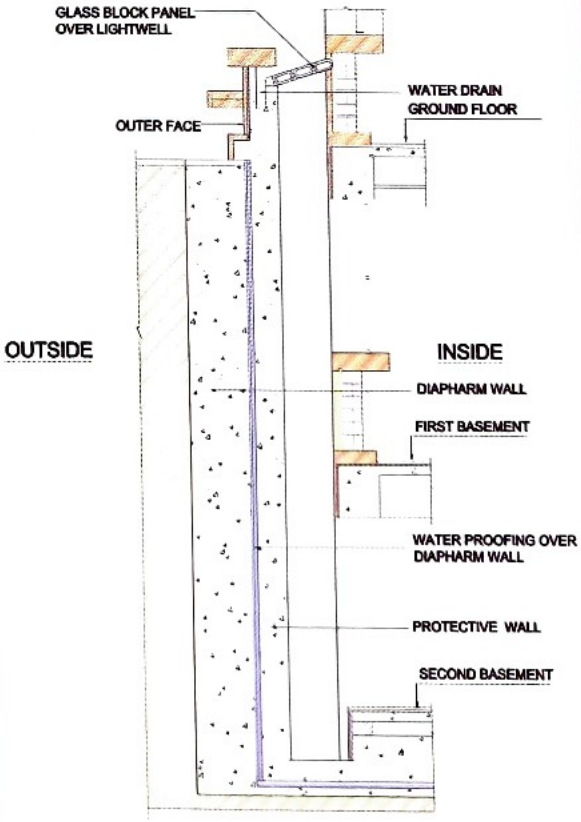


Fig 18.2 : Glass Blocks in Light Well

1.4 Vertical Glass Block Walls

Cast in situ vertical reinforced glass

block walls have been provided along the periphery of all domes (except Auditorium and Focal domes) to allow diffused sunlight inside the dome area. The glass blocks are frosted from inside so that the exposed surfaces remain smooth and clean.

The glass block wall was designed on the basis of guidelines given by the glass block manufacturer. The thickness of RCC ribs between two glass blocks was kept 20mm with two layers of 6mm dia mild steel reinforcement in both direction. Concrete of mix 1:1:2 (1 cement : 1 coarse sand : 2 graded stone aggregate 10 mm down grade) admixed with conbex 100 non shrink compound was used. In order to ensure that the glass block walls are free to expand or contract without inducing any stresses, the glass block walls were structurally separated from the supporting structures (stainless steel channels) by providing expansion joints along the vertical & top edges and sliding joint at bottom. Since the length of glass block walls was within 6m, no expansion joint was required at intermediate location.

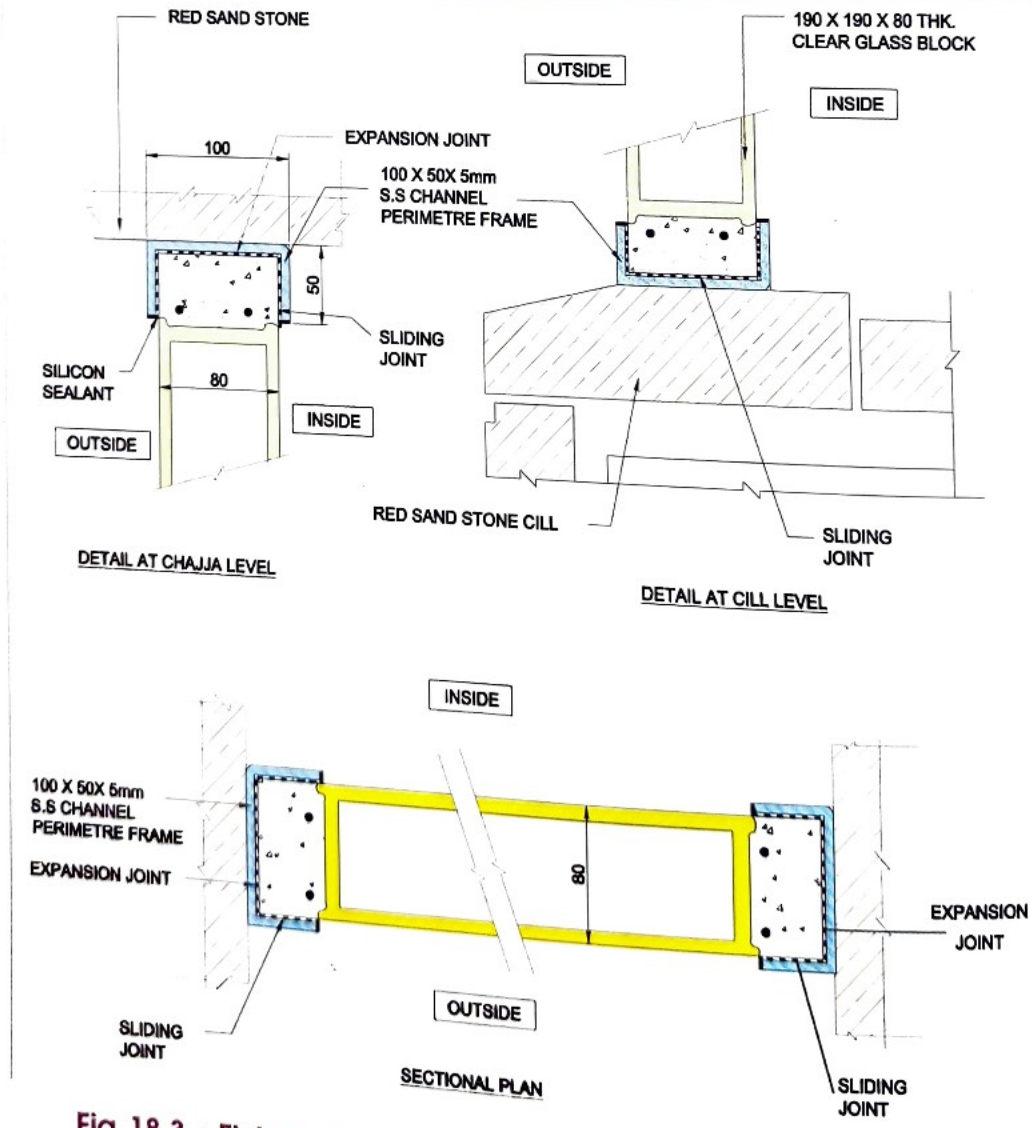


Fig 18.3 : Fixing Arrangements for Vertical Glass Block Wall

The following procedure was adopted in the construction of glass block walls.



Form Work – Vertical Glass Block Wall

a) Inside surfaces of the stainless steel perimeter channels supporting the glass block wall were cleaned and 10mm thick thermocol sheet was fixed with glue along two vertical and top edges to accommodate the expansion of glass block wall.

b) 4mm thick polystyrene sheet bent to the shape of perimeter channel was fixed along all four sides to act as sliding joint.

c) Wooden form work from inside with 10mmx 20mm wooden beadings (nailed to the form work) running in both direction at spacing of 210mm centre to centre was fixed to the perimeter stainless steel channels.

d) Reinforcement cage consisting of two layers of 6mm dia MS bars at spacing of 210mm centre to centre in both direction was fixed at wall locations.



Vertical Glass Block Wall

e) One layer of concrete was placed to form bottom edge rib and then first layer of glass blocks was laid. The vertical joints between glass blocks were filled with the concrete.

f) The next horizontal layer of concrete was laid and placing of glass blocks of second layer was completed. The beading fixed to wooden form work provided along inner side of the glass blocks ensured the placing of glass blocks in exact vertical and horizontal alignment.

g) The entire glass block wall was completed layer by layer. After laying the top layer of glass blocks and filling the joints with concrete the joints on exposed face of the wall were raked with 20mmx10mm wooden beading and the wall was allowed to cure for 48 hours.

h) The form work provided on inner face of glass block wall was removed, the glass blocks were properly cleaned and the 10mm deep joints were filled with cement mortar 1:2 (1cement:2 sand) admixed with non shrink compound after application of tapecrete slurry on the cleaned joints.

i) After completion of the glass block wall the concrete ribs were cured for 10 days by covering the wall with wet gunny bags from both sides.

j) After the wall became dry, the joint between perimeter channel and the glass block wall were cleaned of mortar etc. and sealed with silicon sealant.

2.0 HEAT REFLECTIVE HEAT STRENGTHENED INSULATED AND LAMINATED DOUBLE GLAZED SAFETY GLASS UNITS

The focal dome consist of glass units fixed over stainless structure. In VIP dome, glass units of size 1.7m x1.7m have been fixed on the openings of the fibre reinforced concrete bubbles. In order to minimize the heat entering into the building to reduce the air-conditioning load it was decided to restrict the shading coefficient of the glass units to 0.25. Since these glass units have been used on the dome as overhead sky lights, it was decided to use heat strengthened laminated safety glass to ensure the safety against any breakage of glass.

2.1 Materials for Double Glazed Glass Units

a) *Float Glass :* The float glasses manufactured by Gujrat Guardian Ltd. were used.

b) *Heat Reflective Glass :* Heat reflective glass of make Saint Gobain (France/ Italy), Glaver bel (Belgium) or ASAHI Japan was specified. The glasses of above make available in India and having shading coefficient less than 0.25 were soft coated which can not be heat strengthened. Therefore heat reflective glass "Sun Guard Silver 10 on clear" of make Guardian USA was used.

c) *Resin :* Siglam Standard resin a product from 'Siglam' have been used for lamination of glass to enhance safety. It is a two component resin. The resin has low shrinkage property, low thermal reactivity and high absorption of ultra violet rays which prevents interior furnishings and carpet from fading.

d) *PVB Layer :* Poly Vinyl Butyl (PVB) layer is available in multiples of 0.38mm thickness which is also used for lamination of glass in place of resin.

e) *Hollow Spacer Bar :* Aluminium anodized hollow spacer bars of size 11.6mm x 6mm having two rows of holes were used.

f) *Dessicant :* The dessicant filled in aluminium spacer bar was synthesized crystalline compounds of Aluminium Hydroxide, caustic soda and sodium silicates. The dessicant was of 3A size. The dessicant was filled in spacer bars at the rate of 35 gm per metre.

g) *Primary Sealant :* The primary sealant was Butyl a single component, thermo plastic, solvent- free sealing compound based on Polyisobutylene. The primary sealant was applied between aluminium spacer bars and glass.

h) *Secondary Sealant :* The secondary sealant for double glazed units was structural silicone of make Dow Corning. Structural silicone was used as secondary sealant to ensure compatibility with the structural silicone used for fixing the glass units with stainless steel structure.

2.2 Design of Double Glazed Glass Units

Following were design requirement for glass units.

a) Shading coefficient less than 0.25

b) Safety against breakage i.e. glass units must remain intact and should not fall down even if any glass in the unit breaks.

c) The glass units must be capable of taking uniformally distributed load of 150kg/sqm.

In order to meet the above requirement following provisions were made.

i. Out of four glasses of double glazed glass units the top glass used was heat reflective with shading coefficient of 0.23.

ii. To guard against any breakage all the four glasses were first heat strengthened (heat strengthening increases the strength by 2 to 2.5 times). The two glass sheets forming the top layer were laminated using PVB (Poly vinyl butyl) sheet of thickness 0.76mm or resin layer of appropriate thickness. Similarly the two glass sheets forming bottom layer were also laminated using PVB sheet of 0.38mm or resin layer of appropriate thickness. This ensured that even if any glass sheet breaks, the PVB or resin layer keeps the glass unit intact without any chance of glass unit falling down.

iii. The top layer of the glass unit was designed to take minimum working load of 150kg/sqm with factor of safety more than 4.0. Allowable pressure P in kg/sqm for laminated glass supported on four edges was worked out and glass units designed as per following formula.

$$P = \frac{3K(t_2 + \frac{t_2^2}{4})}{A} \quad (1+(t_1/t_2)^3)$$

Where K = A Coefficient & is 24 for lamisafe glasses

t_1 = Thickness of thin glass in mm

t_2 = Thickness of thick glass in mm

A = Area of glass panel in sqm.

For glass supported on two edges only the load carrying capacity was taken as P/2. Before finalizing the design of glass units, a sample of laminated safety glass panel of size 1.2m x 1.2m with two heat strengthened sheets of thickness 5mm & 8mm was fabricated. The allowable pressure for this sample glass works out.

$$P = \frac{3x24}{1.2x1.2}(8+64/4)\,(1+(5/8)^3)$$

$$= 1490 \text{ kg/sqm}$$

Applying a factor of safety 4 over allowable pressure.

Safe load carrying capacity = 1490/4 = 372 kg/sqm

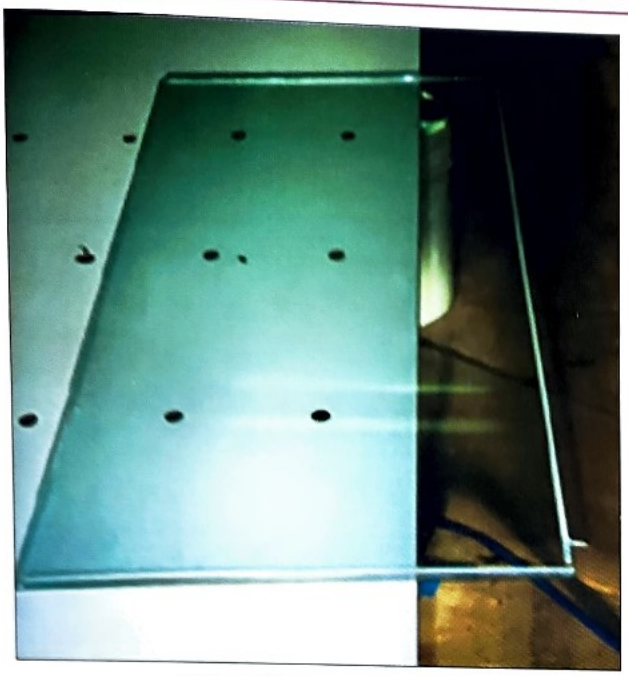
This glass panel was load tested upto load of 450 kg/sqm and no crack was observed.

2.3 Fabrication of Double Glazed Glass Units

a) *Heat Strengthening of Glass :* Heat strengthened glass is a semi tempered glass & is less vulnerable to spontaneous breakage and is generally preferred over toughened glass. Heat strengthened glass is made by heating the glass at uniform temperature of approximately 660°C. The heating temperature & rate of cooling is low in case of heat strengthened glass as compared to toughened glass. Heat strengthened glass allows the inter-layer of laminated glass to adhere more evenly because of flatter surface which also gives less optical distortions. All the four glasses were cut to size & heat strengthened.

b) *Lamination :* Laminated glass is two or more panes of glass with one or more layers of poly vinyl butyl (PVB) or resin between them. Laminate Glass exhibits the characteristics of superior safety glass i.e. strength, flexibility and adhesion. When broken by impact, the glass will adhere to the inter layer and generally stay in position, minimizing the risk of injury from sharp edges and flying or falling glass and strongly resists penetration by the impacting object or person, lamination has been done using resin predominantly (and PVB in a few locations).

The glass sheet was thoroughly washed & cleaned and was applied with spacer tape all along the periphery of the sheet and top glass was fixed. The resin was prepared by adding one percent hardner and stirring it for approximately 10 seconds, to dissolve the hardner. The glass was tilted at 45° angle. The resin was



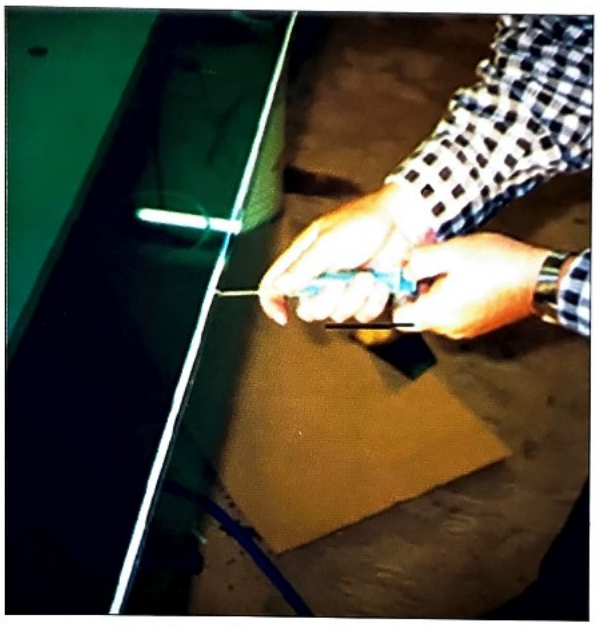
Fixing Spacer Tape



Fixing Aluminium Tape at Croner



Pouring Resin



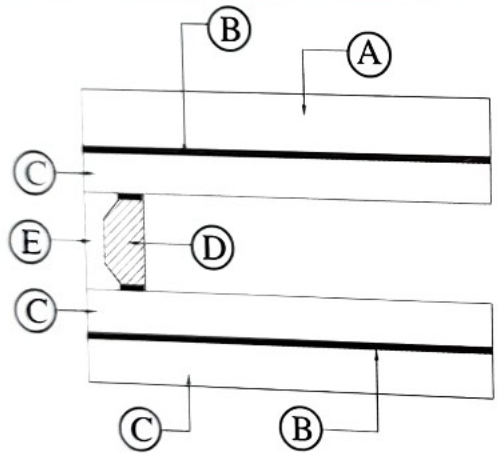
Bubble Removal by Syringe

poured through a funnel between the glass sheets. After filling the glass sheet with resin & bringing it back to original position the top was sealed with double sided spacer tape and the corners with aluminium tape. If any bubble was formed, it was removed with a syringe.

c) *Insulation :* The insulated glass is a prefabricated unit made of two or more glass panes, which have been separated by an air gap and edge- sealed together. This edge seal not only binds the individual sheets of glass together to maintain the mechanical strength of the unit but also protects the space between the glass from outside influences. The air enclosed between the two glass panes is dried with dessicant. Because of the low heat conductivity of the enclosed dry air between the glass panes, heat transmission through the glass unit is drastically reduced.

The aluminium spacers are cut to size, filled with dessicant and joined at the edges in the form of a frame. Primary sealant butyl (Polyisobutalyne) is applied to the edges and made ready to be incorporated in the assembly. Glasses are washed and dried on the computerized manufacturing line and conveyed to the assembly for last inspection and assembled with the aluminium spacer on which primary sealant has already been applied. The assembly is then pressed and conveyed to the applicator table for applying the secondary sealant which is two part polysulphide or two part structural silicone.

The aluminium profile or spacer bar is responsible for establishing the precise distance between the glass panes, as there is a correlation between the distance of the glass panes and the energy saving properties. The dessicant adsorbs moisture in the entrapped air to prevent the condensation inside the glass panes.



A Heat Reflective Glass
B Resin/PVB Layer
C Float Glass
D Aluminium Spacer Filled with Dessicant
E Secondary Sealant (Silicon)

Fig 18.4 : Typical Details of Hermetically Sealed Unit

2.4 Combinations Used

The following combination was used for glass units of ladder purlins & Apex of focal dome.

a) 6mm thick heat strengthened and heat reflective glass (shading coefficient < 0.25).
b) 0.76mm PVB Layer or resin layer of appropriate thickness.
c) 10mm float glass (Heat strengthened)
d) Perforated aluminum spacer bar filled with Dessicant
e) Secondary sealent (Silicone)
f) 5mm thick heat strengthened float glass.
g) 0.38mm PVB layer or resin layer of appropriate thickness.
h) 5mm thick heat strengthened float glass.

As far as petals of focal dome and sky light of VIP dome are concerned the glass combination as mentioned above have been used with the change that float glass of 8mm in place of 10mm thick & 4mm in place of 5mm thick have been used.

2.5 Fixing of Glass Units

a) *Fixing of Glass Units in Focal Dome :* Except for the Apex glass which is supported on 4 edges, the glass units of the focal dome have been fixed on two edges. Stainless steel T section was welded to the structural tubes over which hollow rectangular stainless steel tubes were welded. EPDM gasket specially extruded for fixing glass units were placed on rectangular stainless steel hollow tubes. The steel tube was capped with inverted stainless steel channel. The glass units were placed over EPDM gaskets and bolted to hollow stainless steel tubes using stainless steel bolts, washers and EPDM circular pads to guard against uplift of glass units. The gap between glass units were filled with structural silicone. Even before sealing the glass units joints with structural silicone the glass dome was checked for leakage. The structural silicone was applied after ensuring that no leakage was observed through the joints.

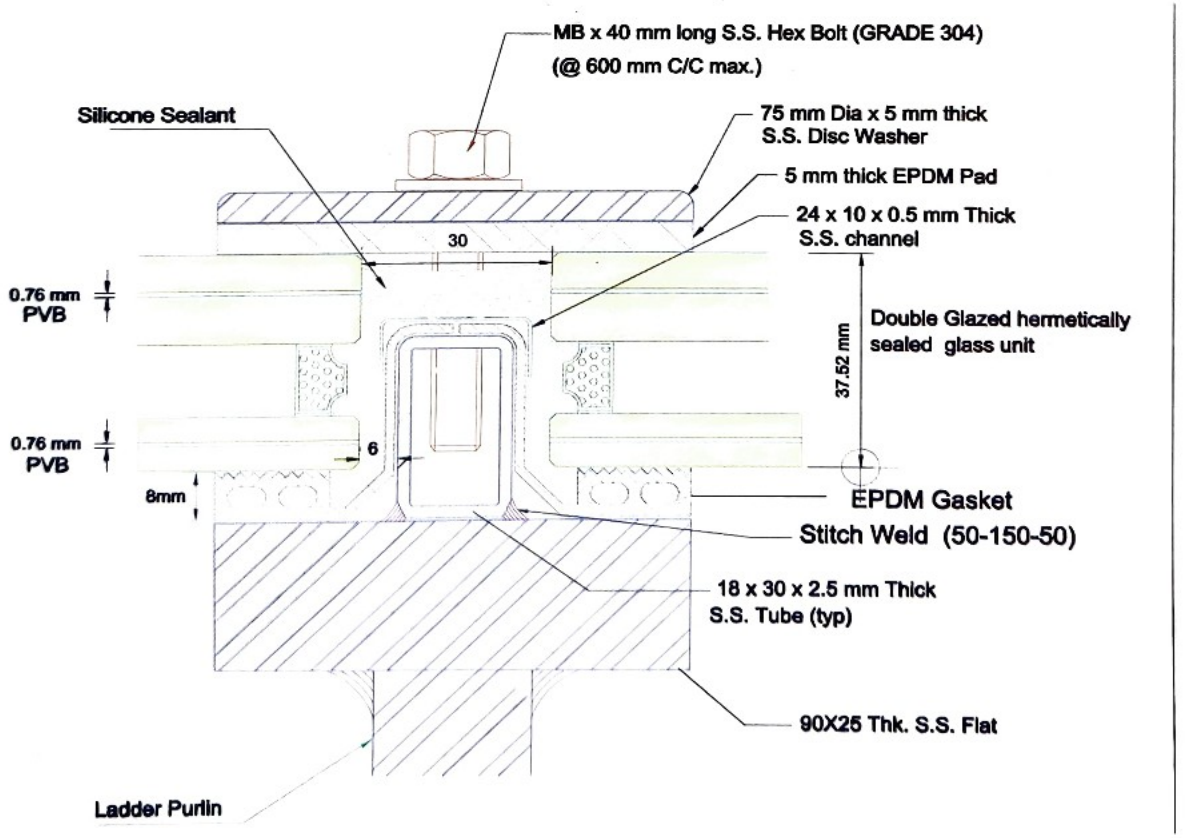


Fig 18.5 : Fixing Arrangement for Glass Unit in Focal Dome

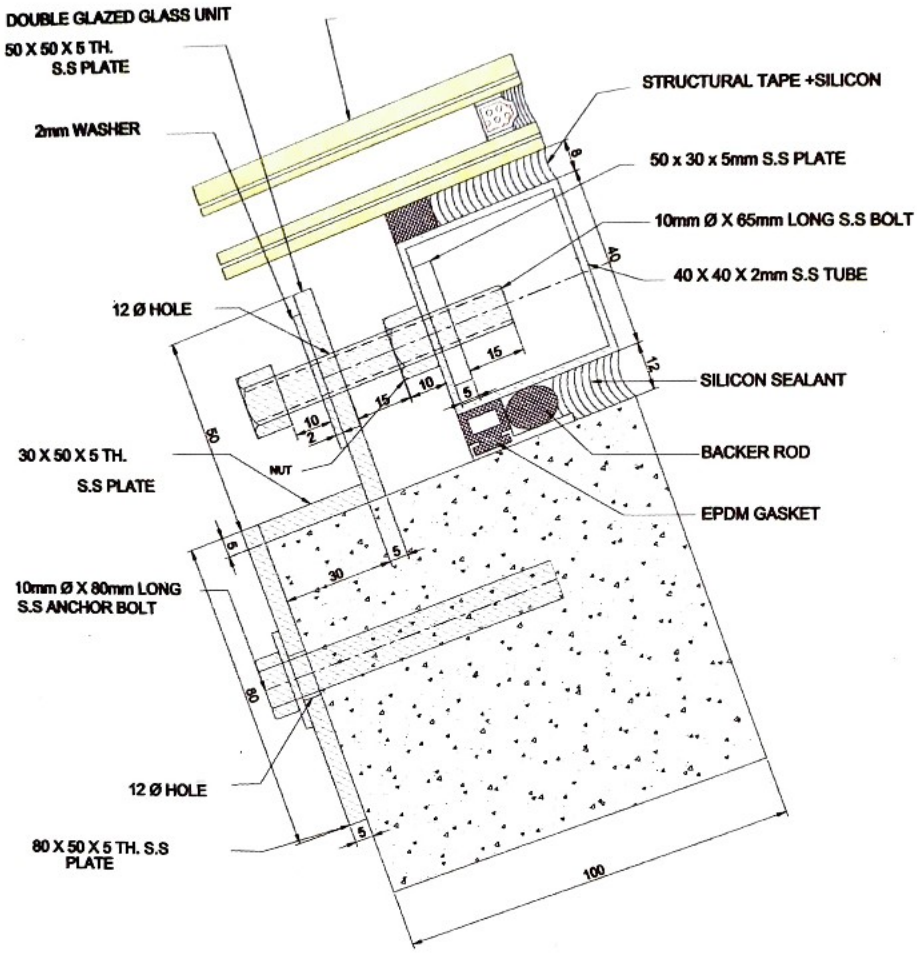


Fig 18.6 : Fixing arrangement of Glass unit in VIP Dome

b) *Fixing of Glass Units in VIP Dome :* The fixing of glass units on the FRC bubbles of VIP dome posed a very peculiar problem as the four sides of the opening supporting the glass units were edges of four different FRC bubbles not connected together structurally. The four sides were free to move independently due to temperature variations. A special mechanical arrangement consisting of stainless steel hollow tube, nuts, bolts and brackets was made in such a way that movement of edges of different FRC bubbles are not transferred to the glass units at the same time glass units were mechanically held down to the FRC bubbles against uplift.

3.0 HEAT REFLECTIVE INSULATED AND LAMINATED DOUBLE GLAZED SAFETY GLASS UNITS

Along the periphery of domes, heat reflective, insulated & laminated double glazed safety glass units have been fixed in combination of the glass block walls. The inclined glass units have been fixed in the focal dome between the petal and bottom ring beam and in part bubbles of BPST, AV, Services, Library & Museum Domes. The

vertical glass units have been fixed along periphery of all the domes except Auditorium. The heat reflective glass in these units are lighter in shades compared to the horizontal glass for focal & sky lights of VIP domes.

3.1 Materials

The heat reflective glass in these units is "sunguard silver 20 on clear", Dessicant and sealant are same as in case of glass units for skylight.

3.2 Combination used

The following combination was used for glass units of vertical / inclined glazing of domes.

a) 5mm thick heat reflective glass (shading coefficient < 0.25).

b) 0.38mm PVB Layer or resin layer of appropriate thickness.

c) 5mm float glass

d) Perforated aluminum spacer bar filled with Dessicant

e) Secondary sealent (Silicone)

f) 3mm thick float glass.

g) 0.38mm PVB layer or resin layer of appropriate thickness.

h) 3mm thick float glass.

Since these glass units are fixed in vertical /inclined position, there is no live load on these glass units except wind load, hence the glasses in these units were not heat strengthened. Another reason for not doing heat strengthening of these glass units was that these glasses are at eye level from terrace and heat strengthening would have resulted in waviness in glasses which is considered as a visual defect. Since the heat strengthening was unavoidable in horizontal glass units, the same was done for glass units of skylights of focal & VIP domes even though it resulted in some waviness in the glass units (un-noticeable to the untrained eye).

3.3 Fixing of Inclined Glass Units in Focal Dome

The inclined glass units have been supported along top and bottom edge on stainless steel profiles. The vertical joints have been sealed with structural silicone from outside. From inside the joints have EPDM gaskets pressed in the joints. The top and bottom joints are sealed with structural silicone.

3.4 Fixing of Glass Units in Part Bubbles

The part bubbles of 5 domes i.e. BPST, AV, Services, Library & Museum have vertical cutouts in the shape of segments of circles. The cutouts are curved in plan and elevation. Since making of curved double glazed laminated glass units were extremely difficult, the glass units in each cutout has been made in three segments. These glass

units have been fixed at top and bottom with stainless steel brackets. The joints along all the sides have been sealed with structural silicon from both the sides.

3.5 Fixing of Vertical Glass Units

The vertical glass units have been fixed along the perimeter of domes below the FRC chajja. Powder coated extruded aluminium frame have been fixed along the perimeter using stainless steel anchor fasteners. The glass units have been fixed using EPDM gasket and powder coated aluminium extruded snap-on-beading.

4.0 WORK DONE

The following quantities of various items have been executed.

Sl.No.	Item	Quantity
1.	Glass Block Light Well	800 sqm
2.	Glass Block as sky light for Domes	224 sqm
3.	Vertical Glass Block walls in Domes	607 sqm
4.	Heat Reflective Heat Strengthened Insulated and Laminated double glazed safety glass units	
a)	Focal Dome Petals	300 sqm
b)	Focal Dome Ladder	200 sqm
c)	VIP Dome	33 sqm
5.	Heat Reflective Insulated & Laminated double glazed safety glass unit	
a)	Inclined Glass in Focal Dome	120 sqm
b)	Part Bubbles of Library, Museum, BPST, AV & Service Dome	34 sqm
c)	Vertical glass along the perimeter of the Domes	324 sqm

FALSE CEILING

1.0 GENERAL

Various types of intricate and elegant false ceiling have been provided depending upon the importance of the location, use of the area, type of wall lining/cladding used in the area and functional requirements. In most of the areas the false ceilings have been provided with accoustic backing. Following types of false ceiling have been provided in the building.

Sl.No.	Type of False ceiling	Location	Area in sqm
1.	Gypsum Board	To cover services in corridors, horizontal & vertical drop ceiling and coffers in FB	20134 sqm
2.	Burma Teak Wood Battens	Committee Rooms, Halls, VIP Entrance GF	1987 sqm
3.	Cedar Wood Cross Combed Panel in Coffers	Staircases, BPST, AV & VIP Office Rooms, Banquet Hall, LAARDIS, Pantries	1261 sqm
4.	Cedar Wood Battens	Auditorium Balcony	302 sqm
5.	Stainless Steel Plank	Ground & First Floor Corridors	1365 sqm
6.	Perforated Aluminium Plank	First Basement Corridors	568 sqm
7.	Stone Jali	5m wide Corridors except SB AV, VIP & Services entrance, Auditorium-Foyer	1588 sqm
8.	Solid Sand Stone	VIP & Services Entrance Porch	80 sqm
9.	Micro Fibre Acoustic Tile	Auditorium Stage	270 sqm
10.	Cedar Wood Cross Combed and Battens	Auditorium Dome	587 sqm
11.	Cedar Wood Cross Combed	BPST, VIP & AV dome	717 sqm
12.	Sisham Wood Cross Combed	Core 2 Nos. & Services Dome	559 sqm
13.	Burma Teak Wood Battens	Core- 2 Nos., Library & Museum Dome	1179 sqm
14.	Vinartex	Exposed Webs/Ribs of Coffers, beams etc.	21690 sqm

2.0 GYPSUM BOARD FALSE CEILING

The gypsum board false ceiling consisting of galvanized iron framing system with

12mm thick gypsum board manufactured and supplied by India Gypsum Ltd. have been used. The specifications stipulated galvanizing with zinc coating of 600 micron for GI sections as per IS 277-1985 but GI section of this grade of zinc coating were not available. Also according to clause 7.2 of the said code, zinc coating depends on the thickness of G.I. section and varies from 200 micron to 350 micron on 0.18mm to one mm thick sections. The GI sections with zinc coating of 220 microns have been accepted with necessary cost adjustment. The gypsum board surface has been finished with plastic emulsion paint. The gypsum board false ceiling is very versatile. The openings of any size and shape to accommodate the light fittings, speakers etc. can be made easily. The repair and maintenance is also easy. The gypsum board false ceiling provided in specific areas is discussed below.

2.1 Gypsum Board False Ceiling within Coffers

This has been provided to accommodate the light fittings, speakers etc. and to cover the conduits/pipes etc. mainly in coffers of first basement. The GI frame for gypsum board has been fixed in coffers with the help of GI anchor fasteners fixed to side of coffers. The spacing/design of GI frame work have been provided at various locations depending on type of fitting to be provided.

2.2 Gypsum Board Horizontal and Vertical Drop Ceiling including Ceiling in Corridors

The gypsum board drop ceiling in big halls and corridors have been used to cover the services like AC ducts, electrical cables, cable trays, sprinkler system, GI pipes etc. and to accommodate the linear AC grills, speakers and light fittings. The gypsum board drop ceiling have been used in corridors of second basement and rooms/big halls at all the floors. This has also been used in combination with stainless steel planks and perforated aluminium planks.

The minimum clear height between floor and false ceiling was to be maintained as 2400mm. The following modifications were required at site during execution for accommodating various electrical services,

a) A GI flat of 25mm x 0.5mm size was provided on the backside of gypsum board all along AC grill for its stability.

b) The linear light fittings were to be provided in second basement drop ceiling in big halls/rooms and corridors. The spacing of intermediate channel was adjusted as per length of light fitting so that it does not foul with light fittings.

The greatest disadvantage noticed with the Gypsum Boards was that they developed growth of fungi in damp and humid conditions during monsoon in the two basements. Once this problem came to our notice, we had to reschedule our programme for false ceiling, concentrating first on the upper two floors and then resuming the work in the basements, by which time the monsoon had passed and the ambient air was drier. Once the AC system was commissioned, of course, the problem of fungus did not recur.

3.0 BURMA TEAK WOOD BATTEN FALSE CEILING

Each and every batten of first class Burma teak wood was checked by Junior Engineer/Assistant Engineer and signed In token of approval for conformity with specifications before finishing. The sal wood frame used has been chemically treated and exposed surfaces of Burma teak wood have been finished with French spirit polish and then coated with 25-35 micron thick melamine coating. Unexposed surface of battens have been finished with wood primer. The Burma teak wood batten false ceiling provided in specific areas is discussed as below.

3.1 Burma Teak Wood Batten False Ceiling in Coffers

The false ceiling has been made of first class Burma teak wood battens of size 88mm x 19mm with a gap of 12mm between battens, fixed on 40mmx40mm sal wood frame. The supporting system consist of MS angle of size 25mm x 25mm x 3mm fixed on two opposite sides and a M.S. tee of size 30mmx30mmx3mm in the centre, welded to M.S. insert plates already available in coffers.

The false ceiling is made of two panels of battens in such a way that it can be placed on M.S. frame or removed just by tilting the panel. One Burma teak wood batten is permanently fixed to M.S. Tee member with screws. The accoustic backing of 40mm thick mineral wool wrapped in markeen bags was placed over the false ceiling panels. Hessain cloth, dyed black, has been nailed on the lower surface of sal wood frame for uniform appearance of grooves before fixing Burma Teak Battens.

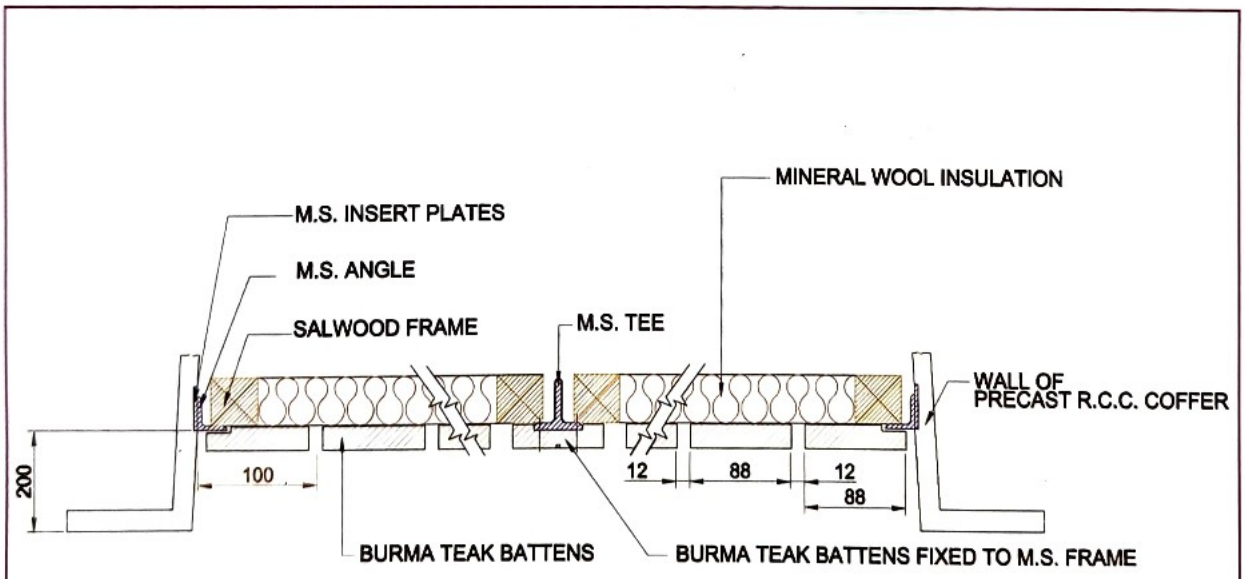


Fig 19.1 : Burma Teak Wood Battens False Ceiling in Coffers

3.2 Burma Teak Wood Battens Drop Ceiling

The Burma teak wood battens in combination of gypsum board have been used for drop ceiling in VIP entrance lobby at ground floor. The battens are 15mm thick, 75mm wide with a gap of 12mm. The gypsum board and Burma teak battens both have been fixed on GI frame work as for gypsum board false ceiling. The black dyed hessian cloth has been fixed over the frame work to have uniform appearance of grooves.



Burma Teak Wood Battens Drop Ceiling - VIP Entrance

4.0 CEDAR WOOD CROSS-COMBED PANEL FALSE CEILING IN COFFERS

The false ceiling is made of cedar wood cross combed panels made from battens of width 93mm and thickness 19mm by making parallel grooves 3mm wide @ 6mm centre to centre in one direction on one face upto half thickness and in perpendicular direction of same size on other face for the remaining thickness in such a way that at crossing of grooves 3mm x 3mm holes are visible. In effect, therefore, these panels act as sieves allowing sound to filter through to be absorbed by the acoustic treatment above the false ceiling. The panels are made by nailing the cross-combed battens to the sal wood frame with a gap of 12mm between two battens. The supporting frame work is made of powder coated MS Tees and angles, dividing the coffer into 4 panels. The panels are then fixed to frame with stainless steel clamps of Z shape. The total number of cedar cross combed panels provided in the building are as below :

Sl.No.	Size in metres	Total Numbers
1.	0.52 x 0.52	3453
2.	0.52 x 0.40	587
3.	0.52 x 0.41	612
4.	0.40 x 0.40	20
5.	0.52 x 0.20	20
6.	0.52 x 0.48	81
7.	0.41 x 0.46	2
8.	0.52 x 0.38	4
9.	0.41 x 0.48	4
10.	0.52 x 0.16	14
11.	0.52 x 0.31	12

Above dimensions are for circumscribing rectangle which also includes many

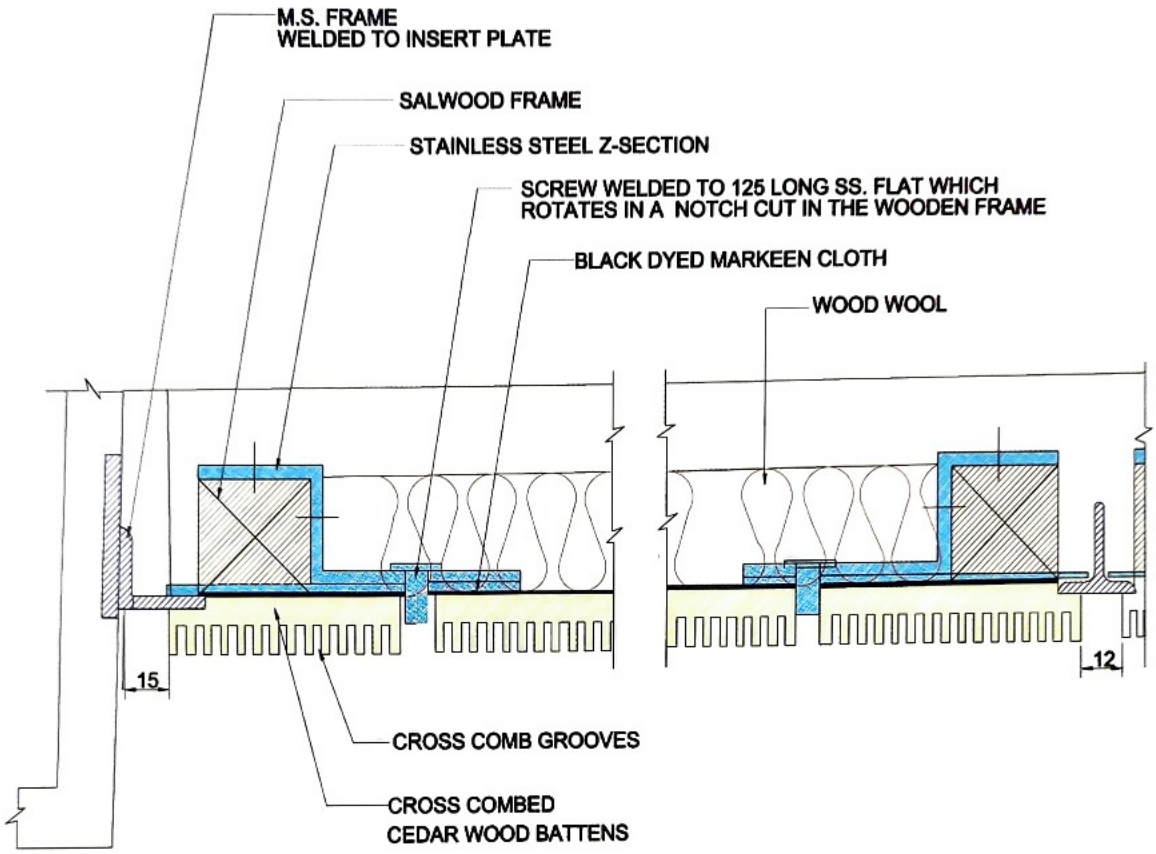


Fig 19.2 : Cedar Wood Cross Combed False Ceiling in Coffers

trapezoidal/curved shape panels provided as per shape of coffers. The disadvantage with cross-combing is that it makes the panel very flimsy since the process of combing removes a substantial amount of the material. While manufacturing such cross combed panels a large amount of wastage was reported. Once a panel was manufactured it was very difficult to make any holes for allowing electric flexible conduits, without damaging the panel. For such identified panels, drilling was done in the timber plank before the cross- combing operation was taken up.

5.0 CEDAR WOOD BATTEN FALSE CEILING

Plain cedar wood batten false ceiling with acoustic backing has been provided in the false ceiling of Auditorium balcony to match the cedar wood cross combed and plain cedar wood batten false ceiling of Auditorium dome. As per architectural drawing stipulation was made in agreement for provision of 150mm wide battens for false ceiling. After preparation of the sample it was observed that 150mm wide battens for balcony ceiling were appearing to be too large (being closer) as compared to 100mm wide battens used for dome ceiling. Hence it was decided to reduce the width of cedar wood plank to 75mm to match the false ceiling of dome.



Cedar Wood Battens False Ceiling – Auditorium

The frame work consists of chemically-treated sal wood members of size 75mm x 50mm fixed at maximum spacing of 550mm centre to centre in both directions with M.S. flat suspenders of size 40mm x 6mm and 50mm thick glass wool insulation of density 48kg/cum wrapped in hessian cloth which was fixed to wooden frame work with nails. The entire frame work along with glass wool insulation was then covered with black dyed hessian cloth. The cedar wood battens 19mm thick were nailed to the frame work with 12mm gap between the battens. Since the balcony is curved, the battens were fixed in radial direction. In order to maintain uniform groove width of 12mm, the battens were cut in the shape of radial segments of circular disc. The circumferential planks of width 300mm have been provided to accommodate the light fittings. The groove between radial and circumferential cedar wood battens was covered with cedar wood beading. The exposed surfaces of cedar wood planks have been wax polished. The unexposed surfaces were painted with wood primer before fixing of cedar wood planks.

6.0 STAINLESS STEEL PLANKS FALSE CEILING

The corridors are having a number of electrical services and for regular maintenance of these services easily removable false ceiling arrangement was necessary. Stainless steel plank in combination with gypsum board was found as the most appropriate solution, also keeping in view the aesthetics of the building. The

stainless steel planks covered with protective layer of PVC (to avoid damage during construction) were procured from SAIL. The PVC layer was removed after completion of work. The stainless steel planks of size 305mm x 1450mm and 0.5mm thick (for 2.5m corridor) and 305mm x 800mm and 0.5mm thick (for 5m corridor) having dull satin surface finish have been used. The two ends of stainless steel planks have been crimped which allows the plank to be simply snap-fitted on to GI clip on the supporting frame, by applying a gentle upward pressure. This also allows for demounting of individual plank by pulling out whenever required.



Stainless Steel Planks False Ceiling - Corridor

The frame work for false ceiling as per agreement was not possible due to various services. Therefore, the supporting system had to be suspended from 40mm x 40mm x 6mm M.S. angle introduced across the corridor @ 1200mm centre to centre spacing resting on lintel beams. The problem of support system in 5m corridor was similarly solved by supporting 40mm x 40mm x 6mm MS angle on lintel beam on one end and fixing up the other end by a suspender from ceiling.

The following difficulties have been experienced during execution of this work –

a) The thickness of stainless steel planks used is very less i.e. 0.5mm, due to which the planks are susceptible to denting and bending. This could have been avoided using thicker planks.

b) The false ceiling system also provided linear continuous grills on both the sides. To maintain the alignment, the grills were connected to each other. Since the collar of the grills overlapped the steel planks, it was observed that for removing just one plank (for maintenance purposes) one would have to first remove a very large number of grills. This would be not only cumbersome but it would also be difficult to obtain perfect alignment while re-fixing the grills. A number of alternatives such as provision of easily removable light fittings or powder coated aluminium sheets at regular interval in between grills (in order to reduce continuous fixed length of grills) were discussed and finally it was decided that after every 4th or 5th grill one grill without connectivity may be used for easy removal of grills/planks.

c) The cutting of accurate openings (circular shaped) for light fitting in stainless steel planks of 0.5mm thickness was difficult. Punching of holes by machine was not possible. Manual cutting of openings had to be resorted to. Jagged edges had to be properly filed in order to avoid hurting the hands of electrical workers while fixing and wiring electrical fittings.

d) The gypsum board strips of 50mm to 100mm width have been provided between wall and AC grills. The stability & straight line edge for these strips could be achieved with great difficulty. The use of hard material such as particle board, wood etc. would have given better results.

7.0 POWDER COATED PERFORATED ALUMINIUM PLANK FALSE CEILING



Aluminium Plank False Ceiling

Aluminium planks having epoxy polyester powder coating of 50 microns have been used. This false ceiling is identical to stainless steel plank false ceiling in all respects except for the material and therefore, same supporting system has been used as for stainless steel plank false ceiling. The size of perforated aluminium planks used is also same, however thickness is 0.7mm as compared to 0.5mm thick stainless steel planks. The openings of exact size/shape for sprinklers could not be made due to perforations and washer was placed in position to achieve regular shape.

8.0 SAND STONE JALI FALSE CEILING

Sand stone jalis were stipulated for supply to contractor by the department. Hence the same were procured from the pre-qualified firms.The sand stone jali false ceiling has been provided in the coffers to match with the sandstone cladding/sand stone jali wall lining/marble slat wall lining. The sand stone jalis mainly of sizes 525mm x 525mm & 525mm x 400mm and thickness 30mm with accoustical backing of wood wool panels are placed over the powder coated M.S. frames as per details given below.

a) Sand Stone for Jali

The large block of white sand stone (Dholpur) excavated from quarry was brought to gang saw and cut into large slabs of required thickness plus 3mm to allow for finishing margins. The Junior Engineer/Assistant Engineer inspected the work site and took sample for testing from each lot and it was numbered duly signed with date. After receiving the test report in conformity with specifications the sand stone slabs were accepted for making jalis. The large slabs were then cut into required sizes plus 50mm length and breadth to allow for finishing.

b) Making of Jali

Full size GI sheet templates for different patterns of jali were made. The marking was done with the help of templates on sand stone slabs and the jalis in shape were cut manually using hand cutting tools. The exposed surfaces of jalis were then fine chisel dressed and the edges were chamfered as per the drawings. The chamfered faces of jalis were finished with emery papers to make the surface smooth.

c) Fixing Arrangement

Powder coated mild steel frames having four squares/rectangles were fabricated with peripheral M.S. angle of size 25mm x 25mm x 3mm and central M.S. Tee of size 30mm x30mm x 3mm. The frames were welded to M.S. insert plates already left in the coffers at the time of casting of coffers. The coffers with light fittings were identified and M.S. frames were fabricated with shape so as to accommodate the light fittings.

d) Placing of Jalis

The insulation panels of 13mm thick wood wool of density 300kg/cum conforming to IS:3308 and IS:3348 have been used. The wood wool pieces were cut to the size of jalis and placed over the jalis. The jalis along with the wood wool

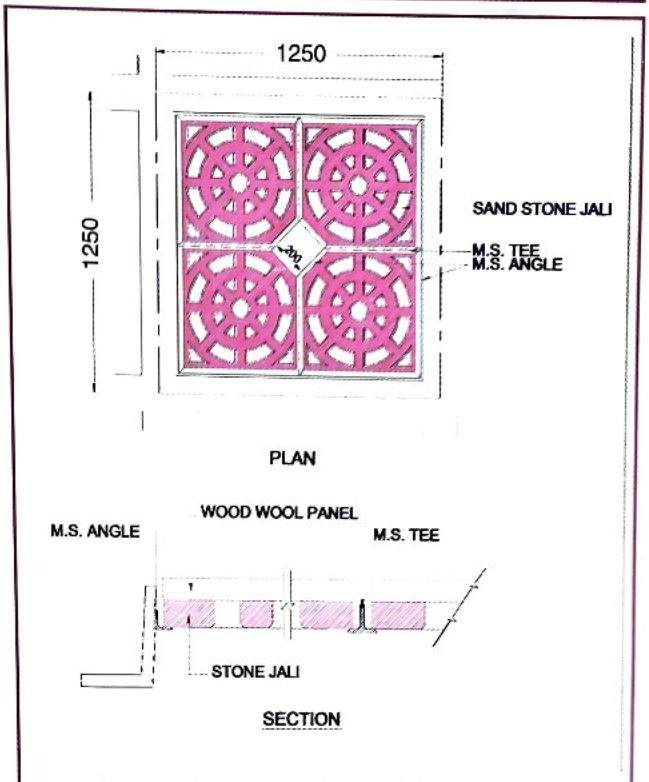


Fig 19.3 : Stone Jali False Ceiling – Coffer



Chief Engineer Explaining the Details of Stone Jali False Ceiling

insulation panels were then placed over powder coated M.S. frames by diagonally rotating and tilting the jalis.

e) Silicone Based Water Repellent

The silicone based water repellent DF105 of GE Silicone coating was applied to all the surfaces of stone jalis before placing in position to prevent deterioration of jalis due to ingress of moisture, gases etc. into the pores of jalis.

9.0 SOLID SAND STONE FALSE CEILING

The fixing and other specifications are same as for stone jali ceiling except that accoustical insulation has not been provided in case of solid sand stone ceiling. The solid sand stones have also been provided inside the building in the ceiling within coffers where the regular jali could not be placed being irregular/very small in shape and size.

10.0 MICRO FIBRE ACCOUSTICAL TILES CEILING

Micro fibre black coloured accoustical tiles of Anutone make comprising of size 610mm x 610mm and 15mm thick and of density 600kg/cum have been provided for false ceiling over stage of Auditorium. The use of tiles for false ceiling of stage was recommended by BECIL (acoustic consultants) to reduce noise level on the stage. Anutone Absolut tiles have been placed over M.S. frames of Angles 50mm x 50mm x 6mm welded back to back with gap of 14mm. The frame has been suspended from RCC ceiling by 40mm x6mm M.S. Flat hangers. The frame have been painted with black epoxy paint. The Anutone Absolut micro fibre accoustical tiles have the following advantages –

a) Zero Distrubance from Sound

Very high sound absorption is achieved with Noise Reduction Coefficient of upto 0.90 across all the frequencies; this means that from the low frequency output of subwoofers to mid and high frequency output from the screen/surround speakers, these tiles effortlessly absorb it all.

b) Zero Disturbance from Light

With powerful xenon lamps in modern projectors and brighter images from the state-of-the-art electronic projectors on white screens, more light bounces off the screen. All this additional light needs to be absorbed. The specially developed and processed matt black surface finish of these tiles ensures near-zero reflectivity ensuring that the audience views only the images on the screen and not the reflections dancing on the ceiling.

11.0 FALSE CEILING IN DOMES

The false ceiling was to be provided under the HP-FRC bubbles in the panels created by ribs of the bubble. A part of rib is exposed and covered with vinartex finish. While casting the bubble P.V.C. sleeves were left in the ribs for passing bolts to hold the frame for false ceiling. Each bubble has been divided into a number of panels and

each panel is part of a spherical surface. The false ceiling has been provided to match the curved surface of the bubbles.

11.1 Sal Wood Frame Work

The sal wood framing members have been specially cut to the required curvature and size matching with the bubble surfaces. On an average it was noticed that from a lot of sal wood nearly 15% was wasted due to curved members of false ceiling. There were a total of 272 bubbles with different shapes and sizes. The numbers of sal wood frame members were therefore huge. Different codes were assigned to the framing members of different curvatures and sizes for identification.

A working platform supported over Doka frames was made so that the work can be done more precisely and conveniently. Each and every piece of sal wood was checked by Junior Engineer/Assistant Engineer for conformity to specifications and after approval of framing members the frame work was fabricated for each panel separately. Bituminious paint was then applied on the sal wood frame surfaces which were to come in contact with FRC bubbles, other surfaces of frames were treated with wood primer. The frame was fixed to FRC ribs using 8mm dia stainless steel bolts. Wherever, minor sawing/ planing was required to be done, the same was applied with solution of chemical (zinc chloride & Potasium dichromate 4:1) treatment and then with primer. The sal wood frame made of 40mm x 50mm size in general was provided as per drawing.



Fixing Salwood Frame – Core Dome

11.2 Accoustic Wood Wool Insulation

The space between the sal wood frame members was filled with 40mm thick wood wool insulation board of density 300kg/cum. The wood wool insulation board was fixed to the sal wood frame using stainless steel nails and fevicol and covered with dyed markeen cloth.



Fixing Wood Wool Insulation – Core Dome

11.3 First Class Burma Teak Wood Battens

First class Burma teak wood battens of required size and curvature were brought at site of work after complete coding for identification. Each batten was inspected and batten conforming to specifications were signed by the Junior Engineer/Assistant Engineer to ensure that any unchecked/ unapproved batten is

not used. The approved battens were fixed to the sal wood frame with stainless steel headless nails in required pattern as per architectural drawings. Wood primer was applied on unexposed surfaces and wax polishing on exposed surfaces.



Burma Teak Wood Battens Ceiling – Core Dome

11.4 Shisham Wood/Cedar Wood Cross Combed Tiles

The shisham wood/cedar wood sleepers were cut into 12mm thick solid tiles as per architectural drawing (hexagonal/rectangular). The solid tiles were cross combed by making parallel grooves 2mm wide @ 4mm centre to centre in one direction on one face upto half thickness and in perpendicular direction of same size on other face for the remaining thickness in such a way that at crossing of the grooves 2mm x 2mm through and through holes were visible. During this cross combing process even a small crack or hole in the solid tile breaks the whole tile resulting in more wastages. Wood primer was applied on unexposed surfaces and wax polishing (for cedar tiles) & spray synthetic enamel paint (for shisham tiles) on exposed surfaces.



Shisham Wood Tiles Ceiling - Core Dome

11.5 Sample Approval

False ceiling in one full bubble and one half bubble of every type was made as sample and got approved from the Consultant Architect. In the case of 2 Core domes, after preparation of sample it was observed that false ceiling in bubbles with stainless steel flats was not architecturally good and was changed to Shisham/ Burma teak. Wooden templates were used for maintaining the uniform grooves width.

11.6 False Ceiling in Various Domes

a) *Auditorium Dome : Cedar Wood Cross Combed Tiles & Battens False Ceiling* : The false ceiling for Auditorium dome consists of ceiling on various inverted bubbles (each inverted bubble corresponding to one upright bubble on the roof) and ceiling on plane area in between bubbles. Cedar wood plain battens of 100mm width and 12mm thickness with 20mm clear gap have been fixed over 40mm x 50mm sal wood frame at spacing of 450mm centre to centre with the help of stainless steel nails. The sal wood frame in turn, has been fixed to steel trusses with stainless steel clamps.

As far as bubble portion is concerned, cross-combed cedar wood square tiles of approximately 200mm x 200mm size with clear gap of 20mm have been fixed over sal wood frame with stainless steel headless nails. Cedar wood beading of size 20mm x 4mm has been fixed in gap between cross combed tiles. Cedar wood semi circular beading of 15mm x 30mm size in curved shape has also been provided to cover the circumferential gap between bubble of cross combed tiles false ceiling and plane surface of batten tile ceiling. The border of square panels have been provided with beading of 12mm x 30mm size. The accoustic insulation and finishing as explained above has been done.

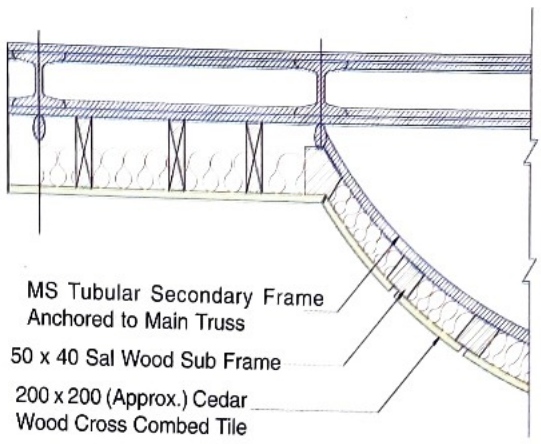
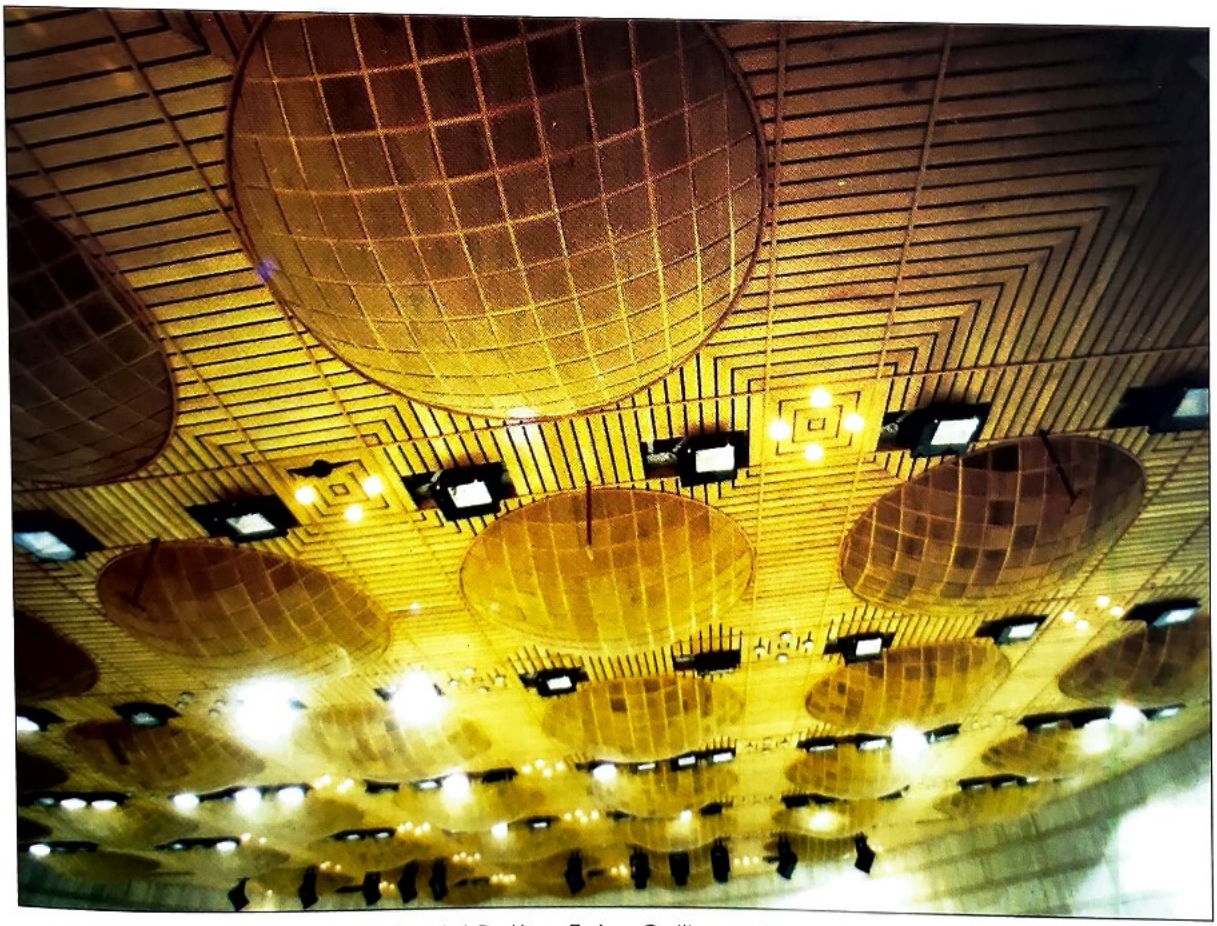


Fig 19.4 : False Ceiling – Auditorium Dome



Cross combed / Batten False Ceiling – Auditorium Dome



Cedar Wood Cross Combed Tiles Ceiling - VIP Dome

b) *VIP, BPST & AV Dome – Cedar Wood Cross Combed Tile False Ceiling* : The false ceiling consist of 12mm thick cedar wood cross-combed square tiles of approximately 200mm x 200mm size with 20mm gap in between the tiles, 20mm x 4mm cedar wood beading in gaps between tiles have been fixed over sal wood frame. The accoustic insulation and finishing as explained above has been done.

c) *Core Block – 2 Nos. and Services Block Dome – Shisham Wood Cross Combed Tile False Ceiling* : The false ceiling consist of 12mm thick shisham wood cross combed hexagonal tiles of approximately 200mm x 200mm size for core block and rectangular tiles of approximately 200mm x 200mm size for Service Block with 20mm clear gap between tiles, 20mm x 4mm shisham wood beading in gaps between tiles have been fixed on sal wood frame. The accoustical insulation as explained above has been done. All unexposed surfaces of wood were finished with wood primer and exposed surfaces were spray painted with white colour synthetic enamel paint in Core block & raw silk colour for Services block.

d) *Core Block (H&J Block) First Class Burma Teak Wood Battens False Ceiling* : The false ceiling consist of first class Burma teak wood curved battens 75mm wide and 20mm thick with 20mm gap in between the battens fixed to sal wood frame with stainless steel headless nails. The accoustic insulation and finishing has been done as explained above.



Sisham Wood Cross Combed Tiles False Ceiling - Banquet Hall



Burma Teak Wood Battens False Ceiling - MP's Reading



Burma Teak Wood Battens False Ceiling - Library Dome

e) *Library & Museum Domes – First Class Burma Teak Wood Battens False Ceiling* : The false ceiling consist of 100mm wide 20mm thick curved battens with 20mm gap between the battens fixed on sal wood frame with stainless steel headless nails. The accoustic insulation and finishing has been done as explained above.

12.0 VINARTEX FINISH

The exposed surfaces of webs and ribs in coffers, beams, column capitals etc. have been finished with Vinartex. Vinartex is a readymix and synthetic plaster consisting of crushed stone chips of 0,5mm to 2.5mm size in proper gradation bonded with synthetic resin, adhesives, chemicals & additives. Basic adhesive used in the manufacture of vinartex is aqueous vinyl acetate & acrylate co-polymer emulsion. Vinartex has been applied with trowel against the dry base and finished thickness has been kept from 2mm to 2.5mm. All excess material over the desired thickness is immediately scraped off and finished surface levelled smoothly by uniform and even pressure with a steel float. Vertical/horizontal grooves > 10mm in width have been provided for each panel of more than 20sqm. The vinartex after drying up does not require any further treatment. It has a very long life. It is a permanent finishing material and can be used on internal as well as external surfaces of building.

WALL LINING

1.0 TYPES OF WALL LINING

Different types of wall lining have been provided depending upon the importance of areas, and functional requirements. The wall lining have been designed keeping in view acoustic requirement and have been provided with acoustic backing. The following types of wall linings have been used in the building.

Sl. No.	Type of wall lining	Location	Architectural consideration	Total quantity
1.	First Class Burma Teak Wood	Library reading area, MPs reading area, Committee Rooms, big halls & office rooms for Senior Officers	Matching with Burma Teak wood false ceiling	1734 Sqm
2.	Cedar Board	Senior Officers Room, Sound & light control, Interpreter & Projector Room in Auditorium	Matching with Cedar Cross Combed ceiling for Senior Officers room, acoustic consideration	1123 Sqm
3.	18mm Thick Marble Slats	Auditorium, 5m wide corridors at GF & FF Committee Rooms, Canteen, Banquet hall & VIP (GF)	Matching with stone jali false ceiling in corridors and aesthetics consideration	2853 Sqm
4.	50mm Thick Slotted Marble Slats	Auditorium stage	Architectural conformity with 18mm thick marble slats wall lining in Auditorium hall	345 Sqm
5.	Sand Stone Jali	Lobby of BPST, AV & Service Block at GF Auditorium Foyer (GF & FF)	Auditorium Foyer & Service Block matching with stone jali ceiling in coffers.	1088 Sqm
6.	Granite Tiles	Toilets (GF & FF) Staircases	Aesthetics, ease of maintenance	4722 Sqm
7.	Marble Stone Tiles	Toilets (FB & SB)	Aesthetics, ease of maintenance	453 Sqm
8.	Ceramic Tiles	Kitchen, Pantries & Photo laboratory (J-Block)	Easy cleaning	1362 Sqm

2.0 FIRST CLASS BURMA TEAK WOOD WALL LINING

The Burma teak wood wall lining consisting of 19mm thick & 150mm wide first class Burma teak wood battens fixed vertically with 19mm thick & 150mm wide first class Burma teak wood horizontal bands have been provided in various areas. A uniform groove of 12mm width has been maintained between horizontal & vertical battens. The framing system for wall lining was made of chemically treated sal wood vertical members of size 40mm x 40mm at a spacing not exceeding 600mm center to center and 8 members of 40mm x 40mm size fixed horizontally with GI screws & plugs with the supporting wall.

Wood primer has been applied on sal wood frame before fixing. Accoustic insulation of 40mm thick mineral wool of density 48kg/cum wrapped in markeen cloth was placed between the sal wood members. The framing system alongwith mineral wool insulation packs was covered by stretching and nailing polyester wire net over the entire surface of frame work and insulation. The polyester wire net and markeen cloth was provided to avoid sucking of mineral wool fibres through return air, being air-

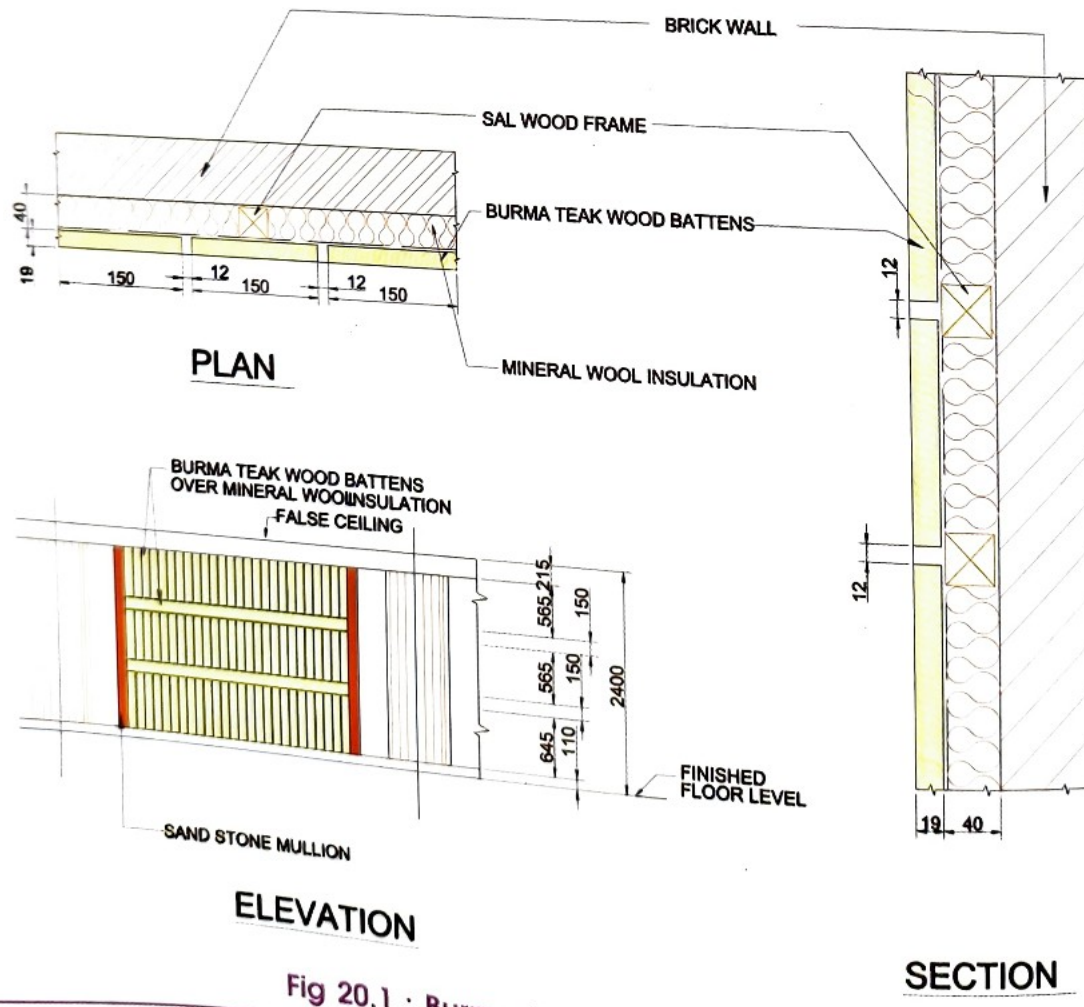


Fig 20.1 : Burma Teak Wood Wall Lining

conditioned area. Selected quality of first class Burma teak wood battens were then fixed to the sal wood frame with headless nails with gap of 12mm between the battens. First class Burma teak wood battens were inspected and signed by Junior Engineer/Assistant Engineer to avoid any chance of using wood below specifications. All exposed surfaces of Burma teak wood were finished with French sprit polish and then melamine coating was applied over polished surfaces.



Sal Wood Frame – Wall Lining

3.0 CEDAR BOARD WALL LINING

Cedar board wall lining consisting of 19mm thick block board with laminated cedar wood veneering on one face and commercial ply veneering on other face of Duro/National make conforming to IS: 1659 with 6mm thick cedar wood lipping all along perimeter of block board panels have been provided in various areas. The cedar board wall lining have been used with and without acoustical mineral wool insulation. The framing system and accoustical mineral wool insulation is similar to that for first class Burma teak wood batten wall lining. All unexposed surfaces have been finished with wood primer and exposed surfaces of cedar board have been finished with wax polishing.

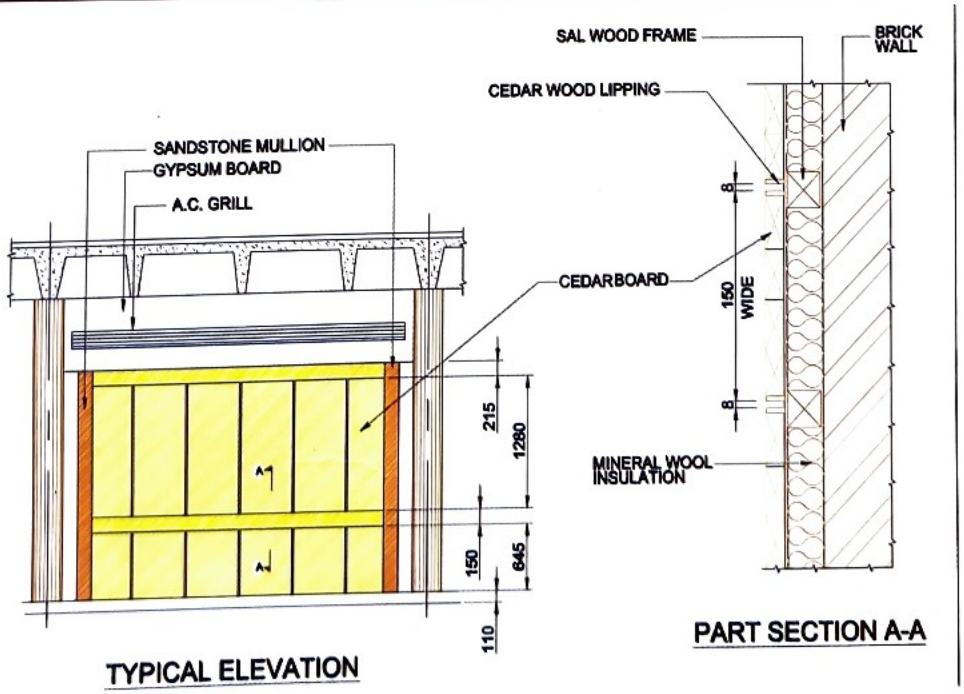


Fig 20.2 : Cedar Board Wall Lining

4.0 MARBLE SLATS WALL LINING -18MM THICK

Accoustical wall lining with marble slats of thickness 18mm and width 150mm/ 75mm fixed vertically with a gap of 12mm with horizontal sand stone bands have been used in various areas. The framing system and acoustical glass wool insulation is similar to that of first class Burma teak wood wall lining except that polyester wire net was fixed over entire frame work except the location of horizontal sand stone bands.

Polished Banswara marble slats 18mm thick of 150mm/75mm width and selected quality were screwed to the sal wood frames with gap of 12mm between the slats. After fixing the marble slats, sand stone bands of size 150mm x 50mm cut to suitable shape were fixed to backing wall with 150mm long & 8mm dia stainless steel dash fasteners at centre to centre spacing not exceeding 500mm in such a way that the sand stone bands firmly secure the sal wood frame and the marble slats to the backing wall. The gap between the sand stone band and backing wall was filled with cement mortar 1:4 (1 cement: 4 coarse sand). The stainless steel stud cap have been fixed on the head of stainless steel dash fastners from architectural consideration.

The following changes were made in wall lining system during execution due to technical reasons.

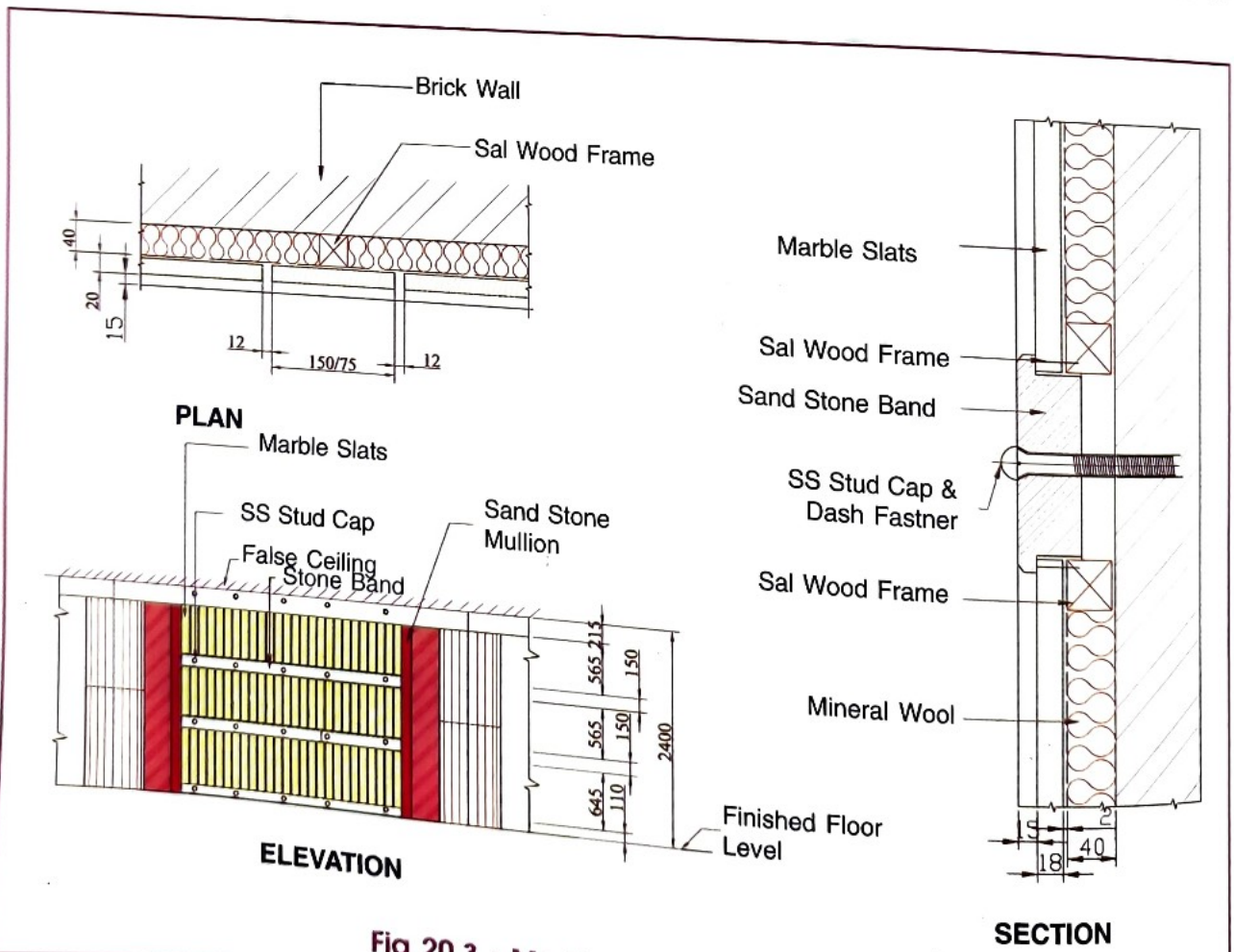


Fig 20.3 : Marble Slats Wall Lining



Shri G.M.C. Balyogi Hon'ble Speaker, Lok Sabha – Inspecting Marble Slats Wall Lining

a) Since 18mm thick Banswara marble slats are brittle & prone to breakage due to any impact/pressure on the slats, additional supports using aluminium Tee of size 25mm x 25mm x 3mm have been provided in the center of each panel of sal wood frame.

b) Marble slats of 150mm width were supposed to be provided for wall lining as per architectural drawing. Marble has a very reflective surface and is not preferred material for acoustically sensitive locations. The width of marble slats was therefore reduced to 75mm (for committee rooms & auditorium), thus increasing the number of 12mm wide grooves & in turn improving the acoustic effectiveness.

c) Marble slats wall lining have been provided on all the walls of Auditorium hall. To add to our woes, the Auditorium was circular in shape and it was almost impossible to achieve good acoustics with marble slats fixed to a circular wall. To get over this problem, the plain circular walls of the auditorium was changed to a serrated surface and the width of the slats were reduced to 75mm. The result is there for all to see (or hear !)- perfect acoustics in the auditorium.

5.0 MARBLE SLATS WALL LINING -50MM THICK

Banswara marble stone wall lining with 50mm thick slotted Banswara slats of special

shape have been provided on the walls of auditorium stage. There was an offset of 310mm between face of column and the surface of wall. It was decided by the Consultant Architect to provide the wall lining along the line of face of column protruding from wall. Since the height of wall is approximately 9.5m it was considered that filling of 310mm thick offset by making brick wall would be structurally unstable and time consuming. In order to support the wall lining, steel structure using M.S. channels was fabricated and fixed to the wall, floor and ceiling. The steel structure was painted with black epoxy paint and Aluminium fabric weighing not less than 300gm/sqm was fixed over steel frame work to hold the glass wool insulation in position. The chemically treated sal wood members of size 40mm x 50mm were fixed vertically to the steel structure at the spacing not exceeding 600mm center to center, sal wood framing members were also fixed horizontally at alternate spacing of 140mm and 267.5mm center to center. The sal wood frame after applying wood primer was fixed to steel structure by screws and U clamps, 50mm thick glass wool insulation of density 48kg/cum wrapped in markeen cloths were placed between sal wood framing members and secured by fixing aluminium fabric covering entire frame work and glass wool insulation surface.

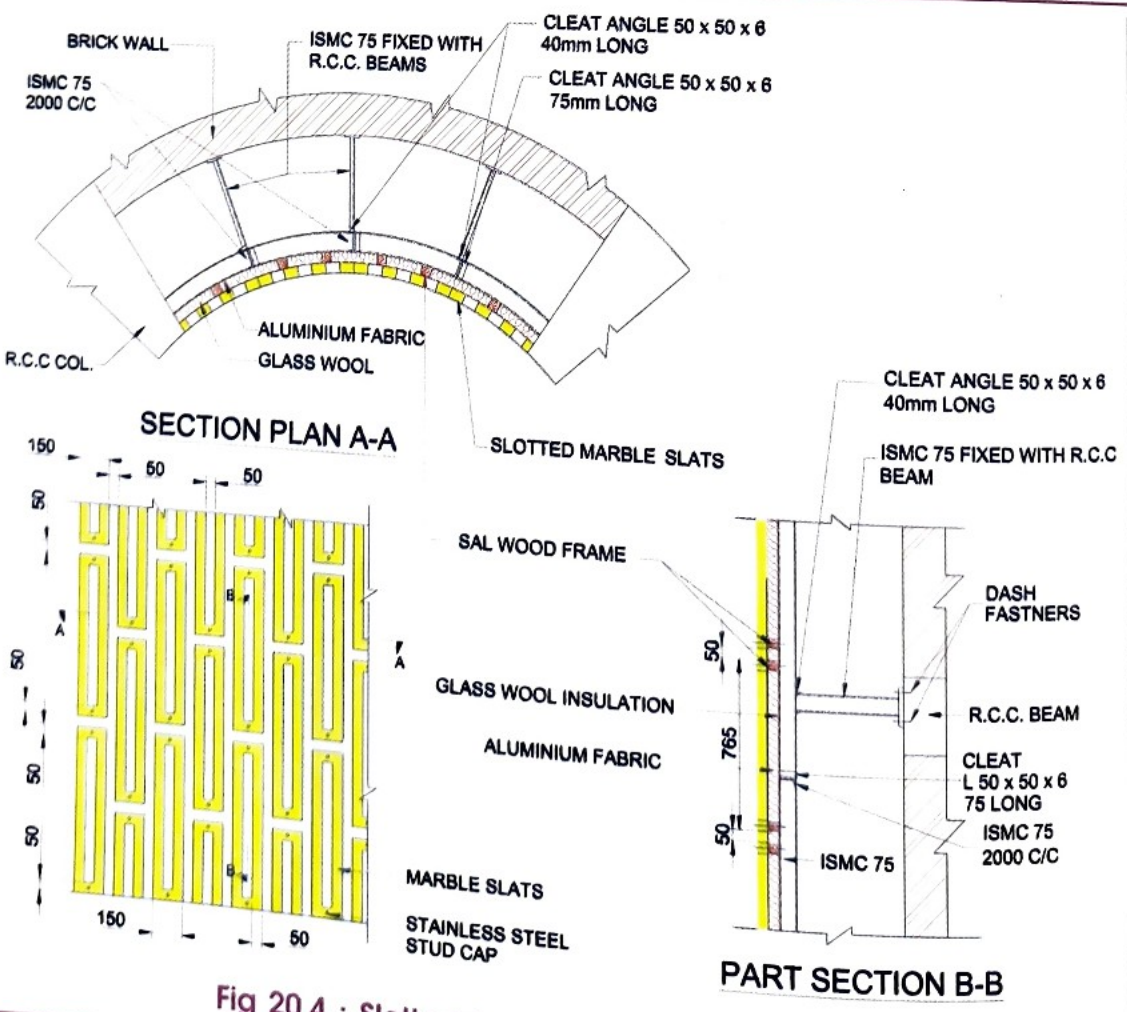


Fig 20.4 : Slotted Marble Slats Wall Lining

Banswara marble slats 150mm wide, 50mm thick and 765mm long were machine cut and central portion of 50mm x 665 mm size was removed using cutting machines/ hand cutting tools. Since 50mm thick marble slates were not readily available, the marble slats were made as per the special order at the work station near the marble quarry site. Holes at each end of the slates were then drilled to accommodate the anchor fasteners. The specially prepared marble slates were fixed to sal wood frame using 8mm dia & 150mm long stainless steel anchor fasteners. The head of anchor fastners were then covered with polished stainless steel stud caps.

The procurement & preparation of Banswara marble slats 50mm thick with slot was a tedious & time consuming job. The scope of work was also changed from time to time since there was difference of opinion between CPWD officers & Consultant for providing slotted marble slat wall lining on back wall of stage. CPWD officers were of the view that marble slat wall lining on back wall of Auditorium stage should not be provided since the same will be covered by the cyclorama screen. Precious time was lost due to this impasse. However, during a meeting with Hon'ble Speaker, it was finally decided that marble slats wall lining as well as cyclorama should be provided. To make up for lost time, marble slats wall lining was provided behind the cyclorama and first class Burma teak wood lining for the space on both sides of Auditorium stage in consultation with Architect.

6.0 GRANITE TILES WALL LINING

Granite tile wall lining using 8mm thick mirror polished machine cut light grey granite tiles of size 600mm x 300mm from Tamilnadu/Karnataka have been used in various areas. The granite tiles were provided continuously over large areas. Since the tiles were of granite stone, there had been a very minor variation in the thickness. Inspite of best efforts made during fixing of tiles, it was found that edges of consecutive tiles were not exactly in the same level at some locations, which was prominently visible due to reflection of light at mirror polished surfaces. Wherever such level difference in corners were observed, efforts were made to rectify by grinding and then polishing the edges. The effect was not entirely satisfactory though passable, therefore the payment was made with cost adjustment. There are variation in the shades of tiles used but the Architect was firmly of the view that such natural variations in shade should be allowed without making a deliberate attempt to achieve uniform shade. Hence no sorting out of tiles was done to achieve uniform shade.

7.0 SAND STONE JALI WALL LINING

Sand stone jali acoustic wall lining using 32mm thick white sand stone jalis and 150mm wide white sand stone band has been used in various areas. Sand stone jali have been made as prepared for sand stone jali false ceiling, except that edges at top & bottom were having a rebate of 20mm x 15mm size for receiving sand stone band. The frame work and acoustical insulation for sand stone jali wall lining is similar to that of marble slats wall lining except that aluminium fabric in place of polyester fabric have been stretched over the frame work & mineral wool. The sand stone jalis were screwed to the sal wood frame work in proper lines and levels using stainless steel

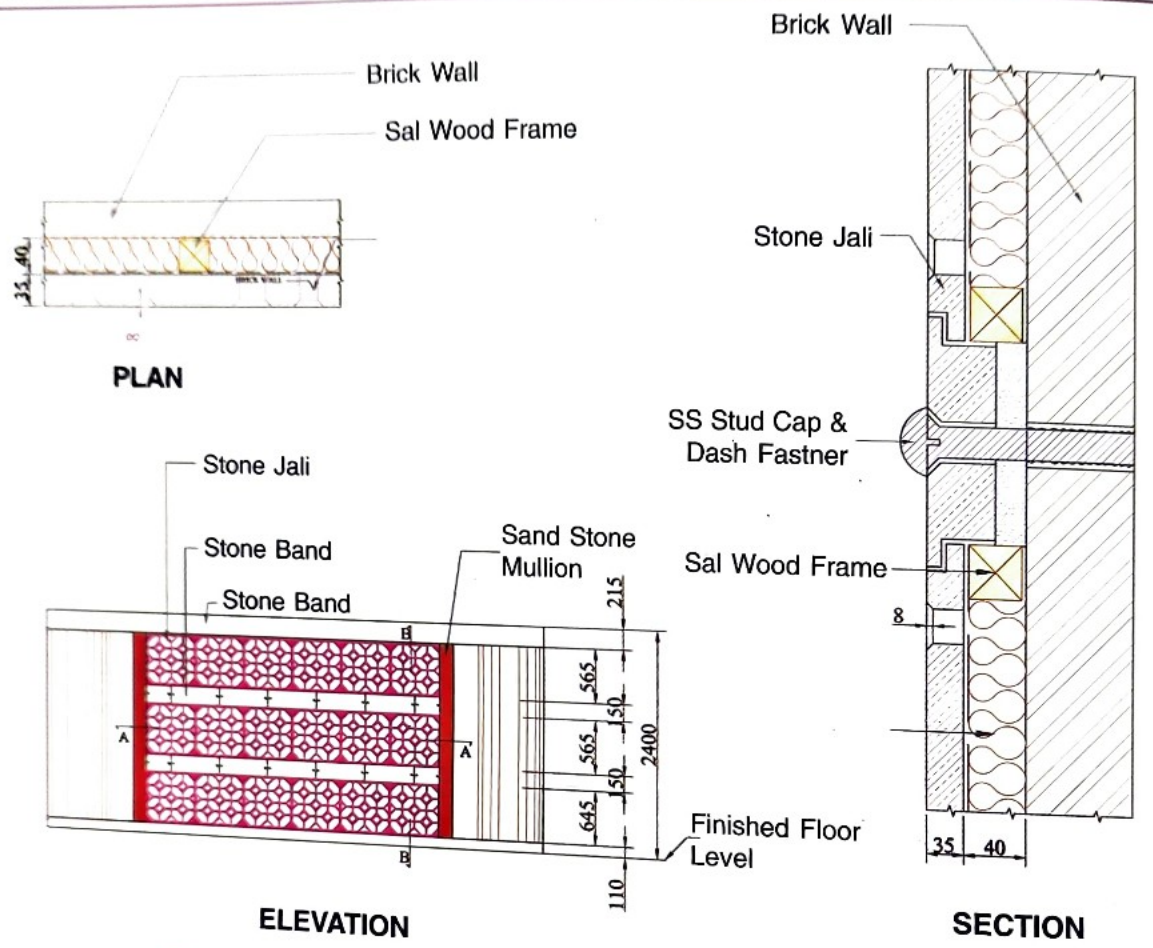


Fig 20.5 : Acoustical Wall Lining with Sandstone Jali

screws, the white sand stone bands 150mm wide & 50mm thick cut to required size and shape were fixed horizontally to the backing wall using 8mm dia and 150mm long stainless steel dash fasteners covering the screwed edges of sand stone jalis, in such a way that they fully secure the sal wood frame work and sand stone jalis to the supporting wall.

The groove of 8mm uniform width was made between the sand stone jalis and between jali & sand stone band. The stainless steel stud caps have been fixed on the heads of stainless steel dash fasteners. Silicone based water repellent DF 105 of GE Silicone has been applied on sand stone surfaces to avoid ingress of moisture.

8.0 MARBLE STONE TILE WALL LINING

Marble stone tile wall lining using 8mm thick 600mm x 300mm Banswara marble tiles have been used in the toilets of first & second basement.

9.0 CERAMIC TILE WALL LINING

Ceramic tile wall lining using 7.3mm thick ceramic tiles of Kajaria make have been provided in kitchen, pantries and photolab where frequent cleaning/washing of walls is required.

WATER PROOFING

1.0 GENERAL

The building consists of eleven blocks excluding the parking area with expansion joints in between. In addition the dome structure has numerous joints between precast bubbles; and on the roof extensive terrace garden has been provided. All these situations therefore needed water proofing treatment of an appropriate type which suited to the behaviour of the materials of construction.

2.0 MATERIALS USED

The following materials have been used for achieving effective water proofing of the building.

2.1 Water Proofing Compound

Water proofing compounds as below conforming to IS:2645 have been used.

a) *Chemseal* : This is a chemical soluble in water, having low viscosity and penetrates into the minutest of cracks & thus runs through the entire thickness of the structure. It forms an impermeable barrier which renders the structure water tight. The chemseal cement grout in addition fills the large cavities & also adds to the strength of structure.

b) *Ferroseal* : Ferroseal products are manufactured by Ferrosite Company, Calcutta. Following two products of Ferrosite company have been used in the work.

i. Ferroseal DDS Liquid : Ferroseal DDS liquid has the property of penetrating the pores of the concrete making the concrete surface impervious. It is a single –component, water- based product, cures rapidly in presence of water and seals the pores within one hour.

ii. Ferroseal Powder : Ferroseal powder is an integral cement based water proofing compound for making mortar and concrete denser & impermeable to capillary action of moisture and makes the surface completely waterproof.

2.2 Silicone Repellent DF-105 of GE

DF-105 is a clear non glossy penetrant offering excellent resistance to chloride ion intrusion while maintaining 100% moisture vapour permeability. This has been used as water repellent coating for stone work. It is used by adding a thinner like xylene & applied with spray gun/brush application.

2.3 Silicone Sealant Silpruf of GE Silicone

Silpruf is a highly flexible one-part, natural cure, silicone sealant. It is unaffected by weathering conditions such as sunlight, ultraviolet radiation, rain and temperature extremes. It can be applied without primer. It is white or black in colour with ultimate elongation of 650% and tensile strength 1.7N/sqmm.

2.4 Polysulphide

Polysulphide sealant has been used for filling in expansion joints which has following properties.

Specific Gravity	:	1.6 ± 0.05
Application Temperature	:	5°C to 50°C
Elongation at Rupture	:	350-400%
Tensile Strength	:	60 ± 20 Psi
Setting Time	:	18 hours at 35° C and 24 hours at 25°C

2.5 Polycoat Products

The following products manufactured by Polycoat Products, a division of American Polymers Corporation and supplied in India through their joint venture M/S APC Polycoat India Pvt. Ltd. have been used. Polycoat products can be applied directly with airless sprayer, brush, trowel or phenolic core roller on a surface which is clean, dry and free from foreign matters.

a) *Poly Prime 21* : Poly prime 21 primer consists of two components side-A & side-B and is prepared by mixing two parts of side-A with one part of side-B. The poly prime is applied @ 0.14 ltrs/sqm of area and is allowed to cure to become almost tack free.

b) *Poly Prime 172* : Poly Prime 172 is a single component, liquid applied aromatic urethane polyurea primer. This primer provides excellent intercoat adhesion and is applied @ 0.135 ltrs/sqm of area. Higher temperature and high humidity significantly accelerate the cure time. It is not ultra-violet-radiation-stable.

c) *Aquaseal 5000* : Aquaseal 5000 is a single-component, liquid-applied, bitumen-modified, coal tar-free, urethane polyurea waterproofing membrane, black in colour. The coating is allowed to be cured at 21°C and 50% relative humidity for a minimum period of 16 hours and maximum period of 48 hours before applying subsequent coats. This is very sensitive to heat & moisture. This is not ultra-violet-radiation-stable. Higher temperature & high humidity accelerates curing time. Aquaseal 5000 has ultimate elongation of 700% and tensile strength of 4.8N/sqmm.

d) *Polycrete R* : Polycrete R is an economical, water based, single component, Ultra-Violet- Stable, acrylic co-polymer, liquid applied, cementatious surface protection coating. It has a unique property to tolerate the variation of temperature and its mortar does not require wet curing. The polycrete R is mixed with cement for use in the ratio of 1:2 (1 Polycrete R : 2 Cement).

e) *Polyeuro –1050 (I)* : Polyeuro-1050(I) is polyurea polyurethane copolymer protective coating. It is tough and flexible material. It is chemical, abrasion and impact resistant. It is not recommended for prolonged exposure to concentrated acids. The maximum elongation as per ASTM D-412 is 40%. This is available in two parts

side A and side B and is prepared by mixing one part of side A with two parts of side B.

f) *Polycoat – Aquaseal Resin :* This is a single-component, moisture-cured, aromatic urethane polyurea resin and when mixed with dehydrated coal tar and accelerater will form an elastomeric water proofing membrane. Polycoat – Aquaseal resin mixture is prepared by mixing one part of Polycoat-Aquaseal resin with two/four parts of Pre-accelerated coal tar. Polycoat-Aquaseal resin mixture with coal tar is applied @ 0.71 ltrs/sqm of surface area to achieve membrane thickness of 685 microns and allowed to cure for a minimum period of 16 hours and maximum period of 48 hours before applying the second coat. Second coat is also applied @ 0.71 ltrs/ sqm of the surface area to achieve membrane thickness of 685 microns and allowed to cure for a minimum period of 16 hours. Polycoat-Aquaseal resin has ultimate elongation of 850% and tensile strength of 18N/sqmm.

g) *Poly-I Guard 246 :* This is single component, cold-liquid-applied, moisture-cured, aromatic urethane polyurea water proofing coating with a catalyst added if required. Poly-I-Guard 246 is applied @ 0.51 ltrs/sqm of the surface area. The elastomeric membrane of 355 ± 51micron is achieved in one coat. Poly-I-Guard 246 is allowed to cure for a minimum period of 16 hours. The second coat is applied @ 0.41 ltrs/sqm of the surface to achieve a thickness of 279 ± 51microns and allowed to cure for a minimum period of 16 hours. Poly-I-Guard 246 has ultimate elongation of 550% and tensile strength of 25N/sqmm. Poly-I Guard 246 is an ultra-violet-stable, fire-rated and traffic-bearing coating. It is suitable for pedestrian as well as vehicular traffic.

h) *Polytuff :* Polytuff is a single component, liquid applied, water catalyzed polyurethane base and top membrane. Polytuff has ultimate elongation of 879 ± 50% and tensile strength of 11N/sqmm. Polytuff can be mixed with approved/ selected rubber granules or fine sand upto equal parts by weight for thickening to apply on slopes or filling cracks and joints.

3.0 WATER PROOFING – TERRACE, TOILETS & SUNKEN AREAS

The concrete structures may develop fine cracks once the initial setting is over. The cracks may be of very minor nature at first but if timely remedial measures are not taken, these cracks starts increasing due to atmospheric conditions. As a result of this serious leakage problems arise. The concrete once affected by seepage starts disintegrating. In this building, the water proofing is all the more important keeping in mind that a considerable part of terrace has provision for terrace garden. Integral cement based water proofing treatment is ideally suited for concrete terraces. The water proofing compound penetrates in cracks and fill all the minor fine cracks which exist in the concrete. It forms an impermeable barrier which renders the structure water-tight. Brick coba treatment with water proofing compound conforming to IS: 2645 has been done on all the roofs, terrace gardens, planters and sunken areas in toilets as per

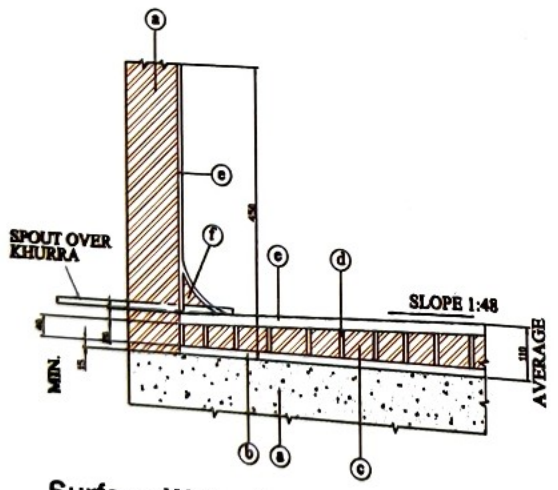
details given below:

a) For terrace including garden and planters area – water proofing with brick coba treatment of average thickness 110mm have been done with brick bats of 40mm size.

b) For sunken areas like toilets water proofing with brick coba treatment of average thickness 50mm have been provided with brick bats of 15-20mm size.

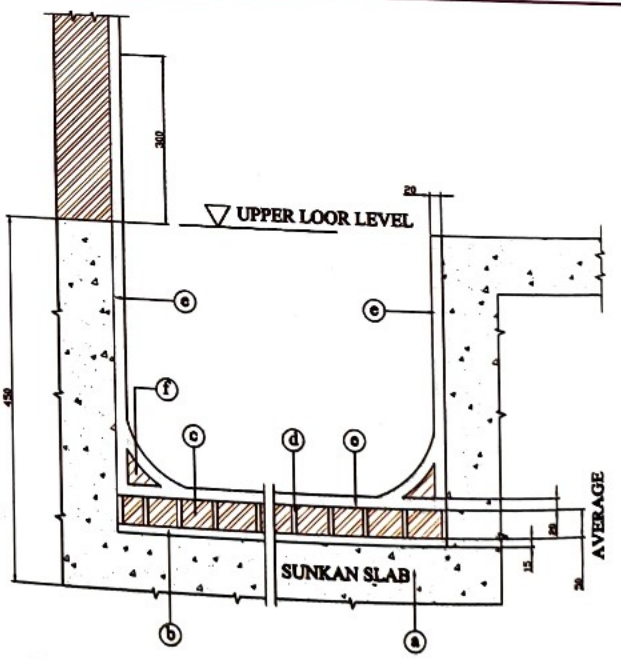
The provision in agreement for brick coba treatment was kept based on discussion with various water proofing agencies dealing in the field, since there was no provision in CPWD Specifications 1977 Vol.I & DSR 93. (Now the provisions have been included in CPWD Specifications 1996 and Delhi Schedule of Rates.)

The drainage pipes were fixed and surface cleaned before water proofing treatment. At the junction of horizontal and vertical surfaces gola with brick bats mixed with cement mortar 1:4 (1 cement: 4 coarse sand) admixed with water proofing compound was made. The vertical wall upto 450mm height above the top of the finished brick coba (for terrace garden & planter area) and 750 mm above the top of sunken slab (for toilets) was treated with 20mm cement plaster admixed with water proofing compound. A floating coat of neat cement admixed with water proofing



Surface Water Proofing Treatment

a) Roof Slab and Side Walls
b) 15mm Thick Cement Mortar(1:4) with Water Proofing Compound (W.P.C.)
c) Brick Bats (Coba)



Sunken Floor Water Proofing Treatment

d) 15 mm to 25mm Joints Grouted with Mortar (1: 4) with W.P.C.
e) 20mm Thick Cement Mortar(1:4) with W.P.C.
f) Gola with Brick Bats and Cement Mortar (1:4) with W.P.C.

Fig 21.1 : Brick Coba Treatment

compound was applied before applying plaster layer. Though the tanking was done with water proofing treatment for entire depressed area in toilet, localized tanking for WC seats was also done as an extra precaution. The water proofing was done in slope and spout of G.I. Pipe of 50mm dia were left at top of water proofing layer before laying lean concrete for draining out of seepage water (if any) to the shafts. The seepage water dripping from these spouts into shaft will also help in giving advance warning for any leakage in pipes/fittings etc.

In order to ensure quality, M/S New Construction Water Proofing Co.,Mumbai and M/S Overseas Water Proofing Corporation, New Delhi were shortlisted as specialized agencies for execution of this work.

The following difficulties have been experienced in water proofing of terrace garden area;

a) The terrace for garden/planter area was filled with good earth soon after satisfactory testing of water proofing treatment. Afterwards a number of services civil & electrical have been laid for which terrace was punctured by various agencies. Due to the presence of filled-up earth, the superstructure contractor tended to miss out on treating some of these punctures. Therefore extra care had to be taken to ensure that all punctures were identified and treated. The filling of good earth, at terrace after completion of all services and testing of terrace for water proofing after plugging various holes would have given better results.

b) The water proofing treatment has been done on side wall of terrace garden/ planter area which has been cladded with sand stone lining. The earth filling for terrace garden was done upto bottom of sand stone cladding, the sand stone being porous, due to capillary action the water reached untreated surface of wall and in turn resulting in seepage through wall. Therefore, the bottom strip of stone cladding was removed for Auditorium terrace garden and level of earth was lowered for the other planter areas which solved the problem of seepage at these locations. The junctions and remaining exposed area were treated with water based ferro-seal compound.

4.0 WATER PROOFING TREATMENT FOR EXPANSION JOINTS

4.1 At Terrace Level

Treatment of the expansion joints at terrace level was the most critical as the Architect did not agree to cover the joints with usual Kerb-and-coping arrangement. CPWD Specifications 1977 Vol.1 provide detail sketch on page 401 for the treatment of such joints. But the locations of the expansion joints was very critical as the same were passing through planters, terrace gardens etc. at varying levels. Hence some special treatment was required for these expansion joints. The Consulting Architect had issued sketch for treatment of these joints. However it was considered necessary to modify the detailing in order to make it more effective.

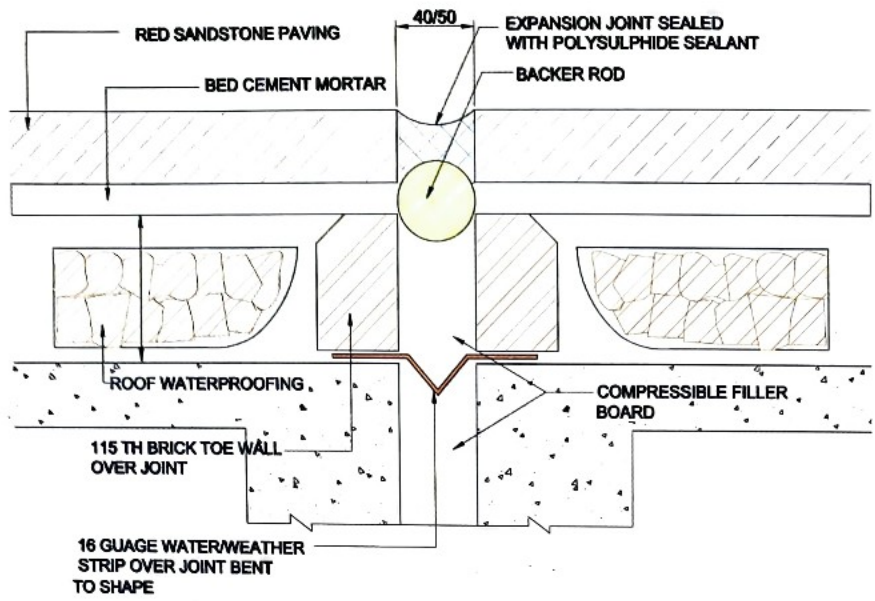


Fig 21.2 : Terrace Expansion Joint Treatment Proposed by Architect (Pathway)

Therefore, it was decided to treat these joints with elastomeric water proofing membrane. This treatment has been done by specialized authorized agency M/S JBM Engineers Pvt. Ltd. using water proofing material of Polycoat products as per details given below:

a) *First Operation :* The first operation consists of

   i. Cleaning and sizing of the expansion joint upto a depth of 60mm from the top. Fixing baker rod/thermocol sheet in the slot and tape over the same.

   ii. Applying a coat of primer 172/21 over the entire joint and on the top horizontal surface upto 50mm on either side of the joint width.

   iii. Caulking the entire length of the joint with Aquaseal 5000 paste (Aquaseal 5000 and rubber granules in 1:1 ratio) upto a depth of 20mm.

   iv. Topping the caulked surface with Aquaseal 5000.

b) *Second Operation :* The second operation consists of waterproofing the top horizontal surface upto 300mm width by

   i. Applying a coat of primer 172/21.

   ii. Applying base coat of Aquaseal 5000.

   iii. Applying first coat of poly-l guard with aggregate.

   iv. Applying top coat of poly-l guard.

c) *Third Operation :* The third operation consists of fixing copper plate with screws and sealing the screw holes and its surroundings by applying Aquaseal 5000.

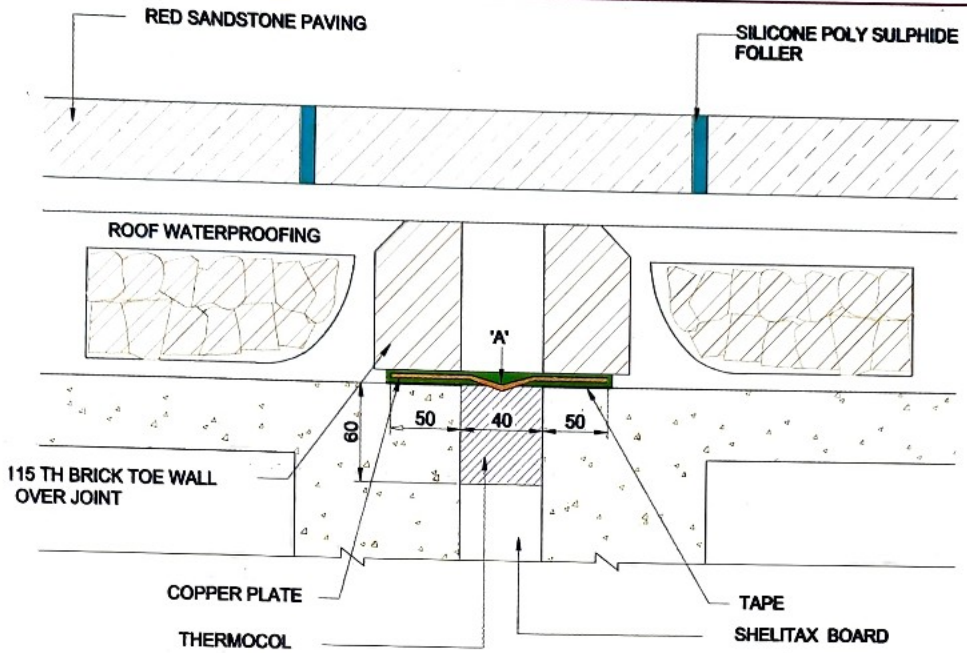


Fig 21.3 : Terrace Expansion Joint Treatment (Pathway)

d) *Fourth Operation :* The fourth operation consists of water proofing over the copper plate by

i. Applying a coat of poly primer 172/21.

ii. Embeddment of nylon fibre.

iii. Applying base coat of Aquaseal 5000.

iv. Applying intermediate coat of poly-l guard with aggregate.

v. Applying top finishing coat of poly-l guard.

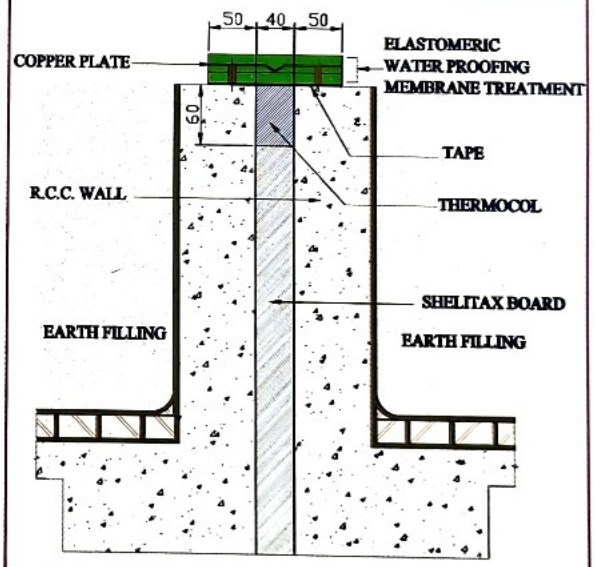


Fig 21.4 : Terrace Expansion Joint Treatment (Planter Area)

The following difficulties were faced after treatment of expansion joints.

a) The copper plate has been fixed with screws at the top of RCC slab which damages water proofing and also causes movement in granite/sand stone/ marble strip due to movement in expansion joint, the problem could have been avoided if copper plate would have been embedded in RCC during casting which was not feasible because of stirrups in beam.

b) In the terrace gardens & planters, the expansion joints have been provided at RCC slab level, which has been raised on both sides by brick work for finishing/treatment at top finished level. The sides have been filled with earth for terrace garden/ planters. This leads to seepage of water through brick work upto expansion joint, leading to further leakage in building.

c) The steps between Auditorium & focal area were having hollow space below and surrounded by terrace garden on two sides & expansion joint on one side. This hollow space got filled up with water with the passage of time leading to leakage through expansion joints. The problem was solved by removing the terrace garden on both sides of the hollow portion and providing proper drainage so that there is no accumulation of water.

d) The GI/CI pipes for various services have passed through expansion joints which have been treated with Polytuff of Polycoat Products.

e) The expansion joints have been modified by creating clear drainage channel on one/ both sides where pipes/ cables are crossing and by constructing RCC walls for planter area and duly treated with ferroseal water proofing compound. The expansion joint have been filled with silicon sealant and finished by placing stainless steel sheet and sand stone coping.

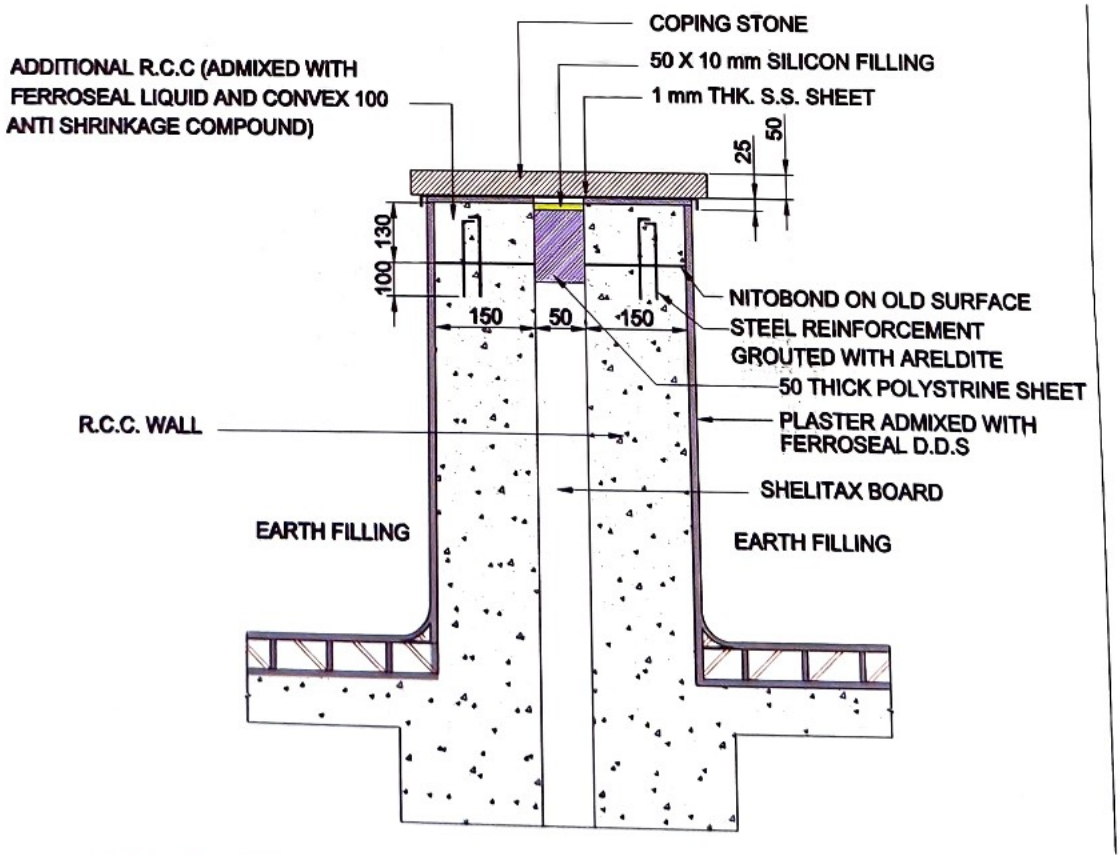


Fig 21.5 : Modified Terrace Expansion Joint Treatment (Planter Area)

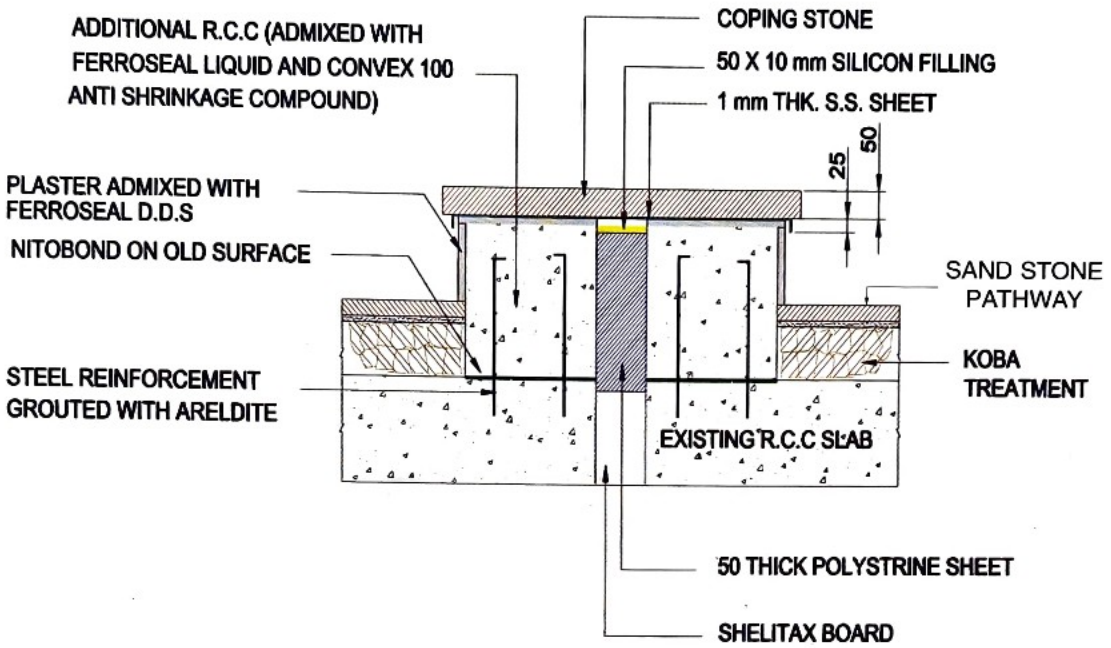


Fig 21.6 : Modified Terrace Expansion Joint Treatment (Path Way)

4.2 At Floor/Ceiling Level & Side Walls/Columns

There was provision to provide polysulphide as filler and expansion material in the expansion joints of the building. It was found during the execution of work that polysulphide sealant is not giving satisfactory result, hence the same was substituted by the silicon sealant. For applying silicon sealant the surface was cleaned properly and the joint was packed with backer rod to give solid base. Tape was pasted along the side of joints to protect the surface. The silicon sealant (SILPRUF of GE Silicon) was filled in the expansion joints. After the completion of treatment tapes were removed. The expansion joints provided in building are 40mm wide. The silicone sealant of following sizes have been filled in expansion joints depending upon location.

a) Expansion joints in column/bottom of the ceiling 40mm x 10mm size.

b) The expansion joints filling of 40mm width in the flooring have been staggered in two parts of 20mm width each and the silicone sealant filling of 20mm x 10mm have been provided in flooring.

c) The joints between column and floor near expansion joints have been filled with silicone sealant of 10mm x 6mm size.

5.0 KITCHEN AND PANTRIES

Elastomeric water proofing treatment was done in the drain of kitchen & pantries

to avoid any leakage/seepage using water proofing materials of Polycoat Products. First coat of polycrete R mixed with cement in the ratio of 1:2 (1 cement: 2 polycrete R) was applied on the surface. Polyester wire netting was fixed on the Ist coat applied. Aquaseal 5000 @ 0.5ltrs/sqm was applied on wire netting. After that Poly I-Guard 246 @ 0.44ltrs/sqm was applied as final coat of water proofing.

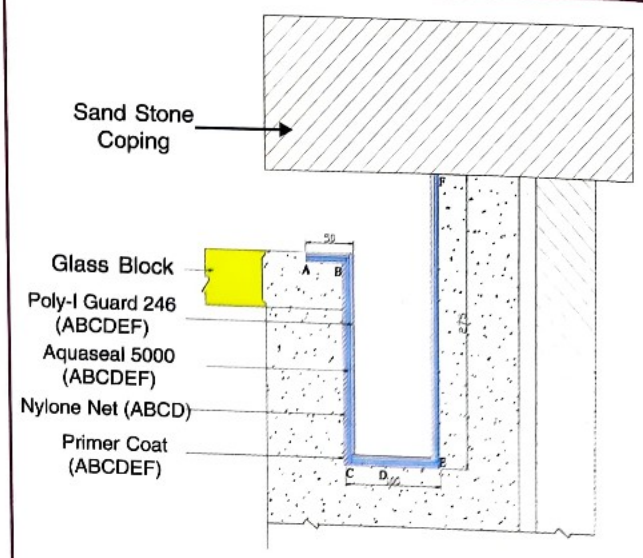


Fig. 21.7 : Peripheral Drain – Glass Blocks level

6.0 PERIPHERAL DRAIN – GLASS BLOCK LEVEL

The water proofing was required to seal the junction of Glass block panels and concrete drain. The water proofing treatment as required for peripheral drain adjacent to ground level Glass Block was done as per details given below using water proofing material of Polycoat Products.

a) The primer coat of poly-euro 1050 @ 0.22ltrs/sqm in full width of drain was applied as first coat.

b) Poly-euro 1050 @ 0.22ltrs/sqm was applied as second coat with polyester netting in 250mm width.

c) Aquaseal 5000 @ 0.25ltrs/sqm in full width of drain was applied as third coat.

d) Poly I-Guard 246 @ 0.20ltrs/sqm was used in two coats as final treatment.

7.0 WATER PROOFING UNDERGROUND AND OVERHEAD WATER TANKS

There are three underground tanks of capacities 1.0 lac ltrs, 1.5 lac ltrs and 4.5 lac ltrs located in basement of service block to meet requirement of water for Fire, Drinking and Air Conditioning respectively. The underground tanks are made of R.C.C. and are 7.5m deep. In addition to the underground tanks, 10 nos of RCC water tanks have also been provided on the terrace for distribution of water to various toilet blocks, kitchen, pantries etc.

The water proofing system capable of withstanding such high hydrostatic pressure and strong enough not to be damaged during normal cleaning operation was required. Further the water proofing system should be such that it fills the pores of the concrete to make concrete impervious and give good surface finish. The detailed study was carried out to find out the suitability of water proofing system for water tanks and quotations were called with provision of three alternative materials i.e. Polytuff SF, Polydee and Ferroseal and the work was awarded to the lowest offeror. Water proofing

with ferroseal was adopted as per procedure described below.

a) The surfaces of the tanks were cleaned/scrapped with wire brush to remove any dirt, grease, loose particle etc from the surface. The brushed surfaces were then thoroughly washed with water. All cracks, junction of floor and walls and sharp corners were repaired with ferroseal powder mixed with cement in the ratio of 1:5 (1 ferroseal powder: 5 cement).

b) After cleaning and repairing the surfaces, two coats of ferroseal DDS liquid mixed with cement in the ratio of 2:1 (2 ferroseal DDS liquid: 1 cement) @ 1.5 kg/sqm of surface area were applied.

c) After application of two coats of cement slurry mixed with ferroseal DDS liquid, 12mm thick cement plaster 1:3 (1 cement: 3 coarse sand) admixed with 1kg of ferroseal powder per bag of cement was applied and allowed to cure.

d) After 24 hours curing the tanks were filled with water to check for any leakages etc. Some dampness was observed at few places in one underground tank after filling the tanks completely. The damp spots although very few in numbers were marked, the tank was emptied and the corresponding location inside was again waterproofed by removing the cement plaster and other loose materials. The tank was again filled with water and no dampness was observed.

8.0 WATER PROOFING OF WATER TANK FOR COOLING TOWER

RCC water tank having capacity of 1.0 lac litres of water was constructed for feeding cooling towers. The tank was constructed in three parts of 20m each with expansion joints 40mm wide between each compartment to allow for expansion and contraction due to temperature changes.

Conventional water proofing system (as compared to that for underground & overhead water tanks) consisting of nozzle grouting of construction joints, corners and RCC wall, guniting with water proof cement plaster was adopted for water tanks of cooling towers because the tanks were almost at ground levels and only 1.5m deep. Two alternate specifications as below were provided in the agreement.

a) Waterproofing system proposed by M/S Structural Waterproofing Company Pvt. Ltd. using acrylic latex integral waterproofing compound and cico non shrink polymeric waterproof grout;

b) Waterproofing system proposed by M/S Overseas Waterproofing Corporation using chemseal Acrylic waterproofing compound & chemical cement grout.

The specification proposed by M/S Overseas Waterproofing Corporation was used as per details given below.

8.1 Vertical Surfaces

a) The water tanks were filled completely with water to find out the leakage/damp

spots in the tanks. After filling with water it was observed that there was dampness at construction joint locations. The damp locations were marked.

b) M.S. threaded nozzles of 18mm dia & suitable lengths were fixed at the damp locations and at spacing of 1.5m center to center in both directions for entire R.C.C. wall. The nozzles were also fixed along the corners @ 1.5m center to center. The nozzles were plugged at both the ends to prevent them from getting clogged by concrete.

c) Chemseal cement grout was injected under pressure through nozzles using pressure pumps. After completing the grouting the nozzles were sealed. The tanks were filled for 24 hours again and it was found that there were no damp patches or leakage spots.

d) The tanks were emptied and guniting with cement mortar 1:4 (1 cement: 4 coarse sand) of average thickness of 25mm admixed with chemseal water proofing compound @ 1% by weight of cement was done.

e) Chemseal cement slurry was applied on gunited surface @ 0.75kg/sqm.

f) One layer of chemseal cement plaster 1:4 (1 cement: 4 coarse sand) of 12mm thickness admixed with chemseal acrylic water proofing compound @ 1% by weight of cement was applied.

g) The chemseal slurry was applied over the chemseal cement plaster.

h) Another layer of chemseal cement plaster 1:4 (1 cement: 4 coarse sand) of 12mm thickness admixed with chemseal acrylic water proofing compound @ 1% by weight of cement was applied.

8.2 Horizontal Surfaces

In case of horizontal surfaces the guniting was not done. After completing the nozzle grouting, chemseal cement slurry was applied over the concrete surface @ 0.75kg/sqm. Three layers of chemseal cement plaster 1:4 (1 cement: 4 coarse sand) each 20mm thick mixed with water proofing compound @ 1% of cement with stone aggregate embedded at random was applied. The chemseal cement slurry was applied between the successive layers of chemseal cement plasters. The plaster was allowed to cure for a period of 7 days and the tanks were filled with water for 3 days to observe the dampness & leakage etc. After testing no dampness was observed.

9.0 SEALING OF ANNULAR SPACE OF SLEEVES, PIPES ETC.

Cast Iron flanged pipe sleeves 194 nos of varying lengths as per site condition were provided in diaphragm walls/retaining walls/protective walls at approximately one metre below the ground floor level for passing electrical cables, wet riser pipes, hot & chilled water pipes for airconditioning, GI pipes for water supply, carbon steel pipes for drainage etc. After passing of cables/pipes for various services the annular space left

around the cables/pipes was required to be sealed, to stop any leakage from outside to inside the building. The operation of sealing has been done in the following three steps using Polycoat products.

a) After cleaning of the sleeves of dirt/dust/ mortar etc., jute soaked in polytuff was inserted concentrically inside the sleeves to a distance of approximately 65mm. Thickness of jute was 25mm. This was provided to stop the flow of material inside the sleeves.

b) One coat of polyprime 172 was applied around the surface of sleeve pipes and cable/ GI pipes etc. @ 0.14 litres/sqm. The surface was allowed to cure for a period of 6 hours. It was applied for intercoat adhesion.

c) Polytuff mixed with rubber granules in the proportion of 1:2 (1 polytuff: 2 rubber granule) was filled inside the annular space of sleeve and GI pipes to a depth of 40mm and allowed to cure for 16 hours.

d) The entire cross-section of sleeve and cables/GI pipes was applied with two coats of polytuff over surface @ 0.2 litres/sqm per coat.

10.0 WATER PROOFING OF DOMES

The domes consists of precast High-Performance fibre reinforced concrete bubbles of spans upto 5m placed over carbon steel/stainless steel structures. The precast bubbles do not have any structural connection to each other and are simply placed over steel structures with a gap of 20mm on all sides. The bubbles are supported on steel structure in such a way that full expansion and contraction can take place in any direction. The steel structure and precast HP-FRC bubbles have different coefficients of thermal expansion and the gap between bubbles is expected to vary significantly due to daily and seasonal temperature variations. These 20mm joints between bubbles act as expansion joints due to variation in width and needs to be properly treated for expansion, contraction & water proofing.

10.1 Basic Requirements

The basic requirements of water proofing material to be used for domes are as below:

a) *Elasticity :* Since significant movement is expected in joints between bubbles, water proofing material should be highly elastomeric i.e. capable of taking expansion more than 100% of its original width.

b) *Adhesiveness :* Material should have good adhesion to concrete surface.

c) *Product Life :* Since the water proofing layer is protected with sand stone/granite tile cladding, the water proofing material should have long life so that the tile work on the dome is not required to be redone frequently due to failure of water proofing.

d) *Ease of Application :* Since the dome surface is curved (and flat at the joints), the water proofing material should be capable of being applied uniformly over such surfaces.

e) *Continuity :* Since the precast bubbles are simply placed over the steel structures with a gap of 20mm between the bubbles, the water proofing layer should be such that it forms a continuous layer throughout the dome covering all bubbles without any physical joint so that there is no chance of leakage through joints between the bubbles or through bubbles itself.

f) *Reliability :* The space below the domes are most important areas of the building such as VIP entrance. Auditorium, focal center, MP's reading, Banquet Hall etc. The length of the joints between bubbles is very large approximately 0.5m for every sqm of surface area therefore the water proofing material needs to be highly reliable on performance.

10.2 Provision in Agreement

After studying various proposals it was found that Elastomeric Membrane i.e. Hydrocide Liquid Membrane (HLM) 5000 proposed by Sunfield (India) Limited, Tremco Proof 60 proposed by Modi Tremco & Polycoat Products proposed by M/s JBM Engineers Pvt. Ltd. were suitable. The provision was made in the agreement for water proofing with these three alternatives to achieve water proofing membrane of 1.5mm finished thickness in two or more coats.

10.3 Water Proofing System used for Domes

The joint of 20mm width between the bubbles was first sealed with silicone sealant as per details given below:

a) The 20mm wide joints between the bubbles were cleaned with wire brush, removing loose material, dust etc. The backer rod of 25mm to 30mm dia was inserted in the joint leaving a gap of 10mm from top. The silicone primer on both faces of the groove was applied. The coloured primer has been used to avoid any chance of human error.

b) The silicone sealant SILPRUF of GE silicone was filled in the joints to make 20mm x 10mm size silicone joint. The top surface was made concave in shape. The sealant was allowed to cure for atleast 24 hours.

The water proofing system proposed by M/S JBM Engineers Ltd. of Polycoat Products has been applied as per details given below.

A. Water Proofing of Bubble Joint for 250mm Width (First Layer)

i. The cracks if any were repaired with Polycoat-Aquaseal resin.

ii. Polyethylene sheet of 150mm width was pasted along the bubble joint to act as separating layer between silicone sealant and water proofing membrane.

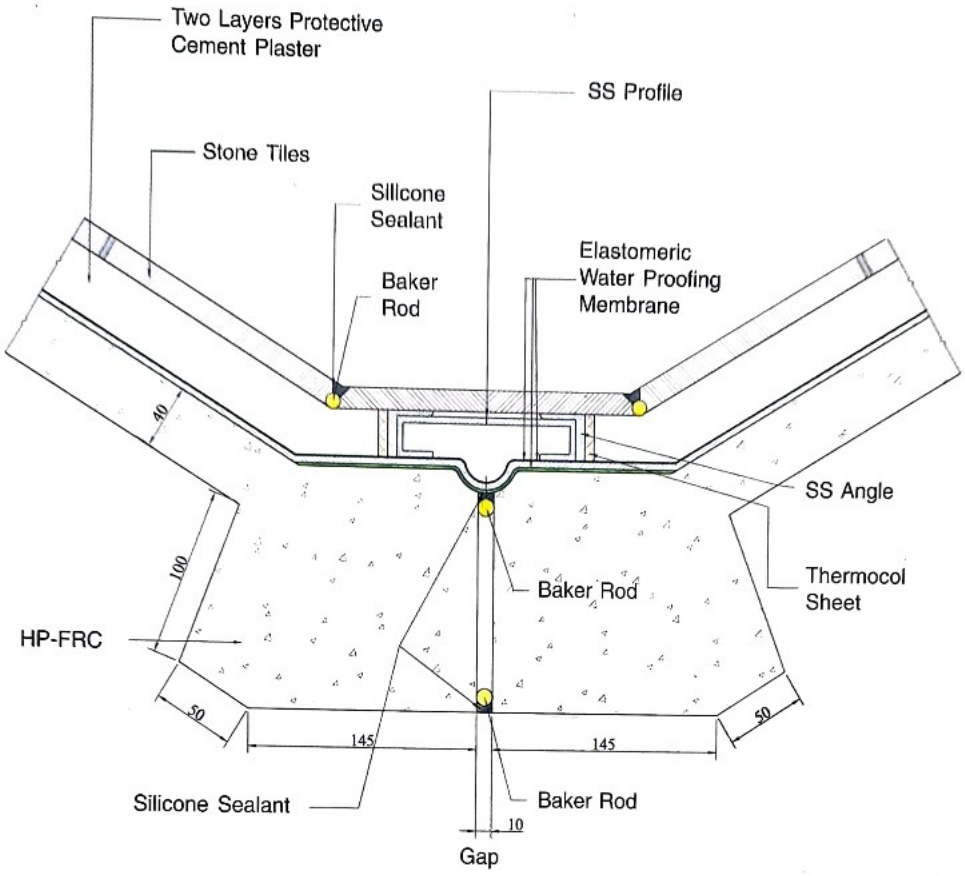


Fig 21.8 : Water Proofing and Drainage System for Domes

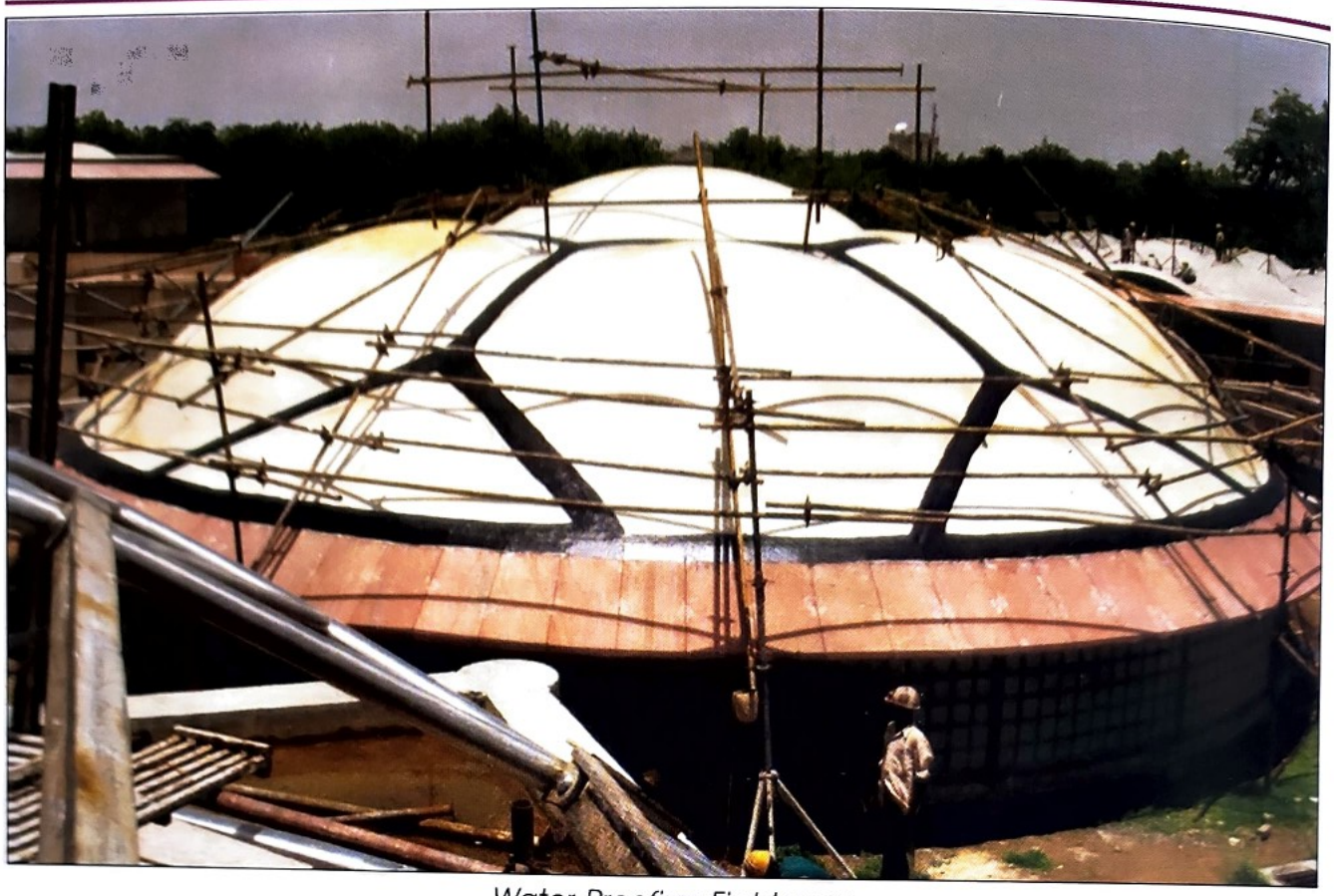
iii. The primer coat was applied along the joint for 250mm width with Poly Prime 21 and was allowed to cure till it becomes tack free.

iv. First coat of Polycoat-Aquaseal resin along the joint for 250mm width was applied after curing of primer coat and was allowed to cure for a period of 16 hours.

v. Second coat of Polycoat-Aquaseal resin along the joint for 250mm width was applied within 48 hours from application of first coat of Polycoat-Aquaseal resin and was allowed to cure for a period of 16 hours.

vi. First coat of Poly-I-Guard 246 along the joint for 250mm width was applied within 48 hours from application of second coat of Polycoat-Aquaseal resin and was allowed to cure for a period of 16 hours.

vii. Second coat of Poly-I-Guard 246 along the joint for 250mm width was applied within 48 hours from application of first coat of Poly-I-Guard 246 and was allowed to cure for a period of 16 hours.



Water Proofing First Layer



Water Proofing Second Layer

viii. The water proofing membrane of minimum 1.5mm total thickness was thus achieved by the above process of 5 coats.

B *Water Proofing of Entire Dome Surface including Bubble Joint (Second Layer)*

i. Polyethylene sheet of 150mm width was pasted along the bubble joint.

ii. Elastomeric water proofing membrane of minimum 1.5mm total thickness was applied on the entire surface of dome continuously as per para a & c to g above.

C *Water Proofing of Bubble Joint for 250mm Width (Third Layer)*

i. Polyethylene sheet of 150mm width was pasted along the bubble joint.

ii. Elastomeric water proofing membrane of minimum 1.5mm thickness along the joint for 250mm width was applied as per para (c) to (g) above.

After applying water proofing membrane as above, 15mm thick protective layer of cement lime mortar 1:1:2:2 (1 cement: 1 lime: 2 Surkhi: 2 coarse sand) admixed with poly propylene fibre was provided in two layers.

10.4 Surface Drainage for Domes

Though there was sufficient slope in dome surface, but a number of valley lines were formed at bubble joints. The provision was made for channels along the joints so as to allow for drainage of seepage water if any from surface cladding (Fig 21.8). The following provision was made.

a) The stainless steel C shaped profile with continuous stainless steel angles on both sides was placed over the joints.

b) Thermocole sheet of 10mm thickness was placed on either side along the stainless steel angle to allow for joint movement due to temperature variations.

c) The granite tile 10mm thick was placed over stainless steel C shaped profile and silicone sealant of 10mm x 6mm size was provided on either side of granite tile and in the cross joints of tiles.

10.5 Prototype Testing

The prototype water proofing system for the bubbles was tested using two precast HP-FRC bubbles placed side by side with 20mm gap. The joint was sealed with silpruf silicone sealant of GE Silicone and the 3-layer water proofing treatment was done as per the details mentioned above. About 600mm wide top surface along the joint was filled with water upto 150mm depth and the bottom of joint was observed for more than 24 hours, no leakage was observed. Then the 20mm joint was increased to 40mm by pushing wedges in the joint from the sides while keeping the top surface flooded with water. Again bottom of joint was observed and no leakage was found. Once the protype testing was over, the actual work was started.

11.0 WORK DONE

The quantities of work done for various types of water proofing are as per details given below.

Sl. No.	Method of Treatment	Location	Chemicals used	Quantity
1.	Brick Coba water proofing	Terrace, Planters & Toilets	Chemseal & ACC brand water proofing compound	14,070sqm
2.	Elastomeric with polyurethane membrane	Expansion joints in terrace	Aquaseal paste sealant. Poly prime Aquaseal & Poly I guard	155m
3.	Water proof filler	Expansion joints at intermediate floors	Silicone (Silpruf) Sealant	914m
4.	Elastomeric membrane	Drains in Kitchen, Pantries & peripheral drain	Polycrete- cement mix, Aquaseal & Poly-I guard.	600sqm
5.	Integral cement based water proofing	Underground & Overhead Tanks	Ferroseal DDS liquid & Ferroseal powder	947sqm
6.	Injection grouting, guniting & cement plaster with acrylic water proofing compound.	Water Tank for Cooling Tower	Chemseal	267sqm
7.	Granule mixed Polyurethane	Annular spaces of sleeves/ pipes.	Poly tuff mixed with Rubber granules.	26nos
8.	Elastomeric, urea Polyurethane membranes – in 3 layers.	For bubble joints and surface of bubbles.	Each layer consisting of Poly Prime, 2 coats of Aquaseal & 2 coats of Poly-I guard.	4685sqm

INTERIOR DECORATION, FURNITURE, FURNISHING INCLUDING KITCHEN EQUIPMENTS

1.0 GENERAL

Furniture & Furnishing has been designed according to the requirement of various functional areas of the building. The provision has also been made for mobile & fixed stacks for housing 3 million volumes of publications which include magazines, journals, books, debates and other periodicals.

2.0 CLOSED MOBILE STACKS

The Closed Mobile Stacks which were provided by M/s Godrej & Boyce Mfg. Company Ltd. have been placed on the second basement floors. The compactor modules of various configurations like MD1, MD2, MD3 & MD4 of width 1200mm, 2400mm, 3600mm and 4800mm respectively with depth of 600mm and height 2185mm have been provided. Each bank of mobile closed stacks consists of Double Faced Mobile units (DFM) with one Double Faced Fixed Unit (DFF) at the other end. The mobile units consists of vertical uprights and horizontal shelves including driving mechanism. In total 4050 nos. of Double Faced Units considering 1200mm length as single unit have been provided. Each compactor module consist of five adjustable shelves capable of being adjusted in steps of 40mm, fixed with suitable fixing clips and stopper excluding bottom-most shelf. The shelves have been made of one mm thick CRCA sheet with six folds, which have been designed and tested for deflection by applying uniform load of 100kg for 48 hours. The maximum deflection was not more than 6mm at the outer edge of the centre of shelf.

The mobile stacks are movable on stainless steel rails with the help of drive assembly, which consists of chain & sprocket mechanism with an appropriate gear ratio and wheel assembly which enables the user to move the loaded compactor box with a force of 0.8kg per 1000kg of load kept in the compactor box. Drive mechanism comprises of sprocket chain of 3/8" with 17 teeth suitably mounted on shaft & bearing with suitable chain tensioner. Drive mechanism have been covered and concealed from all sides from safety point of view. Each mobile compactor is provided with necessary wheels with a pair of bearings of NTN make for movement on the rails. The hand wheel for driving the module has been provided as spoke type having 3 number spokes of AISI 304 grade stainless steel of length 250 mm and diameter 12mm at the end. Each spoke has been provided with Bakelite knob.

The compactors can be mechanically moved from their position to create an aisle space of 800mm or more as and when required and therefore provides more storage space per unit area of the room, as compared to conventional open rack system. These have been provided with manually operated locking arrangement in the form of locking knob to prevent accidental movement of compactor while a person is already accessing a particular compactor through the aisle.

Under carriage structure i.e. base trolley consists of frame work of channels and angles & are of welded construction with HR sheets conforming to IS: 10748 Grade 3 of 3.15mm thickness. The rail assembly consists of one rail channel and one rail of 30 mm square cross section made of AISI 304 grade stainless steel with one rail end stopper and rail joining angle. The rail channels have holes at specified spacing which facilitates fixing to the floor through identified foundation bolts.

The front face of a bank of compactor bodies have been provided with double leaf door shutters having seven-lever locks. Suitable rectangular card-holder pieces as index plate have been provided at the side faces of the compactor. Each shelf has been provided with part-height divider and movable book support stopper. Rubber gaskets have been provided on the periphery of compactor bodies to make these dust free & also to take care of the incidental impacts of one compactor striking onto the other. Gaskets also serves as a safety measure against human fingers/parts being crushed between two compactors.

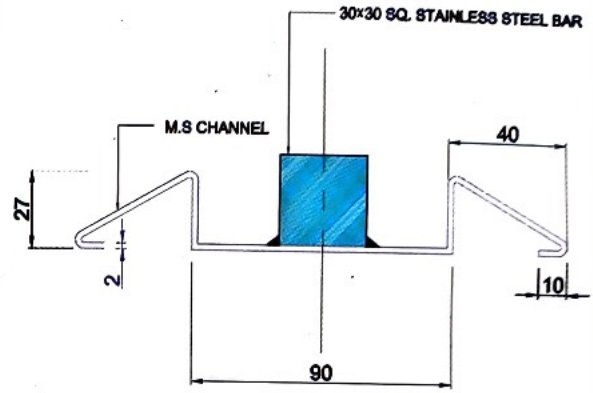


Fig 22.1 : Guide Rail



Mobile Closed Stacks

2.1 Pre-Treatment of Mobile Stacks

The mobile stacks components were pretreated with special anti-corrosion treatment. The pretreatment process consists of degreasing, pickling, Iron phosphating & passivation.

a) *Degreasing :* Degreasing is a process of alkaline cleaning for removal of oils and other semi solids from the metal surface by using caustic soda, soda ash, sodium phosphate and sodium meta silicate in the right concentrations and in controlled temperatures of 65-70°C. After degreasing, the components are rinsed in water for the removal of any alkaline impurities.

b) *Pickling :* Pickling is a process of acid cleaning for the removal of rust & scales by using sulphuric acid. After pickling, the components are rinsed in water for removal of any residual impurities.

c) *Phosphating :* This is a process used to protect steel from any type of corrosive action. Phosphating is the transformation of the metal surface into a new surface. The phosphate layer, being chemically bound to the metal surface, ensures proper adhesion of the paint film under all working conditions. In this process, the components are treated in a phosphoric acid tank with sodium nitrite as accelerator under controlled temperature of 45-50°C. The accelerator imparts a fine texture to the phosphate coating. After phosphating, the components are rinsed in water.

d) *Passivation :* In this process, components were rinsed in dilute chromic acid. The process imparts a light chromate coating which increases corrosion resistance.

2.2 Finishing

After the pretreatment, the components comprising of CRCA sheets were sprayed with epoxy polyester powder coating of beige colour. The components were then oven-baked at controlled temperature of 180°C to 200°C. The under structure components after pretreatment were spray painted with high quality stove enameled paint of chocolate colour. After painting, the components of understructure were baked in a oven at controlled temperature of 120°C to 135°C. The processes ensure a scratch- resistant uniform coating of paint on to the parent metal. The thickness of paint was not less than 50 micron. The process of pretreatment, powder coating or painting was done at M/s Godrej & Boyce Mfg. Co. Ltd.'s factory at Mumbai.

3.0 OPEN STACKS

The open stacks having double faced unit with two configurations i.e. MD1 & MD2 of sizes 1250mm & 2500mm respectively with depth of 550mm and height 2125mm have been provided. The open stack units with four, five & six shelves of following types have been provided as per requirement.

3.1 Powder Coated Open Steel Stacks

Powder coated CRCA sheet shelves are supported on tubular frame of Hot rolled seamless tube upright with threaded MS pin and upright connected with MS universal joint connectors at top.

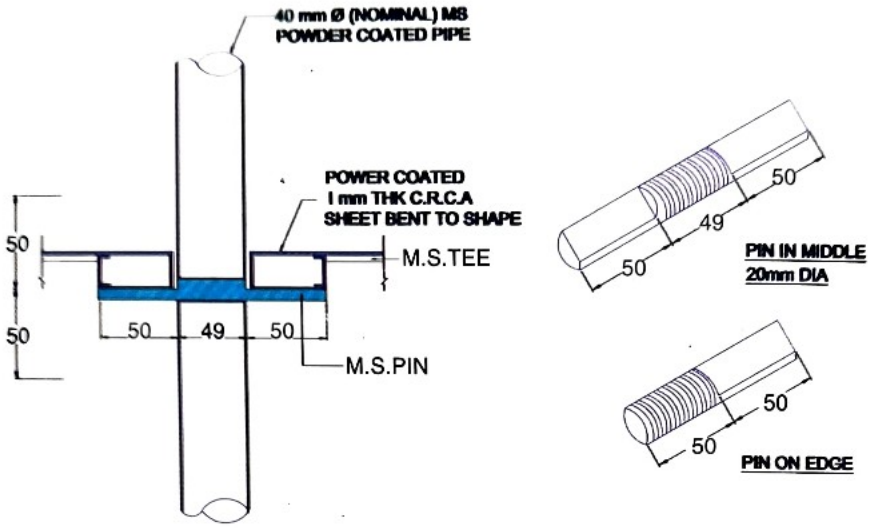


Fig 22.2 : Connection Detail of Shelf with Vertical Member

3.2 Stainless Steel Open Stacks with Wooden Shelves

Stainless steel stacks with shelves made of 25mm thick exterior grade commercial block board laminated with 3.5mm thick Burma teak veneered ply & Burma teak bull nosed beading on the front edges and Burma teak wood lipping on the side edges have been provided. Shelves have been finished with melamine coating over two or more coats of French spirit polish. The shelves are supported on the frame work of stainless steel tubular upright frame connected with stainless steel universal joint connectors.

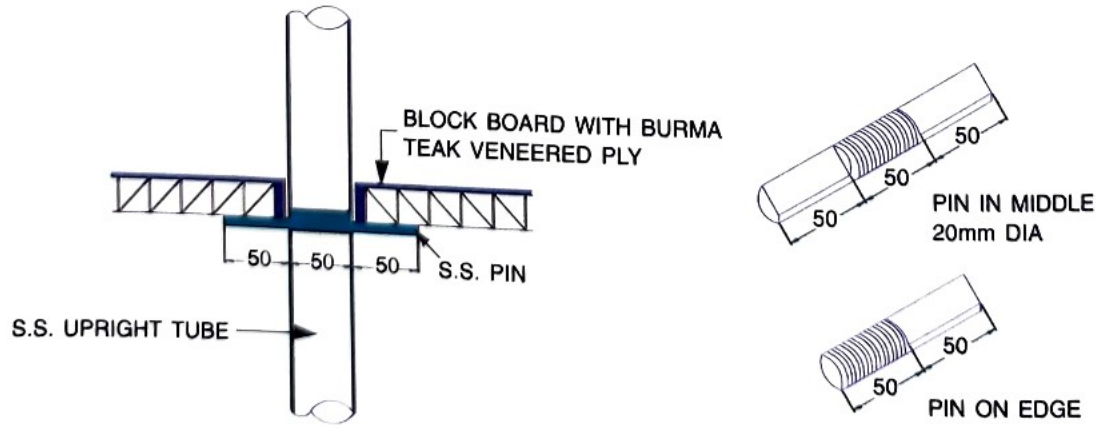


Fig 22.3 : Connection Detail



Powder Coated Steel Rack



Stainless Steel Open Stack with wooden shelves

4.0 GENERAL SPECIFICATIONS FOR WOODEN /STAINLESS STEEL FURNITURE

The specifications for varlous members of wooden/stainless steel furniture are discussed as below :

4.1 Stainless Steel Support System

The supporting structure for work stations, study carrels, conference room tables & other tables are frame work of horizontal & vertical tubes of stainless steel of 50mm dia & 3mm thick connected with universal joint connecter which consists of solid 50mm dia stainless steel ball and different combinations of 16mm dia stainless steel rod enlarged to accommodate 50mm dia stainless steel pipes with minimum thread length of 25mm. The vertical legs of the frame work have been provided with adjustable stainless steel shoe with neoprene pad at the base. The bracing assembly at a height of about 125mm from the floor level have also been provided which consists of 32mm dia stainless steel pipe connected by welding to the vertical legs of the frame work through bracing ring to impart rigidity to the frame work with stainless steel sleeves. The stainless steel of AISI-304 Grade having satin finish have been used.



Universal Joint Connector

4.2 Working/Table Top

The working /table top for workstations, study carrels, conference room tables & other tables have been made from 25mm thick exterior grade commercial block board conformng to IS: 1659: 1990 Grade I type 2 and finished with 3.5mm thick Burma teak veneered ply and 28.5mm x 30mm/40mm x 40mm Burma teak wood bull nosed beading.

4.3 Wooden Shelves

The wooden shelves of 25mm thick exterior grade commercial block board laminated with 3.5mm thick Burma teak ply veneering on top have been provided. The bull nosed beading of 28.5mm x 30mm for open shelves and 8mm thick Burma teak wood lipping for covered shelves have been provided on front edges.

4.4 Wooden Shutters

The wooden shutters of 19mm thick exterior grade commercial block board laminated with 3.5mm thick Burma teak ply veneering on front face and 8mm thick Burma teak wood lipping on edges have been provided.

4.5 Finishing

The exposed faces of wood work have been finished with melamine coating over

two or more coats of French spirit polish and unexposed faces have been painted with wood primer.

5.0 WOODEN STACKS/RACKS

The wooden stacks/racks have been provided which consist of low height stacks, storage units, newspaper & periodical/journal racks, periodical/journal racks under windows/niche, storage racks and cupboards in niches. The newspaper racks, periodicals/journals racks of required length and of 500mm depth and 1325mm and 925mm high have been provided in the main reading areas like library and MP Reading halls. The storage units have been provided for Lok Sabha Secretariat staff to store their files, records & books. The storage racks/cupboards in niche have been provided in the rooms with glazed & non-glazed shutters as per functional requirements.

5.1 Low Height Stack and Storage Units

The low height stacks in two different sizes i.e. 925mm & 1325mm high and 350mm depth and storage units in four different sizes i.e. SU1, SU2, SU3 & SU4 of width 650mm, 1250mm, 1875mm and 2500mm respectively of depth 450mm and height 1320mm have been provided. The sides, back, top and alround skirting 100mm high of 19mm thick exterior grade commercial block board have been provided. All exposed surfaces of block board have been laminated with 3.5mm thick Burma teak ply veneering. The edges have been finished as bull nosed beading or with 8mm thick Burma teak wood lipping depending upon location. The wooden shelves & shutters (for storage units) have been provided as per para 4.3 & 4.4 above.

5.2 Newspaper/Periodicals/Journal Racks

The back, sides, top and partitions have been made of 19mm thick exterior grade commercial block board laminated with 3.5mm thick Burma teak wood ply veneering on outer faces including 8mm thick Burma teak wood lipping at the exposed edges. Top hung flap shutter as per para 4.4 above have been provided with suitable pivoting arrangement made of 8mm dia solid stainless steel pin. Flap shutters have Burma teak wood handle running through the width of the shutter, which also serves as a stopper to hold current magazines or newspapers displayed on front of the shutter.

5.3 Niche Storage Racks/Cupboards

The niche storage racks/cupboards inside rooms have been made in the niches with a view to fully utilize the space available. The back of niche storage unit have been made of 12mm thick boiling water resistant commercial ply. The vertical partitions of 19mm thick exterior grade commercial block board have been provided. The exposed faces have been laminated with 3.5mm thick Burma teak veneered ply. The exposed edges have been finished with Burma teak bull nose beading or with 8mm thick Burma teak wood lipping depending upon location. The shelves and shutters have been provided as per para 4.3 & 4.4 above. The side hung shutters for cupboards have been provided with auto closing hinges, suitable magnetic ball catcher and stainless steel handles on each leaf of shutter with necessary locking arrangements.

6.0 STUDY CARRELS /WORKSTATIONS

Rectangular or L shaped workstations for working of the staff and study carrels for the reading area have been provided. Workstations/study carrels of varying sizes and shapes as per the requirement in different configurations/layouts have been provided.

6.1 Support System

The supporting structure have been provided as per para 4.1 above.

6.2 Working Table Top

The working top have been provided as per para 4.2 above. The side & back edges are protected with 28.5mm x 30mm or 28.5mm x 24mm Burma teak wood nosing/ lipping. A key board drawer of size 275mm x 550mm mounted on roller channel for housing computer key board have been provided.

6.3 Partition

The workstations/study carrels have been provided with low height partitions of 420mm/462mm high above the working top in order to provide adequate privacy. The partitions have been made of 19mm thick exterior grade commercial block board & Burma teak wood strips/battens with grooves and covered with Burma teak wood top rail. The low height partitions have cavity of 38mm to accommodate switch boxes for data communication, light & power and also to facilitate wiring. The workstation/study carrels have been provided with pelmets to house light fittings. The light fittings are wired through wire managers which are hollow circular stainless steel tubes of 100mm dia which allow the passage of wires from floors upto bottom of table and thus no loose/ hung wires are visible. A portion of the low height partitions have been upholstered with matching cloth over soft fibre board to serve as a pin-up board.

6.4 Other Components

Each workstation has been provided with drawer units of size 550mm x 470mm and are fixed with the leg of workstation which is supporting the stainless steel frame. The drawer units have been provided with file jackets and CPU trolleys with each workstation.

7.0 TABLES

The tables for various areas such as conference/lecture/committee rooms banquet hall, canteen, reading area and offices have been provided as per details given below:

7.1 Conference/Lecture/Committee Room Table

One committee room of seating capacity of 26 and three conference/lecture rooms of seating capacities 39, 43 and 190 (150 +40) have been provided for Bureau of Parliamentary Studies & Training. Two committee rooms of seating capacity 24 & 64 for Parliamentary Committee meetings in K Block and one committee room of seating capacity 24 for research & information wing have been provided. The tables of various



Workstation with Storage Unit

sizes and shapes viz. U-shaped, circular shape, Oval shape, skewed shape and rectangular shape have been provided according to layout plans.

a) *Support System* : The supporting structure for tables have been provided as per para 4.1 above except that tubular stainless steel frame work have been given the shape of the committee/conference room tables by bending the pipes at the desired curvature or shape.

b) *Table Top* : The table top have been provided as per para 4.2 above. The shape has been made according to architectural design forming a specified pattern. The table top have been provided at a height of approximately 740mm from the floor level.

c) *Microphone Void* : The table top has been provided with trapezodal microphone void to accommodate control panel, switch board, microphone wires etc. which are part of the conferencing system and also to facilitate wiring management. The microphone voids have been made of 15mm thick Burma teak wood.

d) *Modesty Panel* : The conference tables have been provided with modesty panels of 440mm high to the full length of table in the outer side below the table tops and connected to the vertical legs of stainless steel frame. The modesty panels have been provided at a height of 200mm above the floor. They have acoustical



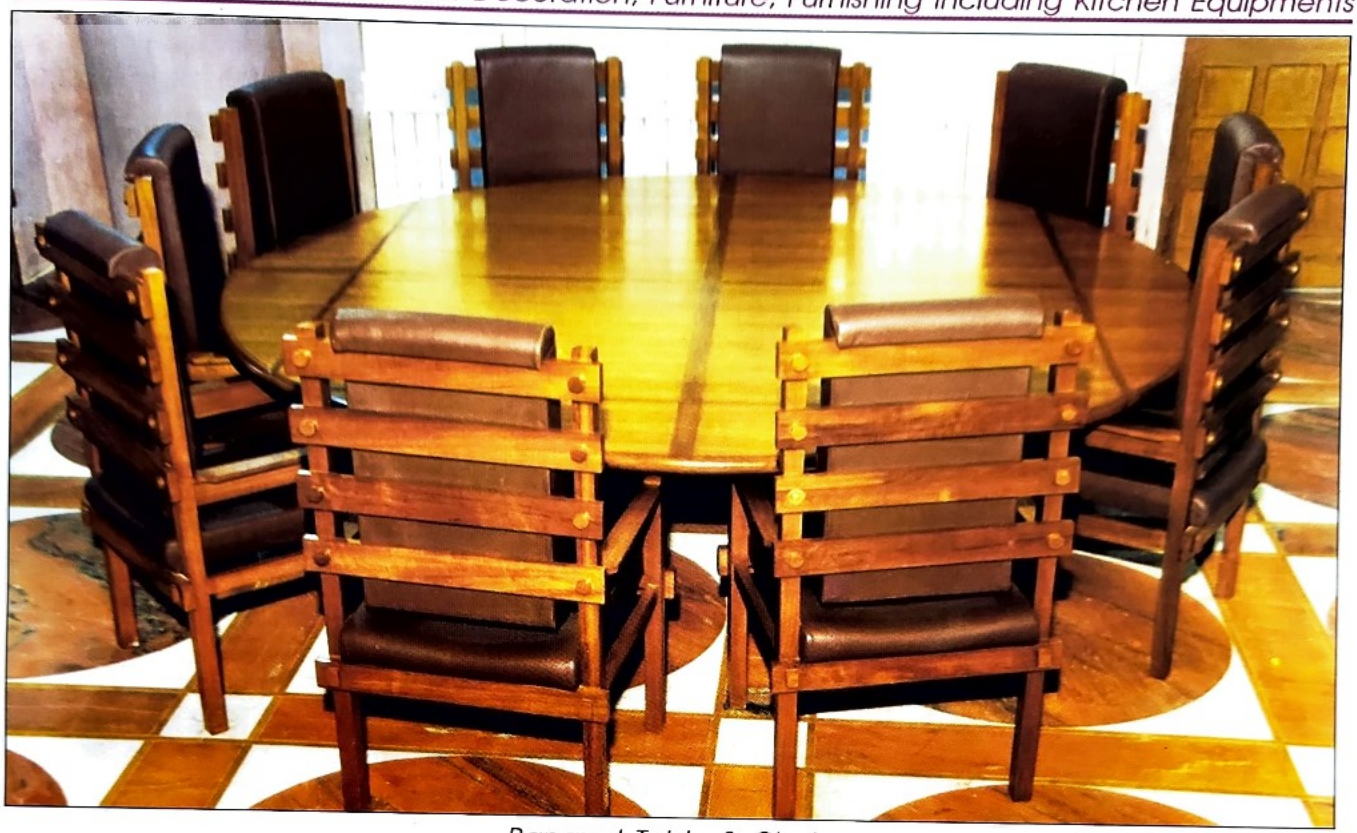
Committee Room Furniture

treatment at one face which consists of 25mm thick mineral wool stuck to 16mm thick plywood panel fabricated from 4 nos of 4mm thick boiling water resistant grade ply-wood or 19mm thick exterior grade block board. A piece of cloth is stretched over the mineral wool and held between 125mm x 30mm Burma teak wood battens. Over the stretched piece of cloth Burma teak wood strips of size 75mmx15mm have been provided with a gap of 15mm in between. This arrangement gives an acoustically efficient and aesthetically pleasing modesty panel.

7.2 Tables for Banquet Hall

Two types of tables have been provided for banquet hall as below :

a) *Banquet Table* : The banquet table has been made of folding type in the shape of a square surmounted by a segment of a circle on each side of the square. The segments are hinged along the side of the square, enabling them to be folded back under the table (to form a square banquet table) or to be unfolded up (to form a circular banquet table). Thus square table of size 1950mm x 1950mm with the chamfered corners may be converted into a circular table. The folding portion has been provided with arch shaped segments with arch radius 1325mm to form the table circular in shape of 2650mm dia. These arch portions have been provided with specially procured haffle drop leaf table fittings which serves 3 purposes viz.



Banquet Table & Chairs

i. act as a hinge for folding and unfolding the segments

ii. hold the segments in position by a snap-fit arrangement, when folded

iii. support the segment in position when it is unfolded

The square portion of table top is supported on four numbers 100mm dia stainless steel pipe of 5mm thickness supported on stainless steel circular plate at the top and the bottom of these vertical legs and suitably connected by 50mm dia stainless steel horizontal pipe. The table top has been made of 25mm thick exterior grade commercial block board and provided with 3.5mm thick Burma teak wood veneered ply. The edges of the square portion of table are protected with 12mm thick Burma teak wood lipping. The outer/external face of circular arc portion is provided with 40mm x 40mm Burma teak wood bull nosed beading. The table top has been given two or more coats of polyurethane paint over the french spirit polish.

b) *High Table for Banquet Hall* : High table of size 1500mm x750mm have been provided for Banquet Hall. The supporting structure and table top have been provided as per para 4.1 and 4.2 respectively as above. The front portion have been provided with modesty panel made from 19mm thick exterior grade commercial block board finished with 3.5mm thick Burma teak veneered ply. The finish is same as given in para 7.2a.

7.3 Reading Tables

Reading tables provided are mainly circular in shape, supported on single central leg of 100mm dia stainless steel tubular pipe of 5mm thick. This leg of frame work is resting on stainless steel four or six prong made from 3mm thick stainless steel plate bent to shape and supported on stainless steel shoe. The table top have been provided as per para 4.2 above.

7.4 Snack Bar Table for Canteen

There are three types of snack bar tables. The table top of first type of table have been provided as per para 4.2 above. Second type of snack bar table have been provided with 38mm thick chilly red polished square granite top procured from Karnataka with bull nosing alround. Third type of snack bar table has been provided as standing type and its top is made of 38mm thick chilly red polished circular granite with bull nosing alround. The supporting structure of all three types of tables have been provided as per para 4.1 above except that for standing type tables one more cross bracing of 32mm dia pipes have been provided at the upper part of the frame work to provide sufficient rigidity.

7.5 Office Tables

The Deputy Director table is 2300mm x 800mm having semicircular portion at one end whereas size of PA table is 1500mm x 600mm with semi circular portion at one end. Side table connected with main tables have been provided of size 1200mm x 600mm. The Deputy Director table have been provided with back storage unit of size 2200mm x 450mm. The supporting structure and table top have been provided as per para 4.1 & 4.2 above respectively. The front portion of table top is provided with modesty panel made of 19mm thick exterior grade commercial block board finished with Burma teak veneered ply. The modesty panels have been fixed with vertical legs of stainless steel frame work with nuts & bolts. The side tables have been provided with key board drawer of size 550mm x 275mm mounted on roller channel.

Back storage unit for Deputy Director table is made from 25mm thick exterior grade commercial block board laminated with 3.5mm thick Burma teak veneered ply and divided in three compartments by providing drawer units and shelves. The shelves portion have been covered with suitable shutters with locking arrangement.

7.6 Centre Table

The centre tables of various sizes 500mm x 500mm, 800mm x 800mm, 900mm x 900mm, 1200mm x 1200mm and 2400mm x2400mm of height 500mm have been provided. The supporting structure & table top have been provided generally as per para 4.1 & 4.2 above respectively.

8.0 SOFA SET

8.1 Sofa Sets Type –1

These are single seater, two seater and three seaters required to be placed in the

open areas for the use of visitors. These elegant looking sofas are manufactured from 25mm dia stainless steel pipe bent to shape and upholstered with leather. The leather was procured from Kanpur and has been tested as per IS: 577 for colour fastness, wet to-and-fro rubbing test and resistance to blocking in addition to usual thickness test. The polyurethane foam used for seat and back has the density of more than 45kg/cum.

8.2 Sofa Sets Type-2

These sofas are made in three pieces and joined to make single seater. The sub structure of these sofas are made from mild steel tubes and flats duly painted with epoxy paint. The back and sides of these sofas are fully upholstered with natural leather procured from Kanpur.

8.3 Sofa Sets Type-3

These visitors sofas are provided in the officer's room which may be single seater, two seaters and three seaters. The supporting frame have been made of stainless steel pipes of 50mm dia (OD) connected with universal joint connectors. The seat and back of these sofas are designed in one piece. The frame work of the seat & back of these sofas are made from Burma teak wood and upholstered with natural leather of same specification as for sofa type-1 and sofa type 2.

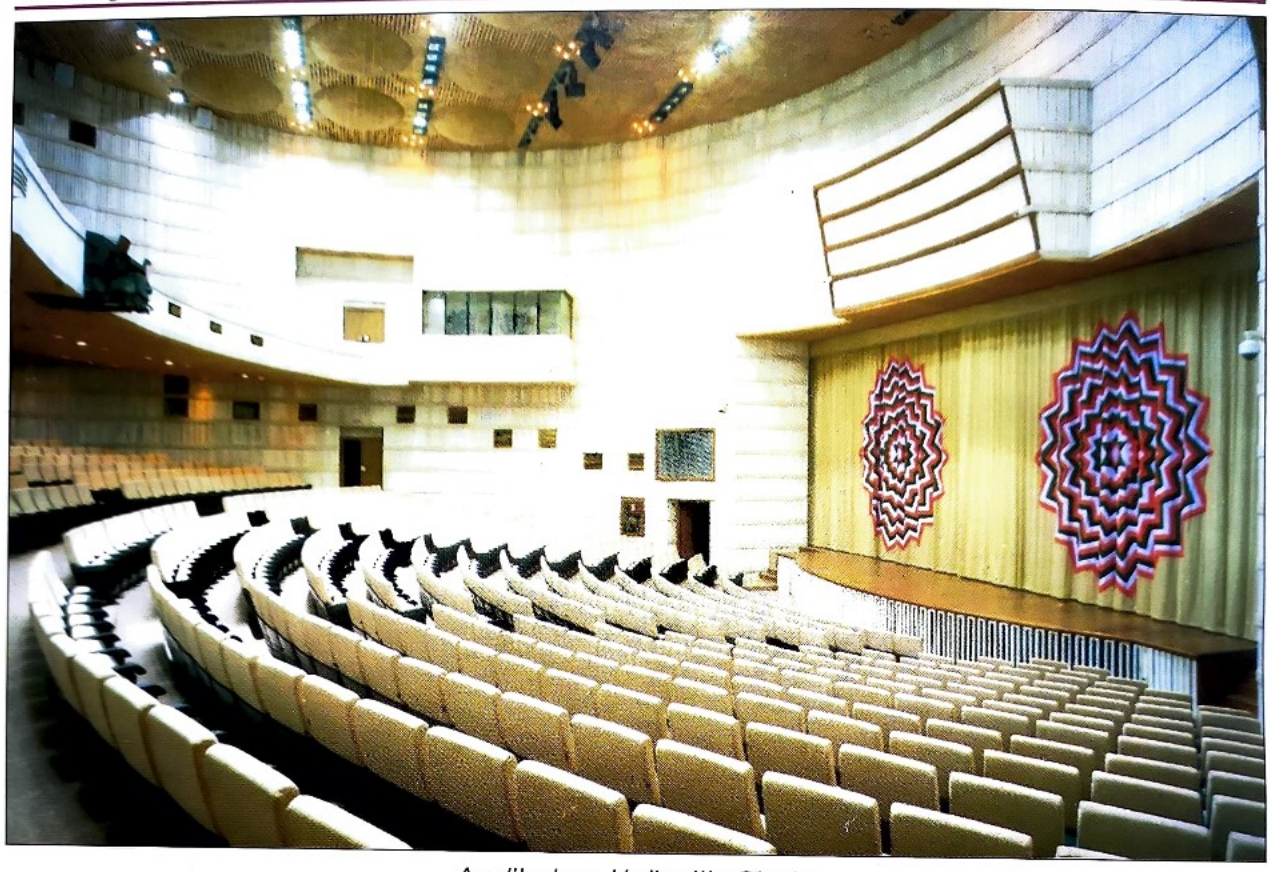
9.0 CHAIRS

9.1 Auditorium Chairs

Auditorium chairs have been provided in Auditorium, Audio-Visual Hall, Press & Public Relation room, and view room with seating capacity of 1067, 131, 64 and 24 persons respectively.

The auditorium chairs have been provided at centre to centre distance of 500mm in the auditorium hall. The minimum height of the seat is 440mm and height of top of back rest is 945mm from the floor. The size of seat provided is 410mm x 480mm. The back is of 640mm high & 470mm in width. Seat consists of cold moulded polyurethane foam of density not less than 45kg/cum, forming an integral mono block except the mounting mechanism rested on 12mm ply base. The mounting mechanism has pins of size 95mm x12mm and have spring attachment. Back of auditorium chair has been made of CRCA tube & MS flats covered with cold moulded polyurethane foam forming an integral monolithic block. In the process of cold moulding the molten polyurethane was then injected into the mould. The mould was then allowed to cool. This process formed a monolithic block. This block was then air cured before being upholstered. The shape of the back and seat have been ergonomically designed to give adequate lumbar and spine support.

The underside of seat and half of the back have been covered with moulded polypropylene shell. The chairs have been provided with intermediate and side stand panels, arm rests assembly and polyurethane handles. The chairs have been upholstered with superior quality fabric for back & seat and leather at both sides of



Auditorium Hall with Chairs

armrest panels. The fabric have been treated with spray of chemical known as fabric protector which forms a thin layer to protect against stains dirt and to impart water repellant property.

Illuminated aisle light box & row lettering for easy identification have been provided at the chairs which are terminating at the aisle. The light boxes have concealed bulb of 10watt/ 24volts with a lamp holder. The chair numbering have been done with plastic sticker. The chairs have been fixed in curved alignment on the steps in the Auditorium & on the floor in other areas. Fixing of legs of chairs to the floor have been done through dash fastener 100mm long.

In the Press Public Relation room 64, auditorium chairs with writing tables have been provided. The writing table of size 250mm x 225mm & 15mm thick have been suitably fixed with polyurethane arm rests. The writing tables have been made folding type with suitable mechanism, so that they can be folded when not in use. These have been provided for left handers as well as right handers both.

9.2 Banquet / Canteen Chairs

The wooden chairs with upholstered back & seat have been provided in Banquet Hall, Canteen and in snack bar. These chairs are made from Burma teak wood frame work. The seat and back of these chairs are upholstered with natural leather and have

been tested as per IS:577. The foam used in seat and back is of density more than 45kg/cum.

9.3 Chairs In Other Areas

Chairs of various proprietary models (either with castors or without castors) of M/s Featherlite Products Pvt. Ltd. or M/s Godrej & Boyce Mfg. Co. Ltd. have been provided. The seat & back of chair are made of 20mm dia MS tubular frame of 16 gauge provided with helical spring with 25mm thick kurlon base and 37mm thick polyurethane foam of density 50±5 kg/cum of required thickness. The arm rest are of moulded self skinning polyurethane and reinforced with MS insert. The seat & back for chairs without castors is supported on mild steel tubular tube of ERW frame. The seat & back for chair with castors is supported on pedestal assembly of 5 prongs made of injection moulding in black 30% glass filled nylon. The twin wheel castors are made of nylon. The chairs have gas lift facility and have 100mm stroke length with a gas pressure of 300N. The chair with castors have tilting facilities also. All the chairs have been upholstered with fabric of specified shade, colour & quality and is colour fast cotton or cotton mixed with threads of silk.

10.0 COUNTERS

Counters with drawer units have been provided in various locations. Working platforms of the counter have been provided at 740mm height from the floor level and are made of 25mm thick exterior grade commercial block board laminated with 3.5mm thick Burma teak veneered ply and Burma teak wood bull nosed beading on the front edges. The counter top at a height of 1100mm from the floor level and facia of the counter has been provided with 38mm thick chilly red mirror polished granite procured from Karnataka. The facia have been fixed in the floor with araldite by making a groove having depth of 50mm in the floor.

11.0 MANUAL CATALOGUE

Manual catalogue of size 1250mm x 660mm with 30 number of drawers of clear size 160mm x 160mm and depth 440mm in each have been provided on the stainless steel tubular frame work as per para 4.1 above.

12.0 CARPET

The Auditorium has been provided with wall to wall Nylon carpet of MILIKEN make (p/561710 ACCOLADE-Tufted broad loom 0183 conclave) on the horizontal & vertical surfaces of seating area with under layer of 12mm thick profil on the horizontal surface and fixed with the help of wooden grippers and adhesive. The layout of auditorium chairs was marked before laying of the carpet and accordingly foundation bolts for fixing the stands of chairs had been positioned/fixed. The carpet was then laid allowing the foundation bolts to pierce through the carpet. Circular holes of about 200mm dia were made in the carpet at treads of the steps of ground floor of the Auditorium to give access to the return air duct.

13.0 VENETIAN BLIND

The windows in office area, committee Rooms, MP's Reading area, Museum, Library and Banquet Halls on first floor, ground floor and first basement have been provided with vertical blinds of Mac Decor Make as approved by the Consultant Architect. The louvers are 75mm wide made of fabric woven from polyester viscose-yarn dyed in fade-resistant colour and coated to give stability, dust repellence and stain resistance. Headrails made of extruded aluminium alloy measuring 45mm wide and 25mm high with a wall thickness of 1.10mm are powder coated. The louvers have self aligning worm and spur gear mechanism to provide a synchronized 180° rotation by use of an aluminium alloy tilt rod. Functioning is controlled by plastic spacer fixed to the carrier body providing a minimum overlap of 14mm in fully closed position The louvers are connected together on both sides with nylon link chain and tensioned by a cord weight. This ensures that the louvers hang straight and flat without buckling.

14.0 KITCHEN EQUIPMENTS

The Parliament Library Building has been provided with kitchen facilities with Kitchen equipments. The layout plans and design was framed in consultation with Indian Tourism Development Corporation (ITDC) and approved by catering division of Ministry of Railways and Lok Sabha Secretariat. The kitchen or pantry facilities have been provided at the following places in the building.

a)	Staff Canteen & Main Kitchen	FF – Service Block
b)	Kitchen Store & Receiving Area	GF – Service Block
c)	Banquet Kitchen	FF – K Block
d)	Pantry & Dish Wash	GF – K Block
e)	Pantries	GF - Four Nos.
		FF – Four Nos.

Basically three types of equipment have been provided in these areas i.e.

14.1 Indigenous Fabricated Equipments

All the equipments have been fabricated with stainless steel of AISI 304 grade non magnetic type having 2B finish as per manufacturer's specifications. It includes equipments like – work table with sink, hot bain marie (elect), tea, coffee/milk dispenser (elect), mobile tables, gas cooking range, vertical refrigerator, gas chinese range, ice cream freezer, bottle cooler, gas dosa plate, tilting fry pan, tilting kettle, idli steamer, planatory mixer, mobile kitchen trolley, dirty dish table, clean dish table, potato peeler, vegetable bins, garbage bins, vegetable storage rack, hand carts, storage racks, hot food trolley, cold food trolley, water boiler, milk boiler, hot cupboards etc.

14.2 Indigenous Readymade Equipments

Kitchen equipments like storage type water cooler of capacity 40 ltrs, 120 ltrs. and 150 ltrs, aquaguard wall mounted, microwave oven, wet masala grinder, slotted angle stacks, weighing scale, insecto cutor (wall mounted), geyser wall mounted, manual sausage filler, soup warmers, kitchen aid mixer etc. have been provided at different places.

14.3 Imported Equipments

Some imported equipments like - mixer (blender), hood type dish washing machine, pre-rinse sink unit with jet spray, high pressure cleaner, vegetable cutting machine, meat mincer, veg/ meat gravity slicer, ice cube making machine, have been provided for smooth functioning of the kitchen. Each pantry has been provided with work table, sinks, hot cupboards, refrigerator, water coolers, tea/coffee milk dispenser, mobile kitchen trolleys, aquaguard & geysers etc. In addition exhaust hoods made of AISI 304 grade of stainless steel with stainless steel filters have been provided in main kitchen at first floor of building.

15.0 WALK-IN COLD ROOMS & DEEP FREEZERS

Five walk in cold room/deep freezers have been provided in the building by considering condenser temperature at 54.4°C and size and suction temperature of various types of walk in cooler has been designed as per details given in under mentioned table.

Sl. No.	Walk in Cooler	Suction Temperature	Size
1.	Cold Room for Vegetable	(-2°C)	2700x2400x2100mm
2.	Cold Room for Dairy Product	(-5°C)	2100x2400x2100mm
3.	Deep Freezer for Mutton & Chicken Product	(-27°C)	2700x2400x2100mm
4.	Cold Room for Multipurpose Storage	(-5°C)	3000 x2400x2100mm
5.	Cold Room for Garbage	(-5°C)	2700x2300x2100mm

The walls & ceiling are fabricated with panels made with a core of polyurethane foam 100mm thick of density 40±2kg/cum and are provided with stainless steel sheet 0.5mm thick on both faces of the core as laminate. These panels are fixed with plastic camlocks. PVC strip curtains of 3mm thick have been provided at the door openings. Stainless steel kick plates of size 900mm x 300mm of thickness 2mm have been provided on doors of each cold room.

The refrigerator system consists of air cooled condensing unit with matching evaporator unit & condensers. The condensing unit (one working and one standby) with compressor, motor, air cooled condenser, fittings, valves, refrigerant controls, thermostat, electric panel, voltmeter, ammeter etc. are installed on top of cold room/deep freezer on a separate base. The condenser & compressor are semi hermetically sealed type of make Kold Tech of Bangkok.

SERVICES

1.0 SEWERAGE & SANITARY INSTALLATIONS

1.1 General

The Parliament Library Building have 11 blocks excluding parking. Nine toilet blocks have been provided in different locations of the building keeping in view the requirement in various areas. All toilet blocks consist of gents & ladies toilet units having mirrors, wash basins, Indian/European WC's at first basement, ground floor and first floor. Out of 9 toilet blocks 6 toilet blocks terminate at first basement level & balance 3 toilet blocks are provided for second basement also with gents toilet unit only.

1.2 Sewerage System for Toilets

The various fixtures such as wash basins, urinals, mirror, water closet etc. were to be provided in toilet blocks as per drawing issued by Consultant Architect. The

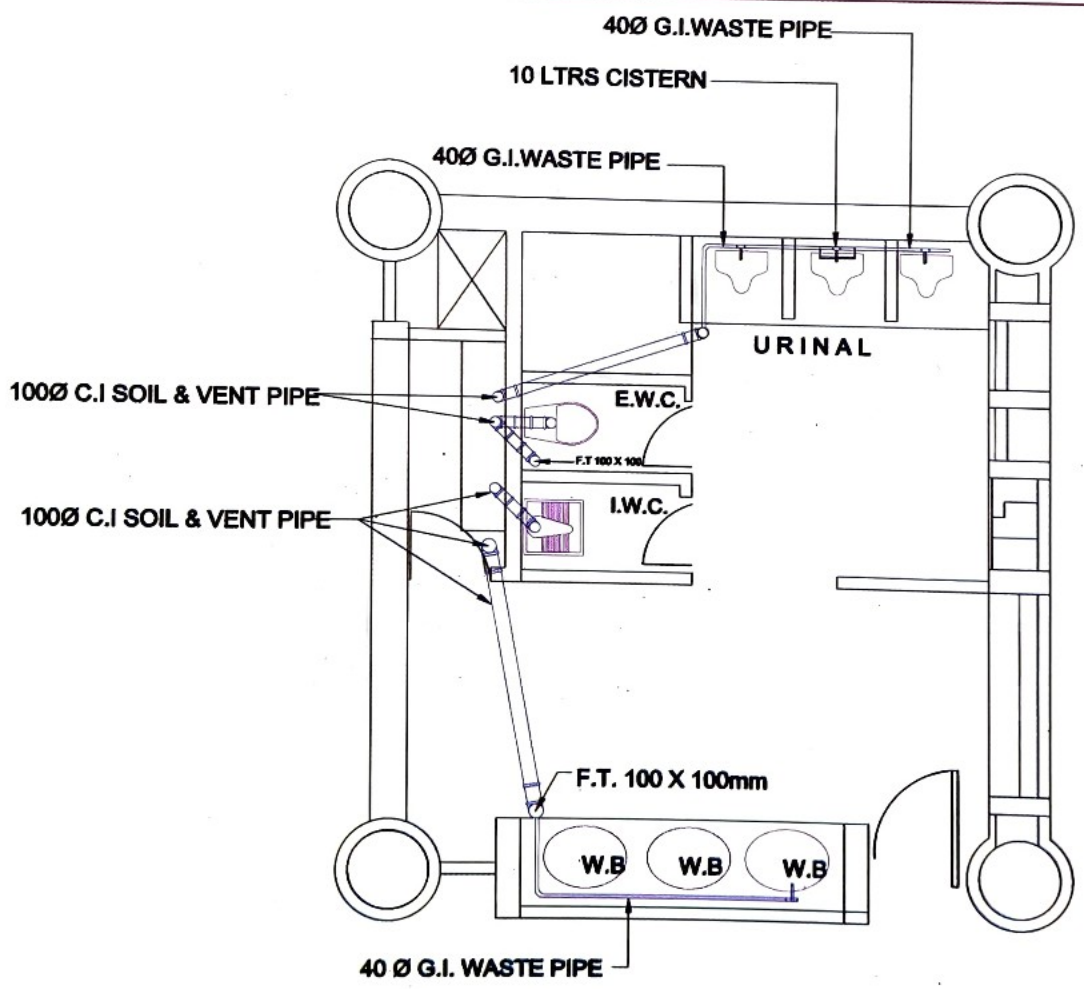


Fig 23.1 : Typical Layout Toilet (Type B)

detailed design of plumbing system i.e. sizes and distribution of water supply lines and sewage disposal lines within and outside the toilet blocks was done in house. Detailed drawings showing exact heights, locations & sizes of various fixtures and fixing details were made and detailed specification were framed. RCC platform has been provided in the toilet shafts at every floor level for attending to maintenance problems and access to the working platform has been made from toilet blocks at every floor level. The level of platform has been kept in such a way that various bends and connection to the vertical stacks are accessible at proper working heights. The diameter and minimum vertical length of flushing pipe for flush valves has been provided as per manufacturers specification.

All waste pipes of dia not less than 100mm to avoid chockage in the waste pipes have been provided under the floor. The layout of waste pipes under floor was done in such a way that there is no bend in waste pipes except at the location of floor traps or gully traps.

1.3 Provision of Sleeves

The planning and design of plumbing system was completed before start of superstructure work. The exact location and level of various disposal pipes including rain water disposal pipes from courtyards were marked in the drawing and cast iron sleeves/pipes of required size were placed during concreting of diaphragm wall capping beam. The cast iron sleeves were specially made with flanges at both the ends and one puddle collar in the center, to be embeded in the concrete to reduce the chance of leakage of water along the outer surface of the sleeves. The sleeves placed in the capping beam were connected with the discharge pipes from various toilet blocks inside and with the external sewage lines outside the building.

1.4 Final Disposal System

Out of 9 toilet blocks 5 toilet blocks are situated along the periphery of building and 4 toilet blocks are in the inner part of the building. As per design of sewerage system, it was planned to dispose the sewage of GF & FF toilets for five peripheral toilet blocks directly outside the building under gravity as the required slope and invert levels were available. However, for the toilets located in the inner core of the building, required slope was not available so it was decided to collect the sewage from all floors of inner toilets into the sumps constructed in the second basement of the building. The sewage from first basement and second basement level of peripheral toilets was also collected in these sumps.

The sumps have been designed for 24 hours retention. The quantities of sewage/ waste water discharging to a particular sump have been worked out to get the capacity of the sump. In total five number sumps of designed capacity (plus 25% for dead storage) as per details given below have been provided.

Sl. No	Location of sumps	Capacity in litres	Toilets discharging to sumps
1.	Library Block	31500	Library-SB &FB, BPST- FB Core-H- FB, GF & FF
2.	AVM Block (AV side)	54280	VIP-FB, AVM(AV side) –SB&FB Core-K- FB, GF &FF
3.	AVM Block (Services side)	45000	Core-J (Core-K side)-FB, GF & FF. AVM (Services side) – SB &FF.
4.	Book Entry Area	54280	Core-J (Core-I Side)-FB, GF & FF. Core-I- FB, GF & FF. Auditorium - GF & FF
5.	Auditorium Towards Parking	24500	Auditorium Green room & Parking all toilets

Cast iron pipes of 150mm dia have been used to carry the sewage from different toilet blocks to sewage sumps. The waste pipe have been provided from first basement to the sumps in the second basement with minimum slope of 1:200 for horizontal lengths. The disposal pipes have been fixed along the counterfort wall and location of bends kept in such a way that all bends are accessible for cleaning and repair etc. in case of chokage & leakage. Each sewerage sump is provided with two submersible pumps (one operating and other standby) of capacity 4.0 to 7.0 HP each. The sewage pumps operates automatically with the sensor, once the level in sump reaches beyond predetermined level.

1.5 External Sewerage

The required invert level of sewer line just outside the Parliament Library Building campus was (-)2450mm for providing average slope of 1:200 in sewerage line. After detailed study it was found that required invert level was available in the NDMC trunk line passing through the Patel Chowk. NDMC laid the sewerline at the approximate cost of Rs. 26 lacs from Patel Chowk to Parliament Library Building at the required invert level of deeper than (-)2450mm. The work of laying sewerlines upto NDMC manhole was done by CPWD. The toilet waste pipe from building has been taken out at invert level of (-)900mm from ground floor level of the building at 5 locations marked SD1 to SD5 for discharge of waste under gravity for ground floor & first floor toilets on the periphery of the building and at 5 locations marked SP1 to SP5 for discharge of waste by pumping from sewerage sumps. The length of the sewerline from starting point to the outlet at Talkatora Road (opposite Ambedkar statue) is about 400m. (Fig 23.2)

1.6 Sample Approval

The samples of all pipes and fittings such as vitereous china ware, CP brass fittings, C.I./SCI fittings were collected from all manufacturers mentioned in the agreement and were inspected. Only those fittings of a manufacturer which were found best were

approved. Even the G.I. unions, bends and pipes manufactured by various manufacturers were inspected and the makes were approved. Problem was faced in procurement of P or S traps for WC's having minimum water seal of 75mm and floor traps having minimum water seal of 50mm. The P or S traps and floor traps of required seal were not available in market and P, S trap and floor traps having minimum water seals of 75mm & 50mm respectively were got specially manufactured from NECO.

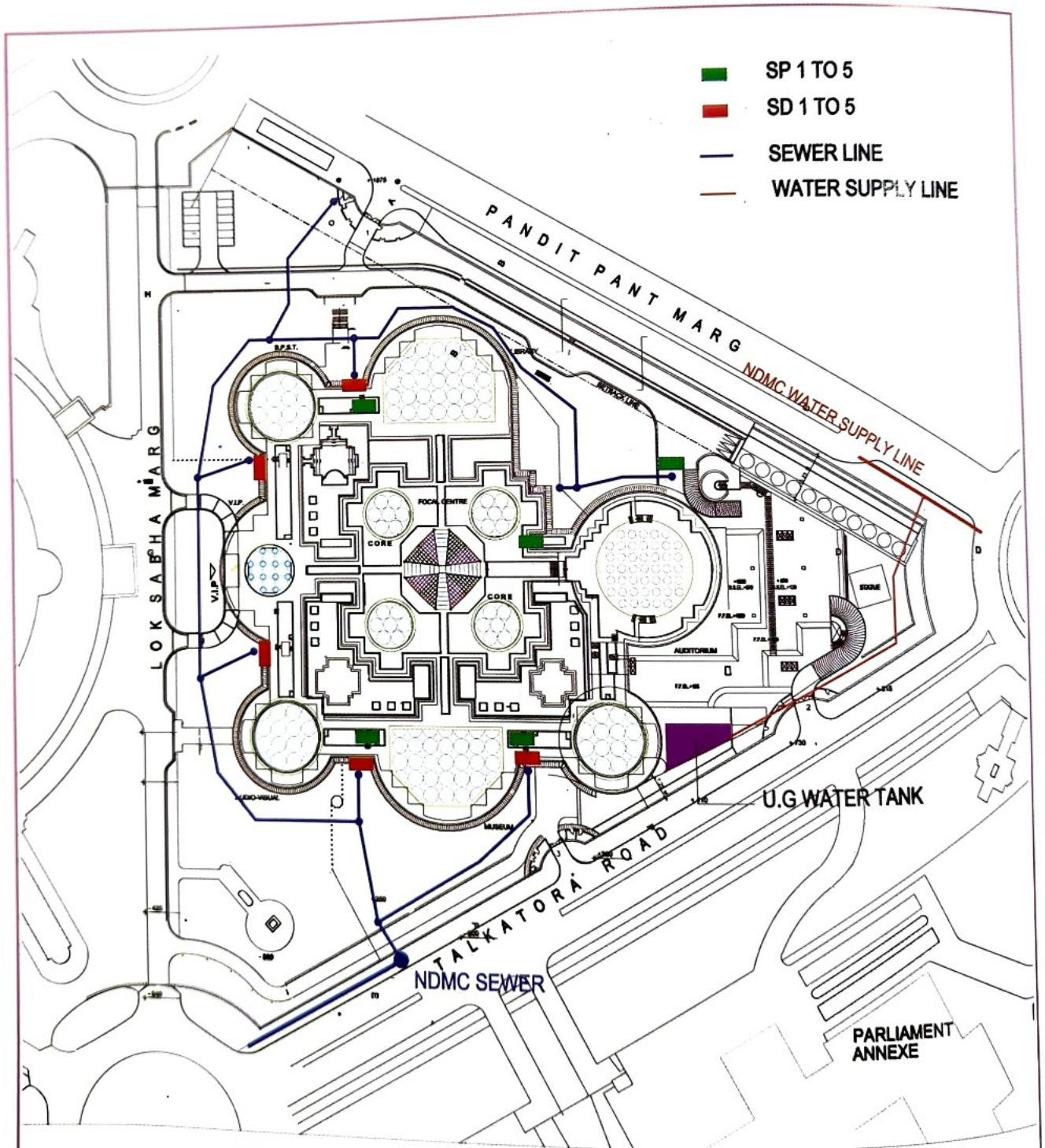


Fig 23.2 : External Sewerline/Water Supply Line

2.0 WATER SUPPLY

2.1 General

Regular water supply is required for

a) Drinking and use in Toilet blocks

b) Airconditioning

c) Horticulture

2.2 Water for Drinking and Sanitary Purposes

a) *Occupancy :* The number of persons likely to occupy different areas of the building was not exactly known at the time of planning and detailing of water supply scheme. The guidelines given in standard text books was therefore followed to work out the occupancy as below;

i.	For closed stack area	@	one person per 75 sqm of area
ii.	For open stack area	@	one person per 50 sqm of area
iii.	For office and other areas	@	one person per 16 sqm of area
iv.	For Auditorium	=	1100 persons
v.	For security staff	@	5% of total occupancy

The total occupancy for the building was worked out as below,

i.	For closed stack area	11175/75	=	149 persons
ii.	For open stack area	5854/50	=	117 persons
iii.	For office & other areas	33342 /16	=	2084 persons
iv.	For Auditorium		=	1100 persons
	Total		=	3450 persons
v.	Add for security staff @ 5% of total occupancy		=	173 persons
	Total estimated occupancy		=	**3623 persons**

b) *Water Requirement :* The number of persons served by each toilet block have been worked out based on area served by the toilet. The quantity of water required was worked out as below:

i. For stack area, offices etc. @ 45 ltrs per person per day as specified in National Building Code Part-IX Section-1 for office buildings.

ii. For Auditorium @ 15 ltrs per person/day.

iii. Provision was made for additional capacity of 12000 ltrs for kitchen & pantries.

iv. Additional 5% of total capacity was considered for security staff.

The total quantity of water required was worked out as below;

i.	For stack, office & other areas 2350 persons	@ 45 ltrs per day	=	105749ltrs
ii.	For Auditorium 1100 persons	@ 15 ltrs per day	=	16500 ltrs
iii.	For Kitchen & Pantries		=	12000 ltrs
iv.	Parking Requirement		=	7500 ltrs
		Total	=	141749 ltrs
v.	Add 5% for security staff		=	7287 ltrs
		Total water required	**=**	**149036 ltrs**
			Say	**150000 ltrs**

c) *Source of Water :* The water for drinking purpose is being supplied by NDMC through 80mm dia water supply Tee connection at Pandit Pant Marg for supply of 1.5 lac litres of water per day. The water from NDMC supply lines through CPWD delivery line of 100mm dia G.I. pipe is stored in underground water storage tank (Fig 23.2). The underground tank is partitioned in three compartments. The water supply is received in the first compartment which has a capacity of 1.0 lac ltrs for fire fighting requirement. Once 1.0 lac ltr capacity tank is full then water spills over to the second compartment meant for drinking purposes. Third compartment for Air-conditioning purpose is filled by tube well.

d) *Underground Water Tank :* The underground water storage tank for full one day requirement i.e. 1.5 lac ltrs has been provided.

e) *Overhead Storage Tanks :* Initially it was proposed to provide one master overhead tank on the terrace and to supply water to different toilet blocks from master tank through gravity. Since the space for master tank was not available on terrace and also the height was restricted, it was decided to provide low height water tanks on every toilet block. The R.C.C. tanks partially depressed below terrace level and partially projected above terrace have been provided. The top of the water tanks has been kept at the top level of terrace garden so as to give unobstructed view of the terrace from the Parliament House. The top slab of the tanks have been finished with red sand stone flooring to match with the walk ways.

The overhead tanks have been provided to meet the half of the daily requirement with the concept of pumping twice a day. Total capacity of all the tanks at terrace is 76,518 litres as per details given below:

Sl.No.	Location of Tank	Tank Number	Capacity in litres
1.	Library Block	T_1	8,211
2.	BPST Block	T_2	3,816
3.	VIP Block	T_3	4,081
4.	AVM Block (AV side)	T_4	5,603
5.	AVM Block (Service side)	T_5	8,378
6.	Service Block	T_6	14838
7.	Core-J Block	T_7	7,943
8.	Core-K Block	T_8	6,618
9.	Core-I Block	T_9	9,030
10.	Auditorium Block	T_{10}	8000
	TOTAL		**76,518 litres**

f) *Head Loss :* Hardy cross method was used to calculate the head loss in various branches as below;

$$H_L = \frac{flv^2}{2gD} = \frac{flQ^2}{2g\,(22/28\,D^2)^2 D}$$

assuming f = 0.02, D in metres, l in metres & Q in ltrs/hour

$$H_L = 5.37 \times 10^{-11}\, Q^2\, l$$

Trial values of discharge in various segments were as under:

Pipe segment	Length in mtrs	1st Trial		2nd Trial		3rd Trial		4th Trial	
		Dis-charge	H_L(m)	Dis-charge	H_L (m)	Dis-charge	H_L (m)	Dis-charge	H_L (m)
OT_5	43	8000	0.148	7600	0.133	7400	0.126	7500	0.13
T_5T_7	30	5905	0.056	5505	0.049	5305	0.045	5405	0.047
T_7T_4	35	3919	0.029	3519	0.023	3319	0.0207	3419	0.022
T_4T_3	45	2518	0.015	2118	0.011	1918	0.009	2018	0.01
T_3T_8	30	1498	0.004	1098	0.002	898	0.001	998	0.002
T_8T_2	40	-157	0.000	-557	0.000	-757	-0.001	-657	-0.001
T_2T_1	35	-1111	-0.002	-1511	-0.004	-1711	-0.005	-1611	-0.005
T_1T_9	110	-3164	-0.059	-3564	-0.075	-3764	-0.084	3664	-0.079
T_9T_6	45	-5422	-0.071	-5822	-0.082	6022	-0.088	5922	-0.085
T_6O	2	-11132	-0.014	-11532	-0.0143	-11732	-0.015	-11632	-0.015
	Total		0.106		0.042		-0.009		0.026

ΣH_L in Third trial is –0.009 hence third trial values were O.K.

Max head loss (excluding bend losses) = 0.2m

Losses in bends = $0.5\ V^2/2g = \frac{0.5}{2g} \times \left(\frac{Q}{A}\right)^2$,

where Q is in ltrs/hour & pipe is of 75 mm dia.

Total bend losses = $10^{-10}\ Q^2$ = $10^{-10}\ (6x(6022)^2 + 16(3764)^2 + 3(1711)^2) = 0.045m$

So total loss = 0.2 + 0.045 = 0.245m

g) *Water Supply Distribution Line at Terrace :* In order to ensure equal head loss at delivery to every tank (so that water reaches every tank at almost same head) the water distribution pipe lines have been made of two loops, inner loop around the focal dome area and outer loop along the periphery of terrace. Rising main of 100mm dia G.I. pipe from the pumps is laid to the terrace through the shaft between service & Auditorium Block. The entire distribution system was then divided into four

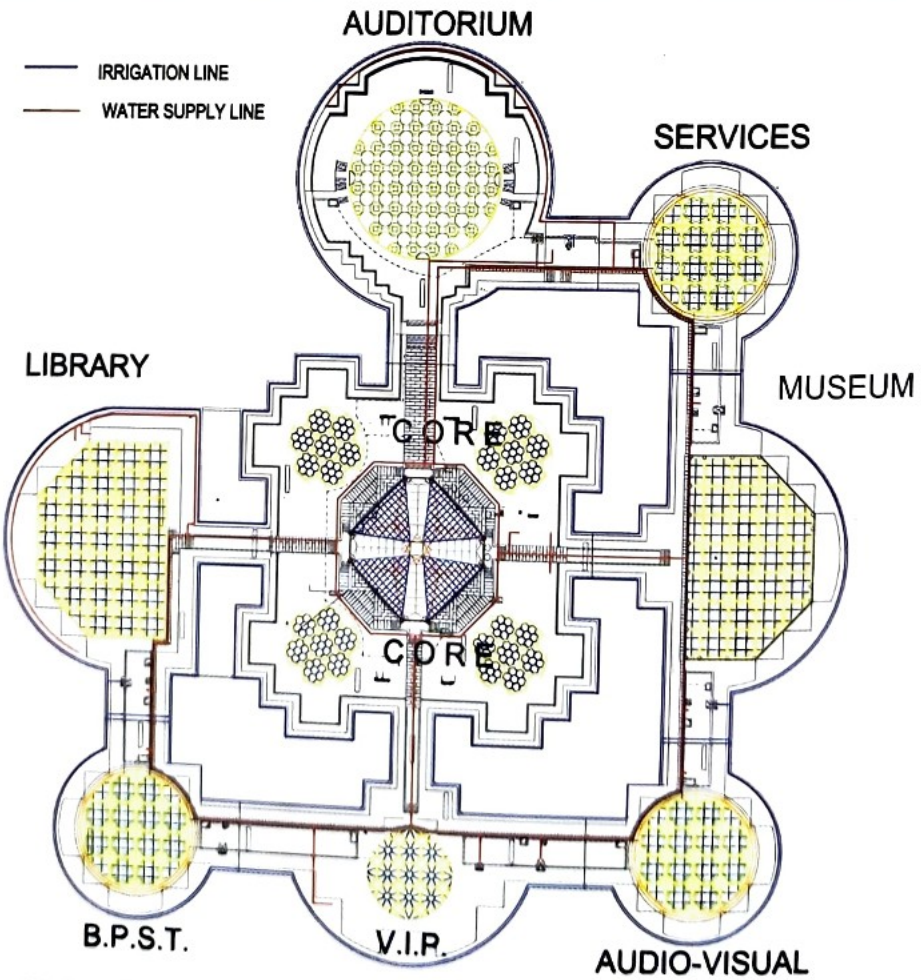


Fig 23.3 : Rising Main and Water Supply/Irrigation Lines at Terrace

segments by providing sluice valves to ensure the segregation of particular segment for repair etc. without affecting water supply in other three segments. (Fig 23.3)

h) *Distribution (Delivery) System :* Distribution from each tank to toilets is as per details below:

i. One number 65mm dia GI pipe has been provided to serve toilets at first floor & first basement

ii. One number 65mm dia GI pipe has been provided to serve the second basement & ground floor

iii. 80mm dia scour pipe has been provided from the tank to second basement peripheral drain to provide for cleaning of terrace tanks. Same pipe has been extended upward & connected to overflow pipe.

iv. From the downtake pipe, one 50mm dia connection has been taken for each floor & further divided into 2 nos 40mm dia GI distribution line to cater the flush valves in WC & one number 25mm dia connection for wash basins & urinals. This 25mm dia pipe has further been reduced to 20mm dia as the line leads towards dead end. All the internal water supply lines have been concealed in brick wall and the walls have been finished with granite/marble tiles as per the Architectural drawing.

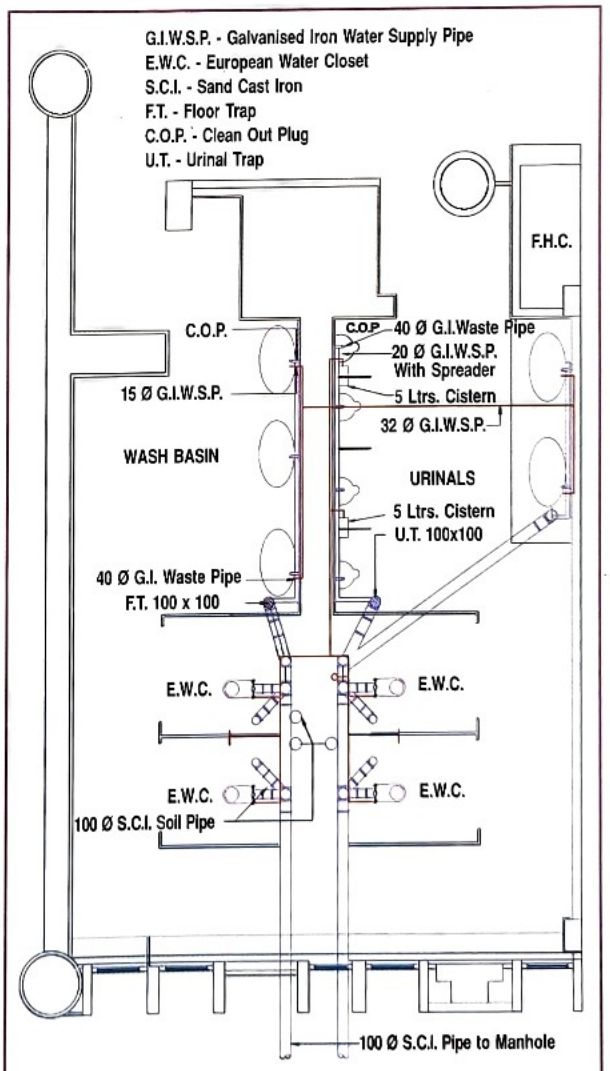


Fig 23.4 : Internal Water Supply/ Sewerage Line for Typical Toilet

2.3 Water for Air Conditioning Purposes

About 45000sqm area of the building is centrally air conditioned. Average daily requirement of water for Air-conditioning is 4,50,000 ltrs. NDMC was requested to supply 4.5 lacs litre water per day for A.C. purpose, however NDMC expressed their inability to supply the same out of their regular drinking water system and suggested installing two dedicated tubewells outside Parliament Library Complex. NDMC have bored these two

tubewells one near north block and another near Parliament House Annexe. The water from these tubewells is stored in the underground water tank of 4.5 lacs litres capacity constructed in the basement. These two tubewells and the supply lines upto the boundary wall of the building were constructed by NDMC as deposit work, and handed over to the Parliament Library Project Team for running and maintenance. The bore well data are as below.

Sl. No.	Description	Tubewell No.1 near North Block	Tubewell No. 2 near Parliament House Annexe.
1	Static Water level	20.28 m	9.24 m
2	Pumping Water level	40.53 m	33.24 m
3	Draw down	20.25 m	24.00 m
4	Discharge	15000 ltrs/hour	12000 ltrs/hour
5	Depth of Bore	89.04 m	88.75 m

2.4 Water for Horticulture

The terrace, internal courtyards & outside open areas in Parliament Library Complex have been landscaped with different types of plants, turfed grass and ground covers. The daily requirement of water for horticulture work is approximately 2.5 lac litres in summer. Since the internal courtyards and external landscape area is frequently used by occupants of the building, using unfiltered water for horticulture purpose was not desirable since unfiltered water sometimes gives a foul smell. Moreover various lawns whether on terrace or in courtyard or outside the building have sophisticated irrigation system consisting of pop-up sprinklers, bubblers, drip lines etc. requiring clean water for their efficient operation. Hence, the use of unfiltered water for horticulture purpose was not considered desirable.

Since NDMC have expressed their inability to supply water even for AC system, it was decided to construct two new tubewells and develop one already existing tubewell in the Parliament Library Building campus itself. The tubewells bored inside the PLB Campus have the following details.

Sl. No.	Description	Tubewell No.1 near Gate No.1	Tubewell No.2 near Ambedkar statue	Tubewell No.3 near Gate No.3
1.	Static water level	13.71 m	13.71 m	13.70 m
2.	Pumping water level	35.0 m	35.06 m	36.0 m
3.	Draw down	21.35 m	21.35 m	22.30 m
4.	Discharge	8000 lph	13000 lph	8000 lph
5.	Pump capacity	7.5 HP	7.5 HP	7.5 HP
6.	Depth of Bore	107 m	90 m	65 m

The three tubewells as above are sufficient to fulfill requirement of water for horticulture. The tubewells were connected to 80mm dia PVC pipe grid laid along periphery of the external areas from where branch lines of different diameter of PVC pipes were laid. The internal courtyard and terrace garden water distribution system (Fig 23.3) is also connected to 80mm dia PVC pipe grid.

Every tubewell has been provided with on line filter, to filter the water before same is fed to the grid. Pressure relief valve has been provided for every tubewell to ensure that the pressure in the lines do not exceed the desired value i.e. 6kg/sqcm even when the valves are closed. Pressure Relief valves have been provided near both the tube wells connected to Irrigation PVC pipe line. Whenever there is a increase in pressure inside the loop, the pressure relief valve opens up and releases the water, till the pressure reaches down to calibrated pressure. The pressure relief valve is calibrated by adjusting the check nut of valve by moving it clockwise or anticlockwise by wrench. The movement of check nut releases or compresses the springs fixed in the valve.

- *Popup Sprinkler* : Popup sprinklers have been provided as per requirement of the landscape, which are connected to 80mm dia PVC pipe grid. Following type of popup sprinklers of Toro company, USA are provided in which the nozzle pops up to a suitable height for irrigation of lawns:



Controlled Irrigation in Green Area

i. TORO-V-1550 : The pop up sprinkler is a medium range rotary sprinkler. It is exclusive multimatrix nozzle system designed to give users the ability to adjust flow, radius and trajectory without changing nozzles. The nozzle allows adjustment of radius from 4.6m to 16.8m (without interrupting the nozzle stream) with radius adjustment screws. Similarly trajectories could be adjusted between 7^0 to 25^0 for maintaining effective coverage. Its flow varies from 4 litres to 34 litres per minute. The body of the popup is non-corridible heavy duty type. It has a working pressure of 1.7kg/sqcm to 5.2kg/sqcm. These popup sprinklers have been provided in lawns over parking area near AV, AVM, Service Block, I Block and near Reception at Iron Gate No.1

ii. TORO 570 Z Pop up Sprinkler : This type of sprinkler have been provided in courtyard and shrub beds along the wall as these cover small lawns. The working pressure for these pop up sprinkler is 1.4kg/sqcm to 3.5kg/sqcm and throw of 0 to 5m. The body of the pop up is non-corridible heavy type.

Entire horticulture area has been divided into sectors for the purpose of operations of sprinklers, drip lines etc. Every sector is operated for fixed predetermined time decided on the basis of water requirement of plants in the sector.

3.0 DRAINAGE

3.1 Drainage of Raft/Second Basement Area

a) *Necessity :* The Parliament Library Building consists of two basements constructed over a continuous raft of approximately 19,000sqm area. The thickness of raft is 900mm and the bottom of raft is 8m below ground level. General ground water table in the area is around 4m below ground whereas during monsoon the water table rises almost upto ground level. The drainage of raft is required due to following factors.

i. The sprinkler system provided in the basement for fire protection will get activated in the event of fire or during routine testing, resulting in the discharge of water on the floor. This sprinkler water will ultimately flow over the floor/raft.

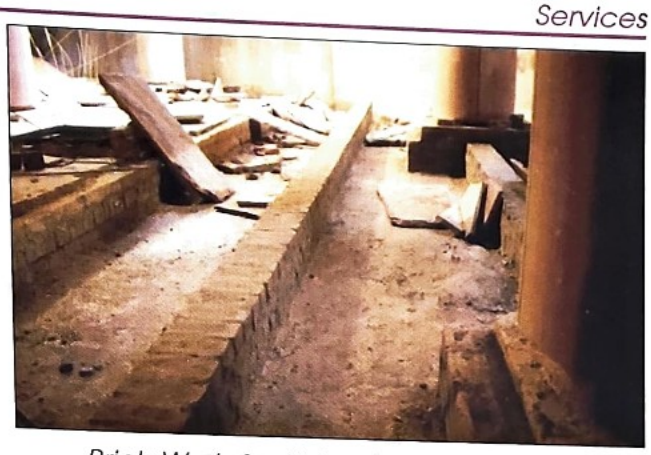
ii. The scour pipe for cleaning of overhead water tanks have been connected to second basement peripheral drains.

iii. The water due to occasional leakages if any from water supply, wet riser and sewerage system through shafts or otherwise will be flowing over floor/raft.

b) *Drainage System :* Following provisions have been made to ensure effective drainage of second basement area.

i. Slope in Raft : Raft has been cast with minimum slope of 1 in 100 to ensure that the water flowing over the raft is drained out quickly. The ridge & valley lines have been provided during casting.

ii. Provision of False Floor : In order to ensure that floor of second basement remains dry even after occasional seepage of water, if any, through raft and diaphragm wall, false floor has been constructed above the raft. The space between false floor and raft (150mm to 750mm deep) have been channelised by providing 9" thick brick walls at spacing of 1250mm centre to centre. The top of wall has been properly levelled by cement plaster. Red sand stones of 600mm x 1220mm x 40mm size have been placed over brick walls to act as permanent shuttering due to difficulty in removal of shuttering subsequently. Over this sand stone shuttering, 80mm thick RCC slab has been laid. Water reaches the external/ internal peripheral drains through these channels below false floor. Manholes have been provided at spacing of 10m centre to centre in each channel in the false floor for inspection and cleaning.



Brick Work for False Floor in Progress

iii. Peripheral drain : Along internal & external periphery of the raft 400mm wide drain with minimum slope of 1 in 100 has been provided to carry the water coming from the floor/raft. The depth of the drain at starting point is 150mm which goes upto 500mm at deepest point. The drain has been covered with 400mm wide red sand stone grating having staggered holes of 45mm dia @ 150mm centre to centre spacing, in both directions to receive water from the finished floor surface. The grating is supported on angles on both sides of drain. These grating are simply resting on these angles and can be removed as and when cleaning of drain is required.

iv. Drainage Sumps : At various points along the peripheral drain 18nos of drainage sumps of sizes 500mm x 2500mm x 1000mm have been provided to collect the water from peripheral drain. Every drainage sump has been provided with electric pump of 4HP which starts automatically when water collects in these sumps upto a certain level. The automation of pumps is done with the help of sensors provided in each sump.

3.2 Drainage of Internal Courtyards

The building has three internal courtyards out of which two courtyards are at ground level and one courtyard has sunken portion at 1.2m below ground level. The rain water directly falling in the courtyards and from the adjoining terrace needs to be drained properly. The following drainage system have been provided to ensure that the water in courtyards is drained efficiently.

a) All along the periphery of the courtyards, a drain covered with sand stone grating has been provided. This peripheral drain is connected to one number 126mm internal dia pipe (with welded joint) passing through the sleeve provided at the time of casting of RCC to drain off the water to the external storm water drain.

b) The finished level of internal courtyards have been kept approximately 250mm below the ground floor level of building to avoid chances of water from the courtyards spilling over.

c) In the sunken courtyard, 4HP electric pump in a depressed area created in one corner has been provided to drain out the water from sunken portion of courtyard. The electric pump starts automatically at prefixed level of water with the help of sensor.

3.3 Drainage of Roof

The roof consists of different features at different levels i.e. domes, terrace garden/ Planters and sand stone paved area. The proper drainage of terrace for various areas as above have been achieved by making following provisions;

a) *Drainage of Domes :* All the domes (except focal dome) have been provided with sand stone chhajja of width 1.1m all along the periphery. The height of chhajja in all the domes except Auditorium is approximately 2.5m In case of Auditorium the chhajja height is approximately 5m towards parking side. The Auditorium dome has been provided with a peripheral gutter of width 450mm and depth varying from 225mm to 425mm. The rain water from dome terrace is drained through four rain water vertical gutters provided along the external wall of the Auditorium. The vertical gutters discharge the rain water on the lawn at terrace level. In case of other domes, the rain water from the domes flows over the chajjas and directly falls on the lawn & paved areas at terrace level.

b) *Drainage for Terrace Garden/Planters :* The terrace of the Parliament Library Building is visible from the Podium level of the Parliament House. In order to give pleasing view, the terrace has been partly covered with the terrace garden/ planters for approximately 5000sqm area.

The slope of minimum 1 in 100 has been provided towards spout in brick coba treatment in the areas where terrace gardens or planters were planned. Filter bed of 40mm size brick bats 75mm thick was laid after brick coba treatment, mild steel class B, L-shaped slotted strainer pipes 151numbers of 80mm dia and 750mm long have been provided to discharge the water from the garden/planters at higher level terrace to lower level. These have been further connected to cylindrical sand stone spouts through open drains of 80mm x 150mm size in between. The open channel have been covered with perforated sand stone jali. The water from upper terrace reaches to lower terrace at planters level through these strainer pipes, channels and spouts. Mild steel Class B, L-shaped slotted strainer pipes 107 numbers of 150mm dia and 480mm long have been provided at the outer

periphery of lower terrace of the building for planter area. These strainers are further connected with rectangular sand stone spouts of 900mm length and 150mm x 185mm size internal opening fixed in the outer wall of building to discharge the water to ground below. The rectangular spouts provided on internal periphery discharge the rain water to internal courtyards and the spouts of external planters discharge rain water to external area.

The slotted strainer pipe has been fabricated with two pieces of strainer pipes welded together to make L-shape. The slot sizes are 2mm to 3mm in width, at a spacing of 2mm to 3mm along the periphery and are of 80mm length at a spacing of 80mm along the length of the pipes. Around the strainer pipe 12.5mm graded stone aggregate and compacted coarse sand 150mm thick each have been provided to create filter bed which allows excess irrigation water from soil to reach

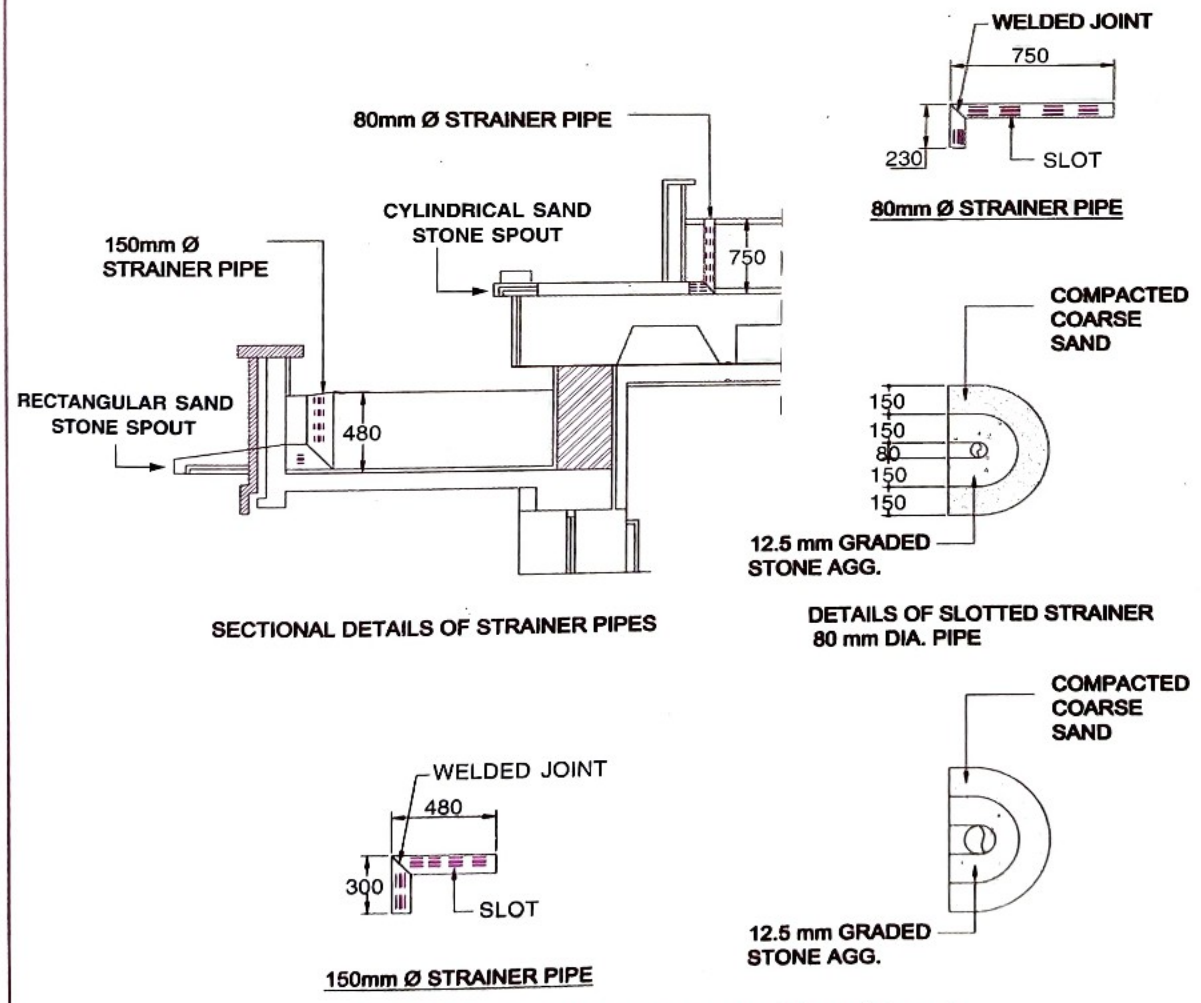


Fig 23.5 : Details of Strainer Pipes/Spouts

upto strainer pipe. The top end of strainer pipe has been kept at the top level of earth to allow surface rain water to reach directly to the strainer pipe for further draining off. The only disadvantage observed in this system is that the strainer pipes gets choked frequently and needs to be watched properly for regular maintenance.

c) *Drainage of Paved Area* : The terrace has 4460sqm red sand stone paved area. Rain water from paved area flows to the peripheral planters (at lower terrace) through open channel drains covered with sand stone grating and from there to the sand stone rectangular spouts.

3.4 Drainage of External Areas

The plot area of Parliament Library Building Complex is approximately 40000sqm, out of which the covered area of building at ground level is approximately 14000sqm. Remaining 26000sqm area has landscaped lawns, ground cover, road etc. The plinth level of the building is below the road level of adjoining roads i.e. Pt. Pant Marg and Talkatora Roads & the landscaping has been done in such a way that general flow of water is towards the building. Hence effective measures were required to be taken to prevent rain water from accumulating near the periphery of the building. Following provisions have been made for effective and speedy drainage of rain water.

a) At three entry gates where external roads are connected to internal RCC Roads, humps having top level approximately 300 mm higher than external road levels have been provided to prevent entry of storm water directly from external roads to the campus. At VIP entrance where raised hump was undesirable, a continuous drain covered with M.S. grating has been provided to catch any water coming from Parliament House side to Parliament Library Building.

b) Along BPST & Library side where general ground is sloping towards building, a continuous swale having invert level 150mm lower than plinth protection level have been provided. Gully chambers covered with RCC grating of size 450mm x 450mm have been provided in the swale at spacing of approximately 10m center to center.

c) Storm water lines of RCC pipes of dia varying from 300mm to 450mm have been laid along the periphery of the building. These storm water lines are connected to gully gratings to collect storm water. Outlets of these storm water lines are connected to the trunk storm water lines passing through Parliament Library Building campus at five places.

LANDSCAPING

1.0 GENERAL

The attempt was to achieve a landscape design expression in harmony with the architectural design where architecture and landscape merge to present a unified environment. Open spaces within the Library Building are subtle and complex. These are located between the inner core of the Building activities and external peripheral functions. Courtyards and Terrace Gardens form an important feature of design vocabulary, both architectural and landscape. The red and beige sandstones, used in the building are extended to the landscape finishes including pavings, steps, cladding of landscape elements like planters, light fixtures, fire hydrants, etc. thus presenting a sense of continuity.

The plantation scheme responds to the architectural expression- formal in the courtyards and terraces but informal in the areas outside the built form. Selection of plants is based on aesthetic considerations relating to the formal and informal character of the open spaces as well as the climatic considerations of sun & shade, reducing radiation and creating comfort in different seasons. Besides incorporating the existing matured trees on the site. The plantation presents the "Flora of Delhi" and provides variations in form, colour and texture during different seasons.

There are three distinct, but interrelated open spaces- the external open spaces, the courtyards and the terrace gardens.

2.0 EXTERNAL OPEN SPACES

The landscape treatment of various open spaces within the complex and outside the building are based on the functional and aesthetic aspects of landscape design (alignments, scale, setting etc.) which gets reflected in the landscape treatment of the roads, entrances etc. The existing trees including Eugenia jambolana (Jaman), Bombax malabaricum, Azadirachta indica (Neem), Bauhinia spp. (Kachnar) etc. are protected and integrated in the landscape proposal by the use of trees like Azadirachta indica, Bauhinia purpurea, Jacaranda mimosaefolia, Bauhinia variegata, etc. The areas around the building which will have shade have been planted with ground



External Landscape



Trees, Shrubs, Ground Covers – BPST Area



Lawn with Tree between Library and Auditorium

covers like Alternenthra green which wraps around the whole building plinth thereby unifying the various areas. The lawns have been planted in the areas getting sun lights. The overall feeling is of a rolling landscape with various trees, shrubs, and ground covers.

The open space between the Library and the Auditorium block, an "open ended courtyard" outside the building has a large number of trees including Jacaranda mimosaefolia, Erythrina indica, Bauhinia variegata.

3.0 COURTYARDS

The three courtyards, though similar in scale, are designed differently to respond to the adjoining functions in the building. The unifying elements include finishes (red and beige sandstones) and primary trees (Plumeria alba) placed at regular intervals synchronizing with the architectural rhythm of openings and columns of the corridors. Plumeria alba (Champa), traditional trees with regular branching pattern, deep green leaves and white flowers, further help to unify the different courtyards. The creepers viz. clematis gouriana and golden green low hedge of Duranta Goldiana in the upper planters reinforces this unity.



Plantation - Sunken Court Yard



Courtyard with Planters



Courtyard with Water Body

a) The First Courtyard built adjoining the MPs' Reading room and BPST Lecture Room, has an atmosphere of tranquility around a sunken amphitheatre, which is symbolic of LIBERTY of thought, expression, belief, faith and worship. Chorisia speciosa tree in the planter at the back of the stage dominates this courtyard. Grass-jointed paving helps to soften the hard surface. Other plants like Plumeria alba (tree) with white flowers, and clumps of Ficus benjamina 'variegata' (shrub) with bright milky green foliage, reinforces the tranquil atmosphere. Tradescantia albiflora 'Albovittata' (ground cover) with its dark green and deep red leaves act as the unifying element binding the various types of plants within the courtyard.

b) The Second Courtyard is enclosed by the Banquet Hall, and museum. This courtyard is dominated by a large planter with Anthocephalus cadamba (Kadamba), a majestic traditional tree symbolizing JUSTICE- social, economic, and political. The other plants include Ficus benjamina 'variegata' Rhapis excelsa, Pleomele reflexa in the large planter and Plumeria alba, Areca palm, asparagus densiflora, and Duranta Goldiana in other medium and small planters apart from serving the functional requirements of breaking the scale and softening the hard surfaces explore the mental faculties through perceptive senses of touch, smell, vision, thereby adding another dimension to the quality of environment inside the building.

c) The Third courtyard is surrounded by the Museum and Auditorium- its space can be used for outdoor exhibitions. A water pool with black granite cladding gives a dramatic reflection of the surrounding building. Water, which always maintains its level, represents EQUALITY of status and opportunities.

4.0 TERRACE GARDEN

The height of the Library Building has been restricted to the podium of the Parliament House. Strategically located planters with Hemellia patens, Malphigia glabra, Cuphea hyssopifolia, Hibiscus rosa sinensis (arranged in hierarchal manner) Wedelia trilobata (ground cover) and the Lawn areas present an appearance of a formal garden and a fore court for the Parliament House.

Terrace Garden

Project Management

Many times the terms 'Project Management' and 'Project Monitoring' are used synonymous with each other. However, it is obvious that Project Monitoring could at best be a part of Project Management but cannot replace it. The term Monitoring does not give the full idea of the tasks before a Manager and the travails and tribulations that he undergoes while seeing a project through. The role of a Project Manager is not that of just a Monitor but is a delicate mixture of the following.

- A team leader
- A team player or worker
- A go-between for 2 or 3 or more construction disciplines which are at loggerheads with each other
- A go-between for 2 or 3 or more warring contracting agencies.
- A father figure who is willing to accommodate the requirements of lesser players in the job.

The task of the Project Manager is, therefore, unenviable. He could be perceived to be unduly favouring a particular discipline or he could be perceived as being unduly demanding on some other discipline while all the time the Project Manager is only having the interest of the Project upper most in his mind.

The project management principles were applied in earnest right from the start of the project i.e. at the foundation stage. The work was broken down into a number of activities and fortnightly targets were fixed (Fig 25.1). The actual progress was measured against these targets and corrective measures initiated or revised targets were set from time to time. The progress of work was also pictorially depicted on a layout plan, so that the status of various activities at various locations could be gleaned at a glance.

It was because of such close monitoring that the foundation work involving one lakh cubic meter of rock excavation (without blasting), one lakh cubic meter of soil excavation, 410 meters of diaphragm or retaining walls and 2112 numbers of rock anchors could be completed within two years so that the work on super structure could start without delay in July, 1996.

The superstructure activities were monitored by a PERT Chart from which individual quantities charts were prepared specifying monthly, weekly or even daily targets for various items. Emphasis was laid on procurement of materials for various finishing and cladding items.

Thus the superstructure was monitored by identifying key elements - for instance the precasting and placing of coffers. Daily targets were fixed for casting of coffers (100 coffers in a day). The fact that we were able to persuade the contractors to adopt steam curing of coffers to cut down the time taken in the casting cycle (even though this was not part of the contract) speaks volumes of the monitoring strategies that were adopted at that time.

The other items chosen for intensive monitoring (for procurement and fixing) were:

- Wall lining with Burma Teak wood or Marble
- Flooring of different kinds
- False ceiling in coffers
- Wooden frames & shutters

The year 2000 saw the Project entering the last decisive phase. Credit must go to the Project Managers and the Team who had nurtured this project up to this stage. In the middle of year 2000 the position was as follows.

a) The superstructure was around 80% complete (in physical terms) with a large amount of finishing works yet to be done.

b) Practically no progress in respect of the domes, which work had been awarded only in February 2000.

c) A number of E&M services yet to be awarded.

d) Target for completion committed to the Lok Sabha Secretariat was July 2001 (barely a year away).

e) Expenditure incurred up to March 2000 was Rs. 100 crores and the balance Rs. 100 crores was expected to be spent by July 2001.

On the face of it, the task appeared daunting, the most difficult being construction of the domes which was a totally new construction methodology never tried by CPWD before. Equally worrisome was the task of integrating the civil and E&M disciplines in the matter of providing services and false ceiling. One got the feeling that there was some hesitation – a little doubt in the minds of most of the team members about the feasibility of the target (and justifiably so considering the amount of the balance work and complexity of the job on hand). But the message from the bosses was very clear – the July '01 target was sacrosanct.

Therefore, the first task before the Project Manager was to instill among the project team a sense of confidence and pride in what they were about to achieve. Team members in this case were all hand-picked and each of them were experts in their own fields. Therefore, what was required was merely a message from the top that the completion by the target date was our prime objective. It was not enough, however, to convey this message by a mere written communication (an Office Memorandum, if you like) but by action to indicate that we meant business. That is -

- where agencies were to be fixed, by quickly doing that without spending too much time, nit-picking on procedures, costs etc.
- where problems cropped up at site, quickly deciding an alternative solution so that the work could proceed (again, not being too fussy in looking for that elusive "perfect" alternative solution)

- by reviewing at very frequent intervals and in a detailed fashion involving all disciplines
- but most important of all, showing in all its actions that the top management was ready to take calculated risks to help achieve the targets thus establishing that the top management was also very much a part of the team and was willing to stretch itself to ensure completion on target.

The first task was to prepare a detailed programme of work incorporating electrical and mechanical services, furniture etc. The standard MS Project software was found to be most convenient to handle, easy to read and capable of being presented in A-4 size print outs. It also had facilities for linking connected tasks, very much a PERT/ CPM feature.

The programme was made keeping the deadline as July 31, 2001 for completion of the project. The volume of work was so large that the very first programme made for Superstructure ran into 1362 items (Fig 25.2). Obviously reviewing such a large programme in one sitting was not possible. Therefore weekly review meetings were held covering roughly $^{1}/_{5}^{th}$ of the entire programme in one sitting.

For the domes alone, considering the importance and complexity of the job, a separate M.S. Project programme was developed running into 217 items (Fig 25.3). This was a much more manageable programme and the frequency of review was 10 days.

With every review meeting we noticed slippages in a number of items requiring continuous revision of the programme. The M.S. project software has a feature called "base line" which is in effect the original programme. The revised programme is automatically plotted against this base line thereby giving us an immediate feel of the extent of slippage. Some of these slippages were attributable to the department and some to the contractor not being able to arrange adequate resources. In the existing construction industry in India today this is a fact of life that we have to live with. For instance, the main contractor depends on his supplier; who in turn depends on his principals; who in turn looks up to his manufacturer; who is at the mercy of agencies supplying raw materials, supplying electric power to his factory and so on. The chain is long and everyone along the chain is not as committed to the completion of the Parliament Library Building as the main contractor (assuming that he is committed !). This frequent revision of the programmes was therefore a matter of necessity and not to be apologetic about, as long as we were aware that the contractor was making earnest efforts in his subsequent planning to make up for lost time.

In the month of March 2001, we brought out our difficulties to the notice of the Secretary-General, Lok Sabha Secretariat and subsequently to the Hon'ble Speaker himself. They were quite understanding and directed us to complete the work with the shortest possible delay.

The programme initially prepared for Superstructure (1362 items Fig 25.2) was fine in the initial stages when a large number of major Superstructure activities were in progress

PARLIAMENT LIBRARY PROJECT

SUB HEAD: FOUNDATION SYSTEM

DATE OF START : 13.03.94
DATE OF COMPLETION : 12.12.95
MODIFIED DATE OF COMPLETION : 30.04.96

BAR CHART

LEGEND ▭ PROGRAMME ▭ WORK COMPLETED

PROGRESS AS ON 16.07.95

S.No.	ITEM OF WORK	% PROGRESS ON DATE OF REVIEW	BALANCE QUANTITY AS ON 01.03.95
1	SOIL EXCAVATION	76%	35600 M^3
2	ROCK EXCAVATION	96%	31950 M^3
3	INCLINED ANCHORS	85%	164 Nos
4	CURTAIN GROUTING	50%	200 M
5	OPEN CAST R.WALL	23%	88 M
6	PCC BASE RAFT	30%	17550 M^2
7	WATER PROOFING(H)	26%	17600 M
8	BASE RAFT	19%	15900 M^3
9	VERTICAL ANCHORS	20.6%	1400 Nos
10	WATER PROOFING(V)	16%	10400 M^2
11	R. WALL (ISLAND)	3.0%	2300 M^3
12	PROTECTIVE WALL	4.8%	1600 M^3
13	DEMOBILISATION		

1995												1996				REMARKS
March	April	May	June	July	Aug	Sep.	Oct.	Nov.	Dec.	Jan	Feb.	Mar.	Apr.	
5000 4500	4500 4500	4000 4000	3000 2500	1500 1050	525 525									1. THE QUANTITY SHOWS THE PROGRESS REQUIRED IN RESPECTIVE FORTNIGHT
2500 3250	3250 3250	3250 3000	2500 2500	1250 1250	1000 1000	1500 1000	1000 450							
33 33	33 33	32												2. ROCK SURFACE PREPARATION NOT INCLUDED IN MASS ROCK EXCAVATION
50 50	50 50													
12 12	19 20	25												
500 500	750 750	900 800	900 700	600 600	600 600	1000 1000	1000 1000	1000 1050	1050 1050	1100				
350 350	800 650	600 700	650 650	500 550	500 500	1100 1050	1100 1050	1000 1000	1200 1200	1200 1150				
150 300	300 850	800 600	500 600	450 450	450 450	750 900	900 800	850 850	870 870	900 900	900 890			
20 20	25 25	35 45	55 45	45 50	45 50	60 60	50 55	65 65	65 80	80 85	60 64	64 64	64 64	
200 250	250 283	350 370	450 450	375 375	375 375	450 450	450 450	450 450	450 375	375 375	455 430	477 315	335	
30 30	30 30	85 85	85 85	85 85	85 80	70 65	65 120	120 145	145 140	140 150	150 162	150		
26 36	35 45	45 55	50 50	50 60	40 65	70 70	70 75	75 75	80 80	80 75	80 70	70 70		

Fig 25.1 : Monitoring Progress - Foundation System

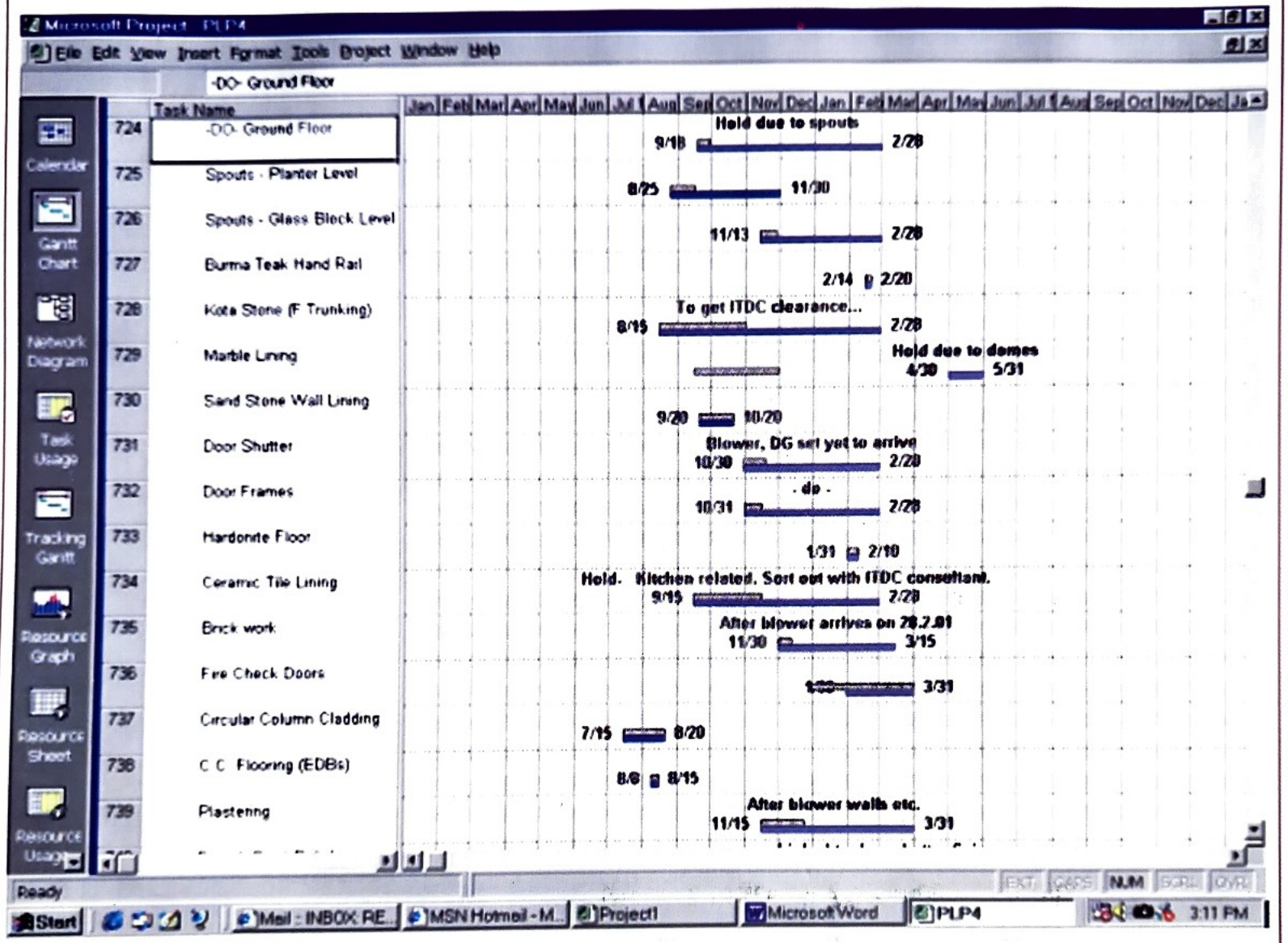


Fig 25.2 : A View of MS Project Monitoring Programme – Super Structure

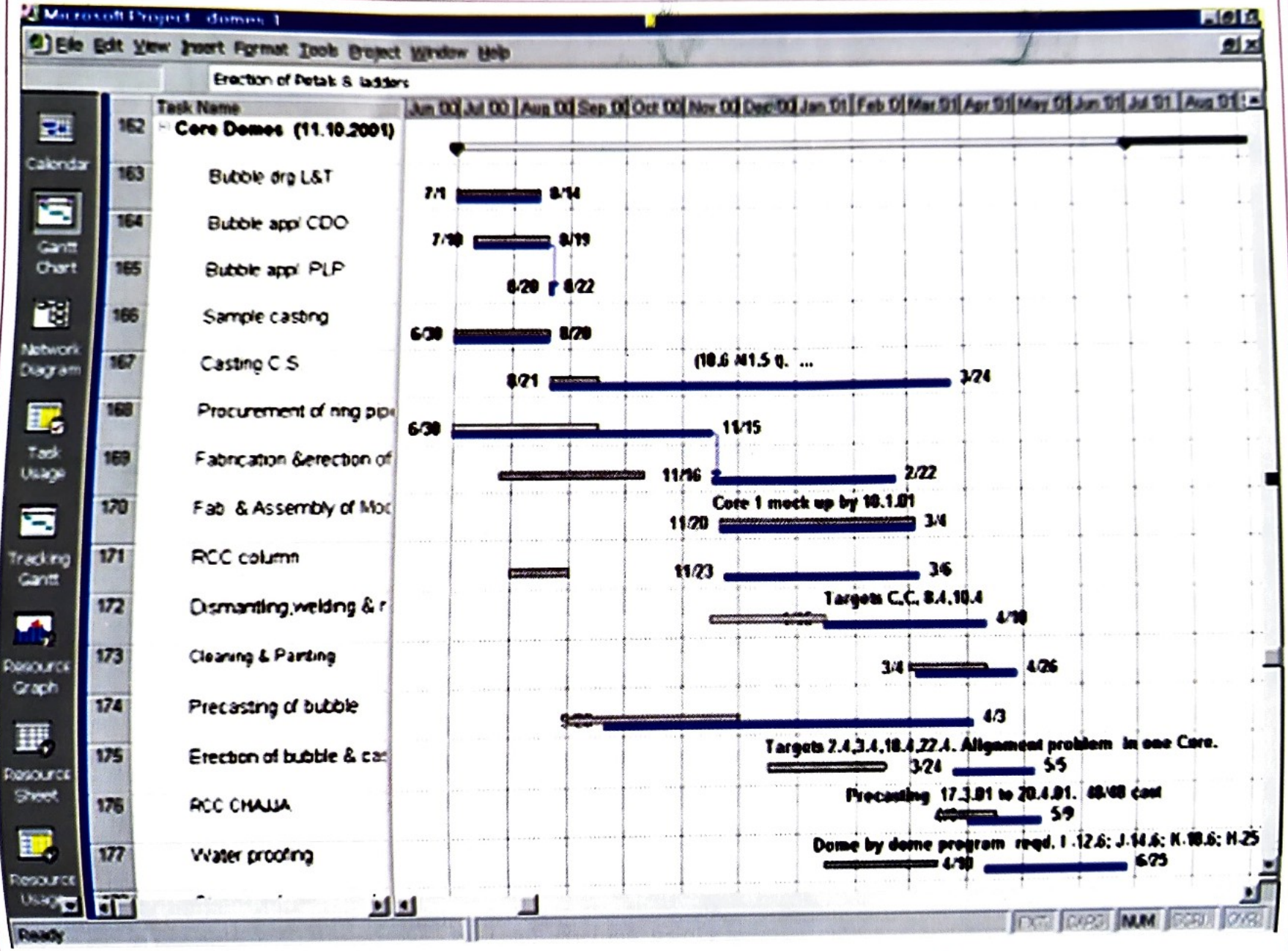


Fig 25.3 : A View of MS Project Monitoring Programme – Domes

TARGET DATE FOR COMPLETION OF VARIOUS ACTIVITIES

BLOCK- CORE - H

Review date : 22.09.2001

Sl. No.	Description	Second Basement	First Basement	Ground Floor	First Floor	Terrace
1.	**TREATMENT EXPANSION JOINTS (LIBRARY)**	30.9.01	30.9.01	15.9.01	10.9.01	10.9.01
2	**COVERING FHC SHAFTS**					
a)	**Electrical Clearance**	**Completed**	**Completed**	**Completed**	**Completed**	**Completed**
b)	Covering	25.9.01	25.9.01	20.9.01	20.9.01	Completed
c)	Cleaning of fixtures & fittings.	31.10.01	5.12.01	31.10.01	31.10.01	---
3.	**COVERING TOILET SHAFTS**	---	---	---	---	20.9.01
4.	**COVERING EXHAUST SHAFTS**	---	---	---	---	20.9.01
5.	**COVERING EDBS (SKIRTING)**	Completed	Completed	Completed	Completed	---
6.	**CLOSING SLEEVES**	---	Completed	---	---	---
7.	**MSCELLANEOUS**					
a)	Covering open drain	Completed	---	---	---	---
b)	Red/White Sand stone coping/ spout.	---	---	---	30.9.01	30.9.01
c)	Cutting holes for Hot & Chilled Water Expansion Tank.	---	---	---	---	15.9.01
d)	Inlet water connection Hot & Chilled water expansion tank	---	---	---	---	20.9.01
e)	S/S pipe in Glazed Window.	---	---	---	15.9.01	---
8.	**FALSE CEILING / FINISHING IN COFFERS**					
a)	Frame work i/c. Primer etc.	---	Completed	Completed	Completed	---
b)	Burma teak panel	---	---	Completed	Completed	---
c)	Gypsum Board	---	31.10.01	---	---	---
d)	Vinartex	Completed	31.10.01	Completed	Completed	---
e)	**Fixing light fittings**	**15.10.01**	**30.11.01**	**Completed**	**Completed**	---
9.	**FRAME WORK - DROP CEILING**	Completed	Completed	Completed	Completed	---
10.	**BOARD FIXING- DROP CEILING**					
a)	**Electrical clearance**	**Completed**	**15.11.01**	**Completed**	**Completed**	---
b)	Board Fixing i/c. centre line & one coat painting	20.9.01	22.11.01	Completed	Completed	---
c)	**Marking openings- Elect-I**	**25.9.01**	**25.11.01**	**Completed**	**Completed**	---
d)	**Marking openings- Elect-II**	**25.9.01**	**25.11.01**	**Completed**	**Completed**	---
e)	**Marking openings- Elect.-III**	**25.9.01**	**25.11.01**	**Completed**	**Completed**	---
f)	Cutting holes/ openings as above	28.9.01	27.11.01	Completed	Completed	---
g)	**Fixing fixtures - Elect. I**	**12.10.01**	**4.12.01**	**Completed**	**Completed**	---
h)	**Fixing fixtures - Elect. II**	**12.10.01**	**4.12.01**	**Completed**	**Completed**	---
i)	**Fixing fixtures - Elect. III**	**12.10.01**	**4.12.01**	**Completed**	**Completed**	---
11.	**DOORS , WINDOWS ETC.**					
a)	Doors	30.9.01	30.9.01	Completed	Completed	---
b)	Door fittings	30.9.01	30.9.01	15.9.01	15.9.01	---
c)	Architrave Refixing.	30.9.01	30.9.01	Completed	Completed	---
d)	Supply & Fixing Door stoppers	30.9.01	30.9.01	30.9.01	30.9.01	---
12.	**FIRE CHECK DOORS/ COMPARTMENTATION**					
a)	Lintel / Openings/ Stone Mullions as per size	Completed	Completed	Completed	Completed	---
b)	Additional walls	Completed	Completed	Completed	Completed	---
c)	New walls above lintel level(QED)	25.9.01	Completed	Completed	Completed	---
d)	Breaking walls above lintel level	---	---	Completed	Completed	---
e)	Fixing Doors	30.9.01	20.9.01	10.9.01	Completed	---
f)	Door fittings	30.9.01	30.9.01	20.9.01	20.9.01	---
13.	**FIRE HOSE CABINET**					
a)	**Fixing Wet Riser Pipe**	**Completed**	**Completed**	**Completed**	**Completed**	---
b)	Finishing Door opening	Completed	Completed	Completed	Completed	---
c)	Fixing frame.	30.9.01	30.9.01	10.9.01	10.9.01	---
d)	Fixing shutters	30.9.01	30.9.01	10.9.01	10.9.01	---
e)	Fixing Glazing	31.10.01	31.10.01	31.10.01	31.10.01	---
f)	Fixing Door Fittings.	30.9.01	30.9.01	10.9.01	10.9.01	---
14.	**FIXING OF T.V. / CAMERA BRACKETS**	---	20.9.01	Completed	Completed	---
15.	**WALL FINISHING / WALL LINING**					
a)	Burma Teak	---	---	Completed	Completed	---
b)	Red /White sand stone cladding	25.9.01	Completed	Completed	Completed	---
c)	Grit wash Rectification & completion	30.9.01	30.9.01	---	---	---
d)	Electrical Clearance Brick work Book Lifts- 2 Nos.	5.10.01	Completed	Completed	Completed	---
e)	Brick work Book Lift- 2 Nos.	10.10.01	30.9.01	30.9.01	30.9.01	---
f)	Electrical clearance facia - Book lift -2 Nos.	15.10.01	15.10.01	15.10.01	15.10.01	---
g)	Granite facia Book lift - 2 Nos.	31.10.01	31.10.01	31.10.01	31.10.01	---
16.	**FLOORING**					
a)	Kota/ MKJ Final Grinding & Polishing					
i)	Cleaning for marking	Completed	18.9.01	Completed	Completed	---
ii)	Marking patchy stones	Completed	19.9.01	Completed	Completed	---
iii)	Replacement	Completed	21.9.01	Completed	Completed	---
iv)	Final grinding Polishing	Completed	30.9.01	Completed	Completed	---

Fig 25.4 : Floorwise/Blockwise Activity Review Chart

ANNEXURE-1

PROGRESS REPORT OF CARBON STEEL CASTINGS (REVIEWED ON 15.02.2001)

Sl No.	Agency	Activity	Total scope	1.2.01	3.2.01	5.2.01	6.2.01	7.2.01	8.2.01	10.2.01	12.2.01	13.2.01	14.2.01	15.2.01
				Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity
1.	M/s R.V.Engineering (Core)	Casting	41.5	37.35	41.5	41.50	41.50	41.50	41.50	41.5	41.50	41.50	41.50	41.50
	(Target 21-2-01)	Machining	41.5	23.21	23.86	25.98	25.98	25.98	28.41	28.8	29.85	31.07	31.60	31.60
		Testing	41.5	19.09	21.06	23.79	25.16	25.16	25.89	26.6	26.6	26.60	30.38	30.38
		Despatch	41.5	18.24	18.24	18.24	18.24	21.64	22.14	24.44	25.82	25.82	25.82	25.82
		Received at site	41.5	18.24	18.24	18.24	18.24	21.64	22.14	24.44	25.82	25.82	25.82	25.82
2.	M/s Hastalloy (Lib/ Mus)	Casting	62.5	46.9	46.9	48.20	48.2	48.20	48.20	48.2	48.2	48.20	51.21	51.21
	(Target 5.3.01	Machining	62.5	33.12	33.12	34.0	34.0	34.0	34.0	34.0	34.0	40.60	40.60	40.60
	Casting = 20.2.01	Testing	62.5	32.10	32.10	32.10	32.10	31.10	32.10	32.1	32.1	34.60	34.60	34.60
	Maching = 25.2.01	Despatch	62.5	23.80	23.8	23.8	23.8	23.80	23.80	23.8	23.8	34.60	34.60	34.60
	Despatch= 28.2.01	Received at site	62.5	18.6	18.60	18.6	18.60	21.40	21.40	21.4	21.40	21.4	21.40	21.40
3.	M/s Kartik Steel (BPST/AV/Services)	Casting	34	20.31	22.95	23.79	24.13	25.12	26.46	26.46	27.09	27.09	27.09	28.06
	(Target -20.2.01)	Machining	34	13.89	14.39	14.98	15.36	16.98	18.10	18.10	18.10	18.10	18.10	21.89
	Casting = 20.2.01	Testing	34	12.89	12.90	13.30	13.70	13.95	14.70	14.70	14.7	14.70	14.70	14.70
	Maching = 25.2.01	Despatch	34	12.39	12.39	12.39	12.39	12.39	12.39	12.39	12.39	12.39	12.39	12.39
	Despatch= 28.2.01	Received at site	34	3.08	3.08	3.08	3.08	3.08	12.39	12.39	12.39	12.39	12.39	12.39

Fig 25.5 : Progress Report - Carbon Steel Castings

SCHEDULE FOR LIBRARY / MUSEUM BUBBLE CASTING

M	T	W	T	F	S	S

Nov -2000

		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	(17)	18	19
20	(21)	22	23	24	(25)	26
27	28	(29)	30			

Type "A" 4 x 1 = 4 Bubbles

Dec-2000

				1	2	(3)
4	5	6	(7)	8	9	10
(11)	12	13	14	(15)	16	17
18	(19)	20	21	22	(23)	24
25	26	(27)	28	29	30	(31)

Type "A" (7x3+1x 2)= 23 Bubbles

Jan-2001

1	2	3	(4)	5	6	7
(8)	9	10	11	(12)	13	14
15	(16)	17	18	19	(20)	21
22	23	(24)	25	26	27	(28)
29	30	(31)				

Type "A" 8x 3= 24 Bubbles

Fig 25.6 : Progress Review - Bubbles Casting

which were not linked with the completion of works of any other discipline. But as we proceeded towards the completion date, we needed to start concentrating on individual floors, individual areas and indeed, individual rooms. So we shifted gears and made out a simpler but more detailed programme which listed out all pending activities floorwise, blockwise and started monitoring them at weekly intervals (Fig 25.4).

Similarly for the Domes (this did not have any linkage with completion of work by other agencies) we had to workout a separate programme chart (Fig 25.5) for watching the receipt of castings at site on a daily basis. Likewise, the precasting of concrete bubbles was a large activity which needed to be watched totally independently (Fig 25.6). The progress of other activities of Domes were of course watched through the original M.S. Project programme.

In the event, the work was substantially completed in January 2002 and we were in a position to inaugurate the building in January 2002. However due to other engagements of the VVIPs, the inauguration could be done only in May 2002.

The Project Management (and not merely Project Monitoring) of this mammoth project was a unique experience in itself. The lessons that it taught us are -

- A Project Manager should be more committed to the Project than any other member of his team.
- He should make every member of the team feel that his assigned task is as important as that of any other memebr of the team.
- He should learn to give credit to his team for the successes and take responsibility for the failures.
- He should be willing to take calculated risks along the way.

But more important than any other is the lesson that one can manage his project much more efficiently if multiplicity of agencies is avoided. More the agencies more chaotic is the scene – and deeper the mess.

QUALITY ASSURANCE

1.0 GENERAL

Parliament Library Project being a prestigious and hi-tech project of CPWD, it was considered essential to follow a quality assurance system befitting the importance of the Project.

Internationally acclaimed ISO–9002 Quality System provides a model for quality assurance and was considered essential for the Project. The basic documents like Quality Manual & Procedure Manual were formulated and submitted to the BIS who are accredited by Raad Voor de Certificate, Netherlands for quality systems certification under ISO–9002.

A number of visits were made by the Auditors & the officers of BIS to the Project site to audit the system evolved. The non-conformities pointed out by the Audit Team were got cleared & BIS confirmed about the grant of licence on September 9, 1996 for a period of three years i.e. September, 1996 to August, 1999. This was the first such certificate under ISO–9002 Quality Systems to be issued to a Civil Engineering Organization by the BIS in the country. Though the certificate was awarded initially for a period of three years ending August 31, 1999, this was further renewed for 3 years i.e. upto August 31, 2002.

2.0 QUALITY POLICY

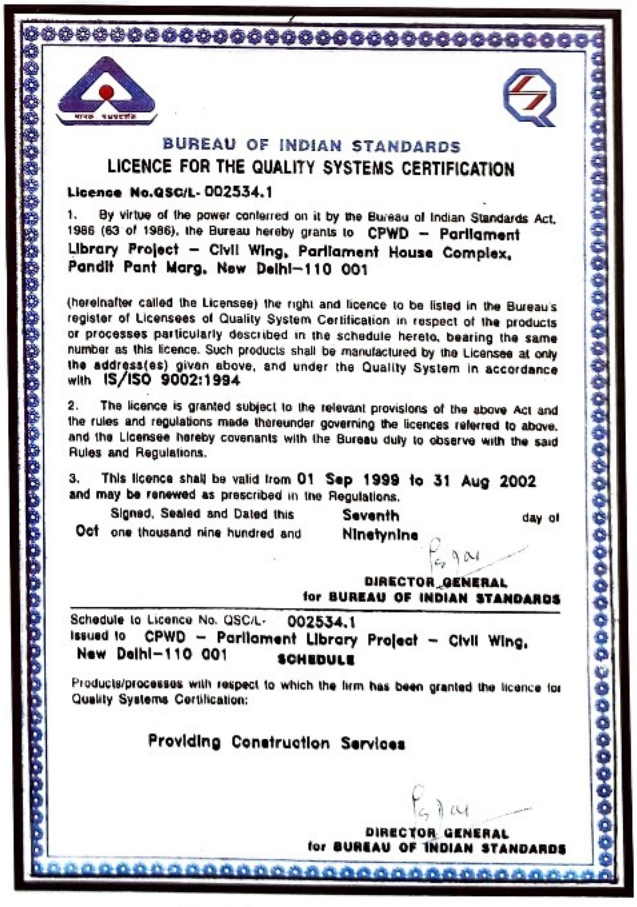
The Parliament Library Project Team's endeavour was to ensure that :

a) the building work assigned to the PLP meets the functional needs of the client.

b) the building conforms to architectural drawings prepared & specifications for finishing items as proposed by the architect.

c) building is structurally sound, cost effective & easy to maintain; the quality of various components of the building conforms to the standards laid down; and

d) there is no time and cost overrun to the extent possible for which appropriate corrective action shall



BUREAU OF INDIAN STANDARDS

LICENCE FOR THE QUALITY SYSTEMS CERTIFICATION

Licence No.QSC/L- 002534.1

1. By virtue of the power conferred on it by the Bureau of Indian Standards Act, 1986 (63 of 1986), the Bureau hereby grants to CPWD – Parliament Library Project – Civil Wing, Parliament House Complex, Pandit Pant Marg, New Delhi–110 001

(hereinafter called the Licensee) the right and licence to be listed in the Bureau's register of Licensees of Quality System Certification in respect of the products or processes particularly described in the schedule hereto, bearing the same number as this licence. Such products shall be manufactured by the Licensee at only the address(es) given above, and under the Quality System in accordance with IS/ISO 9002:1994

2. The licence is granted subject to the relevant provisions of the above Act and the rules and regulations made thereunder governing the licences referred to above, and the Licensee hereby covenants with the Bureau duly to observe with the said Rules and Regulations.

3. This licence shall be valid from 01 Sep 1999 to 31 Aug 2002 and may be renewed as prescribed in the Regulations.

Signed, Sealed and Dated this Seventh day of Oct one thousand nine hundred and Ninetynine

DIRECTOR GENERAL
for BUREAU OF INDIAN STANDARDS

Schedule to Licence No. QSC/L- 002534.1
Issued to CPWD – Parliament Library Project – Civil Wing, New Delhi–110 001 SCHEDULE

Products/processes with respect to which the firm has been granted the licence for Quality Systems Certification:

Providing Construction Services

DIRECTOR GENERAL
for BUREAU OF INDIAN STANDARDS

Certificate of ISO–9002

be taken from time to time.

3.0 QUALITY OBJECTIVES

Basic "Quality Objectives" were,

a) adherence to specifications, with emphasis on defect prevention in all areas of operation;

b) sustain quality of its construction & services to meet the client's stated/implied needs.

c) provide confidence to the PLP team so that the desired quality is achieved/ sustained;

d) provide confidence to the client that the desired quality would be provided in the construction & services;

e) to avoid time and cost overrun;

f) continuous improvement in construction processes/systems;

g) comply with relevant foreign standards in case Indian Standards are not available.

4.0 QUALITY SYSTEMS

The Parliament Library Project has maintained a documented quality system, covering all the spheres of construction activities and allied services to ensure that all activities of construction and services conform to specific requirements. Master list was maintained as per Master List register to identify various documents to be maintained with upto date revisions. The following documents have been maintained for execution of the main works i.e. Foundation System, Superstructure & Domes.

Sl. No.	Subject of Document	Document No.		
		Foundation System	Superstructure	Domes
1.	Drawing Register	—	5B	5D
2.	Drawing Issue Register	6A	—	—
3.	Water Test Register	7A	7B	7C
4.	Soft/Deleterious Material in Stone Aggregate (10/20/40mm)	8A	8B	8C
5.	Sieve Analysis for 10/20/40mm Stone Aggregate	9A	9B, C, D	—
6.	Particle Size Distribution of Sand	10A	10B	10C

c) Protective Wall

d) Counterfort Retaining Wall

e) Horizontal Water Proofing Treatment

f) Vertical Water Proofing Treatment.

g) Injection Grouting.

5.2 Superstructure

a) Columns

b) Beams/Suspended Floors/Staircase Slabs

c) Precasting of Coffers

d) Placing of Precast Coffers

e) Stone Cladding on Circular RCC Columns.

f) Wood Work

g) Flooring

h) Wall Lining

i) Final Inspection.

5.3 Domes

a) Columns

b) Beams/Suspended Floors/Staircase Slabs.

5.4 Sample Check List

The check list for Vertical Rock Anchors is reproduced as below, as a sample.

Sl. No.	Item	Status
1.	Date of Inspection	—
2.	Vertical Anchor No. & Location	—
3.	Whether materials used conform to relevant specifications	Yes/No
4.	Layout as per drawing checked	Yes/No
5.	Drilling of hole upto required depth done	Yes/No
6.	Casing pipe in over burden provided	Yes/No
7.	Whether hole has been grouted for water proofing and required lugeon value obtained.	Yes/No
8.	Whether further redrillings & water proofing of hole is required.	Yes/No

9.	Whether hole is ready for homing	Yes/No
10.	Whether Anchor cable already prepared is of required length and OK	Yes/No
11.	Whether epoxy coatings, PVC sheathing and alkalethene pipe are in order.	Yes/No
12.	Whether anchor hole has been washed and filled up with water immediately before homing.	Yes/No
13.	Whether grout pump is ready with cement grout mixed with water cement ratio of 0.4	Yes/No
14.	Fixed length grouting done	Yes/No
15.	Free length of Anchor filled up with grout has been washed	Yes/No
16.	Whether alkalethene pipe has been withdrawn completely	Yes/No
17.	Whether anchor hole has been covered to avoid ingress of foreign material	Yes/No
18.	Whether records of anchor (Homing & stressing) being kept in approved formats	Yes/No
19.	Signature of Junior Engineer	—
20.	Signature of Assistant Engineer/Executive Engineer	—

6.0 METHOD STATEMENTS

The work of construction of domes involved execution of new items which were to be executed with precision & quality. Method statements were submitted by agency and were approved by Engineer-in-Charge before execution of work for following items.

a) Concreting

b) Reinforcement

c) Welding of Mac Alloy Bars to Castings (40 mm thick)

d) Welding of Carbon Steel Pipes to Pipes or Castings to Carbon Steel Pipes.

e) Welding Procedure Stainless Steel Domes

f) Welding Procedure Carbon Steel Domes

g) Welding Sequence – Schematic Sketches

h) Auditorium Dome Structure

i) Erection Sequence for VIP/Core Dome

j) Erection Sequence for BPST, AV & Services Domes

k) Erection Sequence for Library & Museum Domes

l) Water Proofing Membrane

m) Glass Block Wall.

6.1 Sample Method Statement

The method statement for erection of VIP/Core Dome structural elements is reproduced below, as a sample.

a) *Geometrical Survey* : Over and above the controls on assemblies and material quality specified in material specification, the fabrication and erection of domes require great geometrical precision. Geometrical survey shall be carried out at each step of the fabrication and erection process. All measurements taken shall be recorded. Eventual geometrical rectifications are to be carried out before passing to the next stage. Geometrical measurements shall be accurate to within ±1mm. To achieve this it shall be necessary to use suitable Jigs to allow accurate measurements of system points and assembly points. All steel work elements must be fabricated using form work or Jigs. The relative and absolute fabrication tolerance between assembly points (bolt holes, pin assembly holes etc.) of each steel element should be ±2mm.

b) *Specific Checks*

i. The line, level, diameter & alignment of ring beam shall be rigorously checked.

ii. The length between node assemblies of vierendeel elements shall be checked.

iii. Length, between pin assembly holes on ring beam shall be checked.

iv. All cast components shall be subjected to geometry check.

c) *Erection Mockup Assembly*

i. Procure, roll & weld the plates for ring pipe.

ii. Bend the pipes for ring beam assembly as per desired curvature.

iii. Get all castings done for VIP/Core Dome

iv. Bend and cut the vierendeel pipes to required size/length.

v. Erect the staging frames for mockup assembly on well compacted ground.

vi. Assemble and positioning of ring beam on timber runners kept on ground (tolerance between pin assembly hole ±2 mm).

vii. Progressive assembly of dome structure elements starting from the apex working towards perimeter in concentric rings, positional tolerance ± 5 mm in the tangential surface.

viii. Inspection of mock up assembly for geometrical survey and other dimensional checks.

ix. Tighten the assembly with temporary erection bolts by fixing the shims wherever required.

x. Prepare templates for various types of bubbles and match with the above mockup for any deviations and correct the mockup accordingly.

xi. Indicate the match mark on all joints of the mockup assembly.

xii. Dismantle the pipes and casting assembly between two end connectors and take it down for welding in site workshop.

xiii. Weld the casting supports type F & G on ring beam in position.

xiv. Weld the ring beam excluding the site erection joints in position.

xv. Dress and surface finish the welds to match with pipe and casting.

xvi. Acid pickling of all weld joints of stainless steel (50mm on either side) shall be done to remove any discoloration.

xvii. Carry out non destructive testing on shop welds as per specification and repair if any shall be done immediately followed by NDT.

d) *Erection at Site*

i. Position and adjustment of base plates on concrete columns (tolerance ± 2mm).

ii. Bearing plates shall be temporarily fixed in sliding direction to prevent movements.

iii. Assembly and positioning of ring beam on sliding supports.

iv. Sliding supports liberated only once the ring beam has been completely assembled and checked.

v. Progressive assembly of dome structure starting from the perimeter working towards apex in concentric rings by fixing permanent HSFG bolts & shims.

vi. Align the domes as per required geometry.

vii. Tighten the bolts to required torque only after geometrical survey and adjustment of the structure to tolerance limits.

viii. Complete the site joint welding of ring beam followed by NDT.

ix. Release the trusses and dismantle the staging.

x. Check for deflection, if any.

7.0 QUALITY ASSURANCE PLAN

In order to ensure quality of the complicated "Domes" structures, M/s IRC Engineering Services, New Delhi was approved as testing agency & M/s CEIL Engineers India Ltd. was appointed for third party inspection for various testing procedures & requirements. The quality assurance plan was issued for following items of domes clearly identifying the responsibilities of various agencies.

a) Carbon Steel/Stainless Steel End Connectors.

b) Welding

c) Carbon Steel Tubes

d) Stainless Steel High Tensile Tie Rod.

e) Carbon Steel Structural Fasteners

f) Elastomeric Bearings

g) Epoxy Painting

h) Fabrication of Dome

i) Structural Steel

j) Structural Steel Dome (Auditorium)

k) Carbon Steel High Tensile -Tie Rods

l) Stainless Steel Plates

m) Carbon Steel Plates

n) Stainless Steel Castings

o) Carbon Steel Castings

p) Cement

q) Fine Aggregate

r) Coarse Aggregate

s) Sampling & Testing of Concrete

t) Placement of Concrete

u) Production of Concrete

v) Procurement and Storage of Reinforcement

w) Concrete Admixture

x) Aluminium Work.

y) Stone Work.

7.1 Sample Quality Assurance Plan

The quality assurance plan for stainless steel castings, is reproduced as per Fig 26.1 as a sample.

Sl.No.	Description	Applicable standards	Acceptance criteria	Frequency of performance	Inspection by			
					ECC/Mfr.	Testing agency	CEIL	CPWD
1.	Prequalification	Project Specifications	Project Specifications	Before start of work.	P	-	-	A
2.	Source	Project Specifications	Project Specifications	Well in advance of start of work and as and when need arises.	P	-	-	A
3.	Samples Approval	Project Specifications	Project Specifications	One sample before start of each series.	P	-	-	A
4.	Procurement	Project Specifications	Project Specifications	As per construction schedule.	P	-	-	R
5.	Storage	Project Specifications	Project Specifications	Once in a fortnight.	P	-	-	S
6.	Testing :							
	i) Mechanical Tests	ASTM A 370	A 744 grade CF 3/ Project Specifications.	(i) Two test pieces for every 2 tonnes of casting subject to minimum of one test for every melt	P	-	P	RA
	ii) Chemcial Composition	IS: 228	A 744 grade CF 3/ with carbon content < 0.06%	2 test pieces for every 2 tonnes of castings subject to minimum of one test for each melt	P	-	P	RA
	iii) Heat Treatment	A 744 Gr. CF3	A 744 Gr. CF3	100% of castings by L&T	TC	-	-	RA
	iv) Ultrasonic examination	Stainless steel > IS: 7666 read alongwith level 3 of IS:9565/ Project Specifications.	IS: 7666: 1975/ IS: 9565: 1986/ (Level 3)/ Project Specifications.	Two pieces of every series/ type for 100% ultrasonic examination and remaining pieces checked on basis of 100mm grid.	-	P	W	RA
	v) Radiographic test (less than 75 mm thick)	Project Specifications/ ASTM E-448 (level-III)	Project Specifications/ ASTM E-446 (level-III)	1% of total cast pieces	-	P	W	RA
	vi) DPT	IS: 3658/ IS:11732	IS: 3658-1981/ IS: 11732-1986	1 piece of every series	-	P	W	RA
	vii) Destructive test.	Project specifications.	Project specifications.	0.5% of total pieces.	P	P	W	RA
7.	Dimensional and visual Inspection	Shop drawing and Project Specification	Shop drawing and Project Specification	All cast pieces.	P	-	W	RA
8	Identification of Castings (L&T to submit procedure to be followed for identification of casting to avoid mixing for review).	As per Shop drawing	As per Shop drawing	100%	P	-	W	RA

Legend P - Perform, A - Approval, R - Review, RA - Review & Accept, S - Surveilliance, W - Witness at random, TC - Manufacturer Test Certificate

Fig 26.1 : Quality Assurance Plan for Stainless Steel Castings

8.0 QUALITY ASSURANCE INSPECTIONS

The work for foundation system has been inspected by Chief Technical Examiner and for superstructure, domes and aluminium , doors & windows by Chief Engineer (CSQ), CPWD as per details given below. All the paras raised during various inspections have been replied & inspection reports have been closed as per details given below.

Sl. No.	Date of Inspection	Authority	Inspection report date	Number of Paras	Date for closure of report
A.	**Foundation System**				
1.	12.10.1994	CTE, CVC	9.11.1994	22	13.11.1995
B.	**Superstructure**				
1.	16.5.1997	CE (CSQ)	16.6.1997	17	13.9.2002
2.	16.12.1997	CE (CSQ)	17.2.1998	27	2.8.2002
3.	31.8.1998	CE (CSQ)	14.10.1998	55	30.6.2003
4.	14.1.2000 and 17.1.2000	CE (CSQ)	28.2.2000	41	21.3.2003
C.	**Domes**				
1.	14.3.2001	CE (CSQ)	4.5.2001	25	21.4.2003
D.	**Aluminium Doors & Windows**				
1.	20.10.2000	CE (CSQ)	30.11.2000	27	30.9.2002

9.0 TESTING OF MATERIAL

The field/laboratory tests have been done for various materials used in work as per details given below.

9.1 Water

Water from bore well made at site have been used and tested every three months.

Sl. No.	Test Done	Permissible Value as per CPWD Specifications	Foundation System (Average Value for 12 tests)	Superstructure (Average Value for 35 tests)	Domes (Average Value for 10 tests)
1.	Acidity	i) Less than 1% of 0.1N caustic soda solution. required for neutralization	0.42%	—	—
		ii) Volume of 0.02N NAOH required To neutralize 200ml sample of water using phenolphthalein (10ml maximum)	—	2.48ml.	1.21ml.

2.	Alkalanity	a) Less than 5% of 0.1N, HCL required for neutrallization	4.33%	—	—
		b) Volume of 0.02N H_2SO_4 required to neutralize 50ml of sample using mixed indicator (12.5 ml max.)	—	10.11ml.	8.62ml.
3.	Maximum Organic Solids	0.02%	0.01%	0.007 %	0.07%
4.	Maximum Inorganic Solids	0.30%	0.062%	0.075%	0.07%
5.	Maximum Sulphates	0.05%	0.023%	0.02%	0.021%
6.	Maximum Chlorides	0.10%	0.017%	0.02%	0.015%
7.	P.H.Value	Not less than 6.0	7.80	7.46	6.58

9.2 Stone Aggregate

As per para 4.1.2.5 of CPWD specifications 1977 Volume I grading needs to be tested for every 45 cum of stone aggregate used for RCC work & for rest of items as per decision of Engineer-in-Charge. Also ten percent fine value and percentage of soft or deleterious materials needs to be tested as per decision of Engineer-in-Charge. The number of tests done are given as below :

a) Stone Aggregate 10 mm Size :

Sl. No.	Test Done	Permissible Value as per CPWD Specifications	Number of Tests Done	
			Superstructure (Quantity used 6800 Cum)	Domes (Quantity used 420 Cum)
1.	Grading (IS Sieve Designation percentage passing)		260 Tests	83 Tests
a)	12.5 mm	100	Within Limits	Within Limits
b)	10 mm	85-100	Within Limits	Within Limits
c)	4.75 mm	0-20	Within Limits	Within Limits
d)	2.36 mm	0-5	Within Limits	Within Limits
2.	Deleterious material	5%	84 Tests	77 Tests
3.	10% fine value	5t (min)	—	1Test (Actual 20.4t)

b) Stone Aggregate 20 mm size

Sl. No.	Test Done	Permissible Value as per CPWD Specifications	Number of Tests Done		
			Foundation System (Quantity used 21080 Cum)	Superstructure (Quantity used 14400 Cum)	Domes (Quantity used 632 Cum)
1.	Grading (IS Sieve Designation percentage passing)		252 Tests	376 Tests	50 Tests
a)	40 mm	100	Within Limits	Within Limits	Within Limits
b)	20 mm	85-100	Within Limits	Within Limits	Within Limits
c)	10 mm	0-20	Within Limits	Within Limits	Within Limits
d)	4.75 mm	0-5	Within Limits	Within Limits	Within Limits
2.	Deleterious Material	5%	258 Tests	70 Tests	55 Tests
3.	10% Fine Value	5t (min)	—	—	1 Test (Actual 28.6 t)

c) Stone Aggregate 40 mm size

Sl. No.	Test Done	Permissible Value as per CPWD Specifications	Number of Tests Done	
			Foundation System (Quantity used 2287 Cum)	Domes (Quantity used 572 Cum)
1.	Grading (IS Sieve Designation percentage passing)		38 Tests	26 Tests
a)	80 mm	100	Within Limits	Within Limits
b)	40 mm	95-100	Within Limits	Within Limits
c)	20 mm	30-70	Within Limits	Within Limits
d)	10 mm	10-35	Within Limits	Within Limits
e)	4.75 mm	0-5	Within Limits	Within Limits
2.	Deleterious Material	5%	107 Tests	38 Tests

9.3 Sand

As per para 3.1.5.1 to 3.1.5.4 of CPWD Specifications 1977 Volume I silt content for every 20cum of sand used and particle size distribution for every 40cum of sand used in RCC works needs to be tested. Also as per para 3.3.1 and 3.3.5 of specifications bulking of sand needs to be tested for every 20 cum of sand used. The number of tests done are given as below :

Sl. No.	Test Done	Permissible Value as per CPWD Specifications	Number of Tests Done		
			Foundation System (Quantity used 10275 Cum)	Superstructure (Quantity used 15500 Cum)	Domes (Quantity used 1804 Cum)
1.	Grading (IS Sieve Designation percentage passing)		232 Tests	414 Tests	79 Tests
a)	10mm	100	Within Limits	Within Limits	Within Limits
b)	4.75 mm	90-100	Within Limits	Within Limits	Within Limits
c)	2.36 mm	85-100	Within Limits	Within Limits	Within Limits
d)	1.18 mm	75-100	Within Limits	Within Limits	Within Limits
e)	600 microns	60-79	Within Limits	Within Limits	Within Limits
f)	300 microns	12-40	Within Limits	Within Limits	Within Limits
g)	150 microns	0-10	Within Limits	Within Limits	Within Limits
2.	Silt Content	8% for Foundation & Superstructure and 5% for Domes	346 Tests	849 Tests	106 Tests
3.	Bulking of Sand		—	352 Tests	—

9.4 Cement

As far as work of foundation system and superstructure is concerned, cement was stipulated to be issued by the department which was tested at the source. However for domes & ancillary works cement was to be procured by the agency and has been tested by the Project Team as per relevant IS codes as per details given below:

Sl. No.	Test done	Vikram Brand – 43 Grade (Quantity used 838.5t)		Vikram Brand–53 Grade (Quantity used 131.2t)	
		Permissible Value as per IS:8112-1989	Average Value for 17 tests	Permissible Value as per IS:12269-1987	Average Value for 4 tests
1.	**Chemical Test**				
a)	Maximum Loss on Ignition	5 %.	1.76%	4 %	2.0%
b)	Maximum Insoluble Residue	3%	1.58%	3 %	1.23%
c)	Maximum Magnesia (MgO)	6%.	1.66%	6 %	1.43%
d)	Maximum Sulphuric Anhydride (SO_3)	2.5%.	2.32%	2.5 %	2.10%
e)	Minimum Al_2O_2/Fe_2O_3 Ratio	0.66	1.22	0.66.	1.35

f)	Lime Saturation Factor	0.66–1.02	0.82	0.80-1.02	0.86
g)	Maximum Total Chloride (Cl)	0.1%	0.03%	0.1 %.	0.02%
2.	**Physical Test**				
a)	Minimum Blaine's Fineness (Sqm/Kg)	225	285.12	225	308.25
b)	Setting Time in Minutes				
i.	Initial (Minimum)	30	171.47	30	170
ii.	Final (Maximum)	600	240.59	600	245
c)	Soundness				
i.	Maximum Lechatelier Expansion	10mm	0.32 mm	10mm	0.38 mm
ii.	Maximum Autoclave Expansion	0.8%	0.07%	0.8%	0.06%
d)	Minimum Compressive Strength (N/Sqmm)				
i.	3 days	23	33.29	27	32.38
ii.	7 days	33	46.24	37	44.13
iii	28 days	43	58.03	53	60.63

9.5 Cement Concrete

As per CPWD Specifications 1977 Volume I cube strength tests for cement concrete work are mandatory. The number of tests done are given as below:

Sl. No.	Test Done	Permissible Value as per CPWD Specifications	Number of Tests Done			
			Foundation System (Quantity used 24052 Cum)	Superstructure (Quantity used 24322 Cum)	Domes	
					For RCC (Quantity used 647 Cum)	For FRC (Quantity used 401 Cum)
a)	1:2:4	21 N/Sqmm	—	47 Tests	1 Test	—
b)	1:1.5 :3	26.5 N/Sqmm	646 Tests	268 Tests	4 Tests	—
c)	1:1:2	31.5 N/Sqmm	—	—	52 Tests	—
d)	M20	20 N/Sqmm	—	70 Tests	—	—
e)	M25	25 N/Sqmm	—	1718 Tests	12 Tests	—
f)	M30	30 N/Sqmm	—	7 Tests	—	—
g)	M35	35 N/Sqmm	—	4 Tests	—	—
h)	M50	50 N/Sqmm	—	—	—	130 Tests

9.6 Reinforcement

As far as work of foundation system & superstructure is concerned, reinforcement bars were stipulated to be issued by the department and the testing was done at source. However for domes & ancillary works reinforcement bars were to be procured by the agency and have been tested by the Project Team as per relevant IS codes as per details given below :

Sl. No.	Test Done	Mild Steel Bars Quantity used 54.35t		TMT/Cold Twisted Bars Quantity used 156.05t	
		Permissible Value as per IS:432 (Pt.1)1982	Average Value For 7 Tests	Permissible Value as per IS:1786:1985	Average Value for 35 Tests
a)	**Chemical Composition Percentage by Weight**				
i.	Maximum Carbon	0.23%	0.16%	0.30%	0.20%
ii.	Maximum Sulphur	0.055%	0.023%	0.06%	0.021%
iii.	Maxmum Phosphorus	0.055%	0.022%	0.06%	0.028%
iv.	Maximum Sulpher plus Phosphorous	—	—	0.11%	0.05%
b)	**Physical Test**				
i.	Minimum Tensile Stress (N/Sqmm)	410	500.52	485	621.45
ii.	Minimum Yield Stress (N/Sqmm)	250	388.12	415	497.97
iii.	Minimum Elongation(%)	23%	36.65 %	14.5%	24.88
iv.	Bend Test	To satisfy the test	Satisfactory	To satisfy the test	Satisfactory
v.	Re-bend Test	To satisfy the test	Satisfactory	To satisfy the test	Satisfactory

9.7 High Tension (HT) Wires for Rock Anchors

The HT wires have been procured from M/s Usha Martin and 253t of HT wires have been used for vertical and inclined rock anchors in foundation system. The testing of HT wires have been done in accordance with IS: 1785, Pt. I, 1983 as per details given below:

Sl. No.	Test Done	Permissible Value	Average Value for 13 Tests
a)	**Chemical Composition Percentage by Weight**		
i.	Maximum Sulpher	0.05%	0.02%
ii.	Maximum Phosphorus	0.05%	0.02%
b)	**Physical Test**		
i.	Nominal diameter	7 mm with +2% & -1% variation	7.01mm

ii.	Minimum Ultimate Tensile Strength (N/Sqmm)	1470	1607.91
iii.	Minimum Proof Stress (N/Sqmm)	1249.5	1369.64
iv.	Ductility Test	To satisfy the test.	Satisfactory
v.	Minimum Elongation	4%	5.47%

9.8 Bricks

The position of various tests for bricks is given below :

Sl. No.	Test Done	Permissible Value	Superstructure (Qty used 32,00,000 Nos.)		Domes (Qty used 2,20,000 Nos.)	
			Number of Tests	Average Value	Number of Tests	Average Value
a)	Dimensions for 20 Bricks					
i.	Length (mm)	4320-4680	78	4506	23	4548
ii.	Width (mm)	2131-2309	78	2248	23	2228
iii.	Thickness (mm)	1344-1456	78	1398	23	1429
b)	Compressive Strength (Kg/Sqcm)	75	78	148.50	12	99.33
c)	Maximum Water Absorption	20%	79	11.6%	12	12.77%
d)	Efflorescence	Moderate	77	Satisfactory	12	Satisfactory

9.9 Calcium Silicate Bricks

In all 70cum of calcium silicate brick work have been done in superstructure work for AHU etc. The position of tests conducted is as given below :

Sl. No.	Test Done	Requirement as per IS:4139 :1989.	Number of Tests	Average Value
1.	Shrinkage	0.06%	2	0.035%
2.	Minimum Compressive Strength (without wetting) (Kg/Sqcm)	75	2	227.4
3.	Minimum Compressive strength (wet condition) (Kg/Sqcm)	75	4	176.21

9.10 Sand Stone

The IS code provisions were studied and best quality of sand stones available were tested. The decision was taken to use sand stones conforming to following criteria.

a) Compressive Strength > 300 kg/sqcm (Testing as per IS:1121:1974)

b) Water Absorption < 5% (Testing as per IS:1124:1974)

c) Specific Gravity > 2.1 (Testing as per IS:1122:1974)

The sand stones have been tested for water absorption , compressive strength & specific gravity as per details given below.

Sl. No.	Type of Stone/ Test Done	Superstructure		Domes	
		Quantity used/ Number of Tests	Average Value	Quantity used/ Number of Tests	Average Value
1.	Red Sand Stone	3022cum		623cum	
a)	Compressive Strength	13	513.1kg/sqcm	1	480kg/sqcm
b)	Water Absorption	14	3.02%	2	3.64%
c)	Specific Gravity	9	2.62	2	2.37
2.	White Sand Stone	721cum		60cum	
a)	Compressive Strength	10	528.97kg/sqcm	1	396.7kg/sqcm
b)	Water Absorption	13	2.78%	2	3.8%
c)	Specific Gravity	12	2.58	2	2.13
3.	Pink Sand Stone	164cum			
a)	Compressive Strength	12	568.29kg/sqcm	—	—
b)	Water Absorption	18	2.97%	—	—
c)	Specific Gravity	17	2.59	—	—
4.	Sand Stone for Jali	3026sqm			
a)	Compressive Strength	135	542.50kg/sqcm	—	—
b)	Water Absorption	135	3.96%	—	—
c)	Specific Gravity	135	2.17	—	—

9.11 Wood Work

The wood has been tested for moisture content, species identification, specific gravity, chemical treatment etc. as per details given below :

a) Shisham Wood

Sl. No.	Work/Test Done	Permissible Value as per Contract	Laboratory Tests		Field Tests	
			Number of Tests	Average Value	Number of Tests	Average Value
1.	**Domes & Ancillary Works (Quantity used 7 cum)**					
a)	Specific Gravity	0.7 (min)	1	0.7	NIL	NA
b)	Identification of Wood (species)	To conform	1	Conformed	NIL	NA

b) Cedar Wood

Sl. No.	Work/Test Done	Permissible Value as per Contract	Laboratory Tests		Field Tests	
			Number of Tests	Average Value	Number of Tests	Average Value
1.	Superstructure (Quantity used 25 cum)					
a)	Moisture Content	10% (max)	NIL	NA	27	7.27%
b)	Identification of Wood (species)	To conform	3	Conforming	NIL	NA
2.	Domes & Ancillary Works (Quantity used 16 cum)					
a)	Moisture Content	8% (max)	1	8.5% (failed)	20	5.60%
b)	Specific Gravity	0.60 (min)	2	0.86	NIL	NA
c)	Identification of Wood (species)	To conform	4	2 conformed 2 failed	NIL	NA
3.	Auditorium Work (Quantity used 6 cum)					
a)	Moisture Content	8% & 10% (max)	1	14.5%(failed)	7	8.93%
b)	Identification of Wood (species)	To conform	1	Conforming	NIL	NA

c) Burma Teak Wood :

Sl. No.	Work/Test Done	Permissible Value as per Contract	Laboratory Tests		Field Tests	
			Number of Tests	Average Value	Number of Tests	Average Value
1.	Superstructure (Quantity used 170 cum)					
a)	Moisture Content	10% (max)	23	8.24%	193	7.68%
b)	Identification of Wood (species)	To conform	8	Conforming	NIL	NA
2.	Fire Check Doors (Quantity used 44 cum)					
a)	Moisture Content	10% & 12% (max)	NIL	NA	62	9.12%
b)	Identification of Wood (Species)	To conform	1	Conforming	NIL	NA
3.	Domes & Ancillary Works (Quantity used 24 cum)					
a)	Moisture Content	8% (max)	1	10.5%(failed)	23	6.82%
b)	Specific Gravity	0.60 (min)	1	0.73	NIL	NA
c)	Identification of Wood (species)	To conform	1	Conforming	NIL	NA

4.	**Auditorium Work (Quantity used 30cum)**					
a)	Moisture Content	8% & 10% (max)	6	10.41% (failed)	42	9.98%
b)	Identification of Wood (Species)	To conform	4	Conforming	NIL	NA
5.	**Furniture (Quantity used 112cum)**					
a)	Moisture content	10% (max)	NIL	NA	120	8.49%
b)	Identification of Wood (species)	To conform	23	Conforming	NIL	NA

d) Sal Wood

Sl. No.	Work/Test Done	Permissible Value as per Contract	Laboratory Tests		Field Tests	
			Number of Tests	Average Value	No. of Tests	Average Value
1.	**Superstructure (Quantity used 32cum)**					
a)	Moisture Content	10% & 12% (max)	14	8.21%	71	8.07%
b)	Chemical Treatment	Pass standard	1	Pass standard	NIL	NA
2.	**Domes & Ancillary Works (Quantity used 47cum)**					
a)	Moisture Content	8% (max)	2	10.6% (failed)	49	7.19%
b)	Specific Gravity	0.85 (min)	2	1.0	NIL	NA
c)	Chemical Treatment	Pass Standard	1	Does not conform	NIL	NA
d)	Identification of Wood (species)	To conform	2	Conforming	NIL	NA
3.	**Auditorium Work (Quantity used 26cum)**					
a)	Moisture Content	8% & 10% (max)	1	19.3% (failed)	31	12.87% (failed)
b)	Identification of Wood (species)	To Conform	2	Conforming	NIL	NA

e) Comments on Test Results for Wood

i. Moisture Content : It may be observed from the above table that some samples failed in moisture content test. Instead of rejecting the timber outright, it was decided to examine the issue more closely. As per IS:287-1993, the moisture content of a fully seasoned piece of wood depends

on atmospheric conditions prevailing in the locality in which it is seasoned., although species of wood and cross-section of the piece also have an important bearing. The moisture content of seasoned wood also changes from season to season depending upon the fluctuations in atmospheric humidity. As the climatic conditions vary in the country, it has been divided into four zones for the purpose of IS:287-1993. The seasonal changes in the moisture content of wood occur mostly in Zone II & III, where a very hot dry summer is abruptly followed by a wet rainy season. Delhi falls in Zone-II for this purpose as per IS code. These zones cannot be demarcated in a clear cut manner. Even within a zone, climatic conditions vary at different localities due to physical features such as altitude, vicinity of mountains etc. Therefore the information given in I.S. code is to be applied in a very general manner, taking into consideration the existing local conditions. As per I.S. Code the moisture content in timber to be used should be as near as possible to the value that will be attained in equilibrium with the average atmospheric conditions. As per Table 1 of IS:287-1993 for Zone-II the maximum moisture content permissible varies from 10% to 14% for different uses. Further tolerance of 3% to 5% is also permissible, keeping in view the various factors as above the wood with higher moisture content was accepted with cost adjustment.

ii. Treatability : In a similar manner, we also examined the matter of amenability to chemical treatment in case of sal wood. As per Table 3 at Page 23 of IS:401-1982, the sal wood is classified as class I (Average life 120 months and over) and grade 'e' for treatability , Para B.3.1 of Appendix B defines grade 'e' timber for chemical treatment as below.

"Heart wood is very refractory to treatment, penetration of preservative being practically nil even from the ends."

Thus there is little possibility for determination of penetration of preservative in heart wood while testing. M/s Larsen & Toubro submitted the undertaking of supplier of sal wood M/S Jagdamba Saw Mill vide letter dated May 22, 2001 stating that chemical treatment of sal wood was done by CCA preservative as per IS:401-1982. Sal wood being highly refractory to treatment, this was not detected by the test. The question of acceptance of sal wood which had failed to clear the tests for chemical treatment was discussed among the team members at length. The comparative merits of rejecting the sal wood at a crucial stage of the construction were carefully weighed. A conscious decision was taken to accept the timber (of course with suitable cost adjustment) and get on with the work.

9.12 Stainless Steel Dash Fasteners for Aluminium Windows

The position of various tests is given below:

Sl No.	Test Done	Permissible Value	Actual Value		
			Shell Test	TAG	Bolt
1.	**Chemical Composition Percentage by Weight**				
a)	Maximum Carbon	0.08%	0.03%	0.04%	0.03%
b)	Maximum Sulpher	0.03%	0.012%	0.017%	0.015%
c)	Maxmimum Phosphorus	0.045%	0.025%	0.026%	0.027%
d)	Maximum Silicon	1.0%	0.42%	0.48%	0.43%
e)	Maximum Mangenese	2.0%	1.4%	1.5%	1.2%
f)	Nickel	8.00% -10.50%	8.4%	8.1%	8.5%
g)	Chromium	18.00% -20.00%	18.0%	18.1%	18.5%

9.13 Calcium Silicate Board for Fire Barriers

The board was got tested from CBRI Roorkee for (a) Material Class (Non combustible according to BS 476-Part-4) & (b) Raw density. The Non-Combustibility of material is determined in order to ascertain whether it will or will not contribute directly to fire development. It is intented for selection of materials which, while not completely inert, produce only a limited amount of heat and flame when exposed to a temperature of approximately 750°C under the specified exposure conditions. During non combustibility experiment the board showed temperature rise within limits. In addition at the centre of the specimen duration of sustained flaming was zero (no flaming) and the mass loss was 2.16% which are within the limits specified in BS:476-Part-4. The density was 995Kg/cum.

9.14 Marble/Stones for Flooring & Wall Lining

a) *Kota Stone* : Kota stone 27622sqm have been used for superstructure work. The average value of fifteen tests conducted are as per details below

i.	Water absorption	0.36%
ii.	Hardness	4.54
iii.	Specific Gravity	2.57

b) *Marble* : Marble have been tested for moisture absorption, hardness and specific gravity. The permissible values are

i.	Moisture Absorption	< 0.4%	(Testing as per IS:1124:1974)
ii.	Hardness	> 3.0	(Testing as per IS:1130:1969)
iii.	Specific Gravity	> 2.5	(Testing as per IS:1122:1974)

The actual average value for various tests done for superstructure work are :

Sl. No.	Type of Marble	Quantity Used in Sqm	Number of Tests	Water Absorption (Average Value)	Hardness (Average Value)	Specific Gravity (Average Value)
1.	Banswara/Andhi	4047	119	0.34%	4.01	2.6
2.	Udaipur Pink	298	8	0.26%	4.12	2.58
3.	Jaiselmer Yellow	1756	41	0.35%	4.0	2.59
4.	Udaipur Green	40	2	0.33%	4.0	—
5.	Marble Tiles for Wall Lining – 8 mm thick	453	3	0.33%	4.0	2.56

c) *Granite* : As per IS: 3316:1974 granite with following characteristics is acceptable.

i. Water absorption < 0.5% (Testing as per IS:1124:1974)

ii. Specific Gravity > 2.6 (Testing as per IS:1122:1974)

Granite has been tested as per details given below :

Sl. No.	Type of Granite	Quantity Used in Sqm	Number of Tests	Moisture Absorption (Average Value)	Specific Gravity (Average Value)
1.	**Superstructure**				
a)	Grey- 18mm Thick	3068	14	0.43%	2.65
b)	Pink –18mm Thick	1659	7	0.36%	2.63
c)	Almond-18mm thick	326	7	0.42%	2.63
d)	Sinduri Red-18mm Thick	333	2	0.20%	2.64
e)	Grey Tiles-8 mm Thick	4723	12	0.39%	2.61
f)	Grey- 50 mm Thick	995	4	0.31%	2.63
2.	**Domes**				
a)	Grey Tiles –10 mm thick	1567	1	0.17%	2.63
b)	Black –18 mm thick	173	1	0.23%	2.65
c)	Grey 50 mm thick	591	2	0.34%	2.65
3.	**Furniture**				
a)	Chilly Red- 38 mm thick	275	3	0.45%	2.65

9.15 Water Proofing Compound

The actual test values for conformity to IS:2645 are as below

Sl. No	Requirement as per IS:2645 / Water Proofing Compound	Permeability to Water	Setting Time in Minutes		Compressive Strength in Kg/Sqcm.	
		Maximum 50% of neat mortar	Initial 30 (Minimum)	Final 600 (Maximum)	3 days Not less than160 or 80% of neat mortar	7 days Not less than 220 or 80% of neat mortar
1.	ACC-Brand					
a)	Neat Mortar	—	115	180	215	285
b)	Mortar with Compound	42%	105	160	210	275
2.	Chemseal					
a)	Neat Mortar	—	135	200	220	295
b)	Mortar with Compound	40%	135	195	220	295
3.	Ferroseal DDS Liquid					
a)	Neat Mortar	—	155	220	240	335
b)	Mortar with Compound	34%	165	235	250	350
4.	Ferroseal DDS Powder					
a)	Neat Mortar	—	155	220	240	335
b)	Mortar with Compound	36%	160	225	235	330

9.16 Hardonite Chequered Tiles & Ceramic Tiles

Permissible and average values for 20 tests of hardonite chequered (quantity used 8007 sqm) & for 13 tests of ceramic tiles (quantity used 1702 sqm) are as below :

Sl. No.	Tests Done	Permissible Value as per IS:777-1970 (Ceramic Tiles) & IS:13801:1993 (Hardonite Tiles)	Hardonite Chequered Tiles	Ceramic Tiles
a)	Water Absorption (max.)	10% for Hardonite Tiles 18% for Ceramic Tiles	5.72%	7.02%
b)	Minimum Transverse Stregnth	3N/Sqmm	5.1N/Sqmm	NA
c)	Maximum Abrasion Value	2mm	1.97mm	NA
d)	Crazing Tests	No crazing should occur	NA	Satisfactory
e)	Impact Resistance	No damage should occur	N.A.	Satisfactory

9.17 Steel for Domes

The permissible values & average values of tests done for carbon steel, stainless steel & structural steel used for dome work are as given below :

Sl. No.	Test Done	Carbon Steel (Qty. used 213t)		Stainless Steel (Qty. used 40t)		Structural Steel (Qty. used 129t)	
		Permissible Value	Average Value for 7 tests	Permissible Value	Average Value for 3 tests	Permissible Value	Average Value for 8 tests
1.	**Chemical Composition Percentage by Weight**						
a)	Maximum Carbon	0.25%	0.14%	0.03%	0.026%	0.23%	0.18%
b)	Maximum Sulpher	0.05%	0.024%	0.03%	0.013%	0.05%	0.024%
c)	Maximum Phosphorous	0.055%	0.026%	0.045%	0.023%	0.05%	0.024%
d)	Maximum Manganese	1.5%	1.14%	2%	1.54%	1.5%	0.8%
e)	Maximum Silicone	0.4%	0.33%	0.75%	0.34%	0.40%	0.16%
f)	Maximum Aluminium	0.01%	Less than 0.05%	—	—	—	—
g)	Nickel	—	—	8% - 12%	8.93%	—	—
h)	Carbon Equivalent	—	—	—	—	0.42%	0.32%
i)	Chromium	—	—	18% - 20%	18.34%	—	—
2.	**Physical Test**						
a)	Minimum Ultimate Tensile Strength (N/Sqmm)						
i.	Plates	490-610	592.20	485	592.5	410	481.38
ii.	Tubes	450	561.50	485	592.67	—	—
b)	Minimum Yield Strength (N/Sqmm)						
i.	Plates	350	412.20	170	299.25	250	328.13
ii.	Tubes	310	416	200	381.17	—	—
c)	Minimum Elongation (%)						
i.	Plates	20%	24.80%	40 %	56.68%	23%	30.68%
ii.	Tubes	14%	31.38%	20 %	47.33%	—	—
d)	Bend Test	—	—	—	—	To satisfy the test	Satisfactory
e)	Maximum Brinell Hardness	—	—	201	177.38	—	—

9.18 Carbon Steel & Stainless Steel Castings :

a) *Castings* : The following tests were conducted for castings:

i. Destructive mechanical test was carried out on coupon test pieces at the rate of 2 pieces per heat or 2 test pieces per two M.T. of castings whichever is more.

ii. Two pieces of every series/type were checked for 100% ultrasonic examination, 0.5% of the total casting were chosen at random and sawn along the long axis for dye penetration test of the cut portion.

iii. Remaining pieces were checked by ultrasonic examination on the basis of 100mm grid.

iv. Dye penetration testing was carried out on 100% of the surface of samples selected at random by Engineer-in-charge. As far as possible one piece of each series was chosen. Further testing was limited to accessible chamfers and all surfaces prepared for welding as and when directed by Engineer-in-Charge.

v. Radiographic examination was carried out in certain cases to validate ultrasonic examination. The radio graphic examination was carried out @ 1% of total castings selected at random by Engineer-in-charge.

Since the castings were made at three different locations, the inspection and testing teams were sent to the manufacturers places. The castings were tested and inspected and the lots were dispatched only after completing the inspection and testing. The castings which failed during the inspection and testing were rejected at factory itself.

vi. For proper identification, each cast piece was numbered and the identification numbers were mentioned in the inspection reports. This eliminated any chance of untested/failed castings being dispatched to site.

b) *Welds for Dome Structures* : The welds for dome structures were tested as per details given below :

i. Stage-I : All the joints were visually inspected. The components having defective joints were colour marked for rectification.

ii. Stage-II : All components having passed Stage-I were subjected to liquid penetration flow detection test (Dye penetration test). Components having defective joints were colour marked for rectification. After rectification, the components were re-tested. The components failing in tests were to be rejected. However no components failed in re-test.

iii. Stage-III : 10% of the components having passed the stage-II were subjected to radiographic examination as per IS:1182-1983. If sample fails in radiographic examination, then entire lot represented by that sample were

subjected to the radiographic examination at the cost of the contractor. The components then passed in testing were accepted and failed ones were colour marked for rectification. After rectification, the components were re-tested and the components failing in re-testing were rejected

iv. Stage-IV : Mechanical testing was done on the samples passing radiographic examination to the extent of 10% of samples passed in radiographic examination. If any of the sample fails in mechanical testing the entire lot was required to be rejected. However no sample of welding failed in mechanical testing.

v. Sampling : For radiographic examination one component was picked up randomly for every 10 components welded by the same welder. The sample joints for radiographic examination were jointly marked by CEIL and PLP engineers before starting the radiographic examination.

c) The test results for various tests conducted for castings & welding are tabulated as below :

Sl. No.	Test Done	Carbon Steel Castings (Qty. used 155 t)		Stainless Steel Castings (Qty. used 30 t)	
		Permissible Value	Average Value for 362 tests	Permissible Value	Average Value for 210 tests
1.	**Chemical Composition Percentage by Weight**				
a)	Maximum Carbon	0.25%	0.21%	0.06%	0.045%
b)	Maximum Sulpher	0.035%	0.022%	0.04%	0.018%
c)	Maximum Phosphorous	0.04%	0.031%	0.04%	0.030%
d)	Maximum Manganese	1.50%	1.15%	1.50%	1.10%
e)	Maximum Silicone	0.60%	0.51%	2.00%	1.18%
f)	Maximum Copper	0.40%	0.062%	—	—
g)	Nickel	0.40% (Maximum)	0.12%	8% -12%	9.87%
h)	Maximum Molybdenum	0.15%	0.082%	—	—
i)	Chromium	0.35%	0.215%	17%-21%	18.47%
j)	Maximum Vanadium	0.05%	0.001%	—	—
2.	**Physical Tests**				
a)	Minimum Ultimate Tensile Strength (N/Sqmm)	570	633.07	480	538.50

b)	Minimum Yield Strength (N/Sqmm)	340	398.64	200	338.4
c)	Minimum Elongation (%)	15.0%	21.81%	30%	45.40 %
d)	Notch Impact Strength at 20°C (KCV)	—	—	28 J	134.13 J
3.	**Ultrasonic Examination As per IS:7666 with IS:9565 Level-III**				
a)	Radiographic Testing (Less than 75 mm)	To pass the test	Satisfactory (125 Tests)	To pass the test	Satisfactory (24 Tests)
b)	Dye-Penetration Test	To pass the Test	Satisfactory (100%)	To pass the Test	Satisfactory (100%)
c)	Destructive DPT	To pass the Test	Satisfactory (37 Tests)	To pass the test	Satisfactory (3 Tests)

9.19 Mobile Closed & Open Stacks

a) Stainless Steel Rails, Spokes & Tubes :

Sl. No.	Test Done	Permissible Value	Rails (Quantity used 16.25t) Average Value for 2 tests	Spokes (Quantity used 0.75t) Average Value for 2 tests	Tubes, Plates etc. (Quantity used 25t) Average Value for 102 Tests
I.	**Chemical Composition (Percentage by Weight)**				
a)	Maximum Carbon	0.08%	0.06%	0.06%	0.06%
b)	Maximum Sulpher	0.03%	0.013%	0.014%	0.019%
c)	Maximum Phosphorus	0.045%	0.0175%	0.017%	0.028%
d)	Maximum Manganese	2.00%	1.67%	1.53%	1.562%
e)	Maximum Silicone	1.00%	0.18%	0.19%	0.473%
f)	Nickel	8% -10.5%	8.64%	8.61%	8.53%
g)	Chromium	17.5% - 20.0%	19.42%	18.79%	18.37%
2.	**Corrosion Resistance**				
a)	Boiling Nitric Acid Test	18mg per year	—	—	17.54mg. Per year
b)	Copper Sulphate & Sulphuric Acid Tests	Should not have any cracks or fissures	—	—	No surface cracks or fissures found

b) CRCA Sheets & HR Sheets :

Sl. No.	Test Done	CRCA Sheet (Quantity used 474t)		HR Sheet (Quantity used 80t)	
		Permissible Value as per IS:513:1994	Average Value for 15 tests	Permissible Value as per IS:10748:1984	Average Value for 13 tests
1.	Chemical Composition Percentage by Weight				
i.	Maximum Carbon	0.12	0.06	0.12	0.096
ii.	Maximum Sulpher	0.04	0.011	0.04	0.012
iii.	Maximum Phosphorus	0.04	0.018	0.04	0.018
iv.	Maximum Maganese	0.50	0.177	—	—
2.	Phyical Test				
i.	Thickness of sheet	1.0 mm	1.0 mm	3.15 mm	3.13 mm
ii.	Tensile strength (N/Sqmm)	270 – 410	310.97	330 (min)	425.77
iii.	Yield Stress (N/Sqmm)	280 (max)	233.01	240 (min)	358.23
iv.	Minimum Elongation	23%	44.61%	28%	32.28%
v.	Bend Test	To satisfy the test	Satisfactory	To satisfy the test	Satisfactory
vi.	Maximum Hardness (HV)	65	52.92	—	—
vii.	Freedom from defects	To satisfy the test	Satisfactory	To satisfy the test	Satisfactory
viii.	Maximum Hardness (HRB)	65 HRB	42 HRB	—	—
ix.	Maximum Hardness (HR 30T)	60	47	—	—
x.	Minimum Cupping (mm)	9.8 mm	10.4	—	—
3.	Paint Test as per IS:101-1988 & IS:13871:1993)				
i.	Scratch Hardness	No scratch to be visible	Satisfactory	To satisfy the test	Satisfactory
ii.	Thickness of powder coating (micron) (Minimum)	50	68.87	50	70.62
iii.	Chemical & Stain Resistance	To satisfy the test	Satisfactory	To satisfy the test	Satisfactory
iv.	Salt Spray Test 1000 Hours	To satisfy the test	Satisfactory	—	—
v.	Salt Spray Test 250 Hours	—	—	To satisfy the test	Satisfactory

c) Hot Finished Seamless Pipe

Sl. No.	Test Done	40 mm dia (Quantity used 12t)		25 mm dia (Quantity used 4.5t)	
		Permissible Value	Average Value for 2 tests	Permissible Value	Average Value for 2 tests
1.	Chemical Composition as per IS: 1239 Pt.I– 1990				
a)	Maximum Sulpher	0.05%	0.014%	0.05 %	0.014%
b)	Maximum Phosphorus	0.05 %	0.016%	0.05%	0.020%
2.	Minimum Tensile Strength (N/Sqmm)	320	478.30	320	525.72
3.	Minimum Elongation	20%	35.17%	20%.	40.09%
4.	Bend Test	To satisfy the test	Satisfactory	To satisfy the test	Satisfactory
5.	Paint Test				
a)	Cross Cut Tape Test as per ASTM-D-3359	To satisfy the test	Satisfactory	To satisfy the test	Satisfactory
b)	Minimum Thicknes of Powder Coating	50micron	87.5micron	50micron	86micron
c)	Chemical and Stain Resistance as per IS:13871:1993	To satisfy the test	Satisfactory	To satisfy the test	Satisfactory
d)	Salt Spray Test for 1000 hrs. as per IS:101(Pt.VI/Sec.I)1988	To satisfy the test	Satisfactory	To satisfy the test	Satisfactory

9.20 Testing of Auditorium Chair

The auditorium chairs were tested in factory for following :

a) the polyurethane foam used for seat & back is cold moulded with density not less than 45 kg/cum. Hardness measured on hampden machine at 25% were not less than 20±2 kg.

b) Seat were able to withstand the impact of 57kg load from 50mm height for 1,00,000 cycles without noticeable distress/damage.

9.21 Block Board Type I Grade II for Furniture :

Sl. No.	Test Done	Permissible Value as per IS:1659:1990	25mm Thick (Quantity used 6030sqm) Average Value for 59 tests	19mm Thick (Quantity used 7530sqm) Average Value for 73 tests
1.	**Dimensional Change Caused by Humidity**			
a)	At 90±5% R.H.			
i.	Difference in length	±1 mm	0.136 mm	0.135 mm
ii.	Difference in thickness	±1 mm	0.129 mm	0.130 mm
b)	At 40±5% R.H.			
i.	Difference in length	±1 mm	(-) 0.031 mm	0.032 mm
ii.	Difference in thickness	±1 mm	(-) 0.029 mm	0.029 mm
2.	**Resistance to Water**			
i.	Adheshion of Plies	Should be excellent pass standard.	Excellent	Excellent
3.	**Mycological Test**	To pass the test	Passes the test	Passes the test

9.22 Commercial Ply (B.W.R.) for Furniture :

Sl. No.	Test Done	Permissible Value as per IS:303:1989	4mm Thick (Quantity used 90sqm.) Average Value for 1 test	9mm Thick (Quantity used 750Sqm.) Average Value for 7 Tests	12mm Thick (Quantity used 1970 Sqm.) Average Value for 22 Tests
1.	**Glue Adhesion Test**				
a)	Minimum Glue Shear Strength in Dry State				
i.	Average	1350 N.	1382 N.	1584.86 N.	1503.54 N.
ii.	Individual	1100 N.	1375 N.	1554.29 N.	1465.45 N.
b)	Minimum Water Resistant Test				
i.	Average	1000 N.	1097 N.	1345.29 N.	1237.95 N.
ii.	Individual	800 N.	1080 N.	1318.57 N.	1204.50 N.
c)	Minimum Myclogical Strength				
i.	Average	1000 N.	1033 N.	1387.71 N.	1247.80 N.
ii.	Individual	800 N.	980 N.	1354.43 N.	1213.18 N.
2.	**Moisture Content**	5 to 15%	7.5%	7.8%	8.60%

9.23 Miscellaneous Items

The permissible value and actual average values for various other items tested are given as below :

Sl. No.	Item & Test Done	Nos. of Tests	Permissible Value	Average Value	Remarks
A.	**Superstructure**				
1.	**Mineral wool (Quantity used 7851sqm)**				As per IS:3144:1990
a)	Bulk Density Kg/Cum	5	48 (min)	57.63	
b)	Minimum Recovery After Compression	5	90%	97.27%	
c)	Maximum Moisture Content % by Mass	5	2%	0.32%	
d)	Maximum Moisture Absorption	5	2%	0.26%	
e)	Maximum Sulpher Content	5	0.6%	0.23%	
f)	Alkalinity	5	7-10	7.48	
g)	Shot Content				
i.	Greater than 5mm	5	Nil	Nil	
ii.	Maximum Retained on 500 Micron IS Sieve	5	5%	1.92%	
iii.	Maximum Retained on 250 Micron IS Sieve	5	15%	6.65%	
2.	**Gypsum Board (Quantity used 20136 Sqm)**				As per IS:2095 (Part-III):1996
a)	Water Absorption	4		57.86	
b)	Transverse Strength				
i.	Transverse Direction	4		206.75	
ii.	Longitudinal Direction	4		529	
c)	Jolting Test	1		Satisfactory	
d)	Surface Hardness (Maximum)	1		6	
e)	Bulk Density	1		0.8	

3.	**Galvanizing Coating on GI Ceiling Frame**				
a)	By Triple Spot Test (min)	2	220gm/sqm	301.2gm/sqm	As per IS:277:1992
b)	By Single Spot Test (min)	2	190gm/sqm	286.9gm/sqm	
4.	**SS Dash Fasteners (Quantity used 86000 Nos.)**				
a)	Chemical Analysis				
i.	Maximum Carbon	6	0.08%	0.075%	As per IS:6911
ii.	Maximum Mangnese	6	2%	0.91%	
iii.	Maximum Silicone	6	1%	0.16%	
iv.	Maximum Sulpher	6	0.03%	0.012%	
v.	Maximum Phosphorous	6	0.045%	0.0165%	
vi.	Chromium	6	17.5% - 20%	18.22%	
vii.	Nickel	6	8%-12%	8.73%	
viii.	Molybdenum	6	Nil	Nil	
b)	Corrosion Resistance	6	To satisfy the test	Satisfactory	As per IS:10461 Part I & II
5.	**Chemical Composition of Lead Percentage by Weight (Quantity used 3432Kg)**				**As per IS:782:1978**
a)	Maximum Bismuth	1	0.050	0.020	
b)	Maximum Silver	1	0.005	Less than 0.005	
c)	Maximum Copper	1	0.100	0.012	
d)	Maximum Arsenic	1	0.005	Less than 0.005	
e)	Maximum Antimony	1	0.060	0.018	
f)	Maximum Tin	1	0.005	Less than 0.005	
g)	Maximum Iron	1	0.005	0.003	
h)	Maximum Zinc	1	0.005	0.002	
i)	Maximum Total Impurities	1	0.200	Between 0.055- 0.070	
j)	Minimum Lead (by difference)	1	99.800	Between 99.930-99.945	

b)	**Domes**				
1.	**Silica Fumes (ASTM-C1240/98)**				
a)	Silica, % by mass	1	85 Minimum	88.96	
b)	Loss on Ignition, % by mass	1	6.0 Maximum	1.88	
c)	% Retained on 45 microns	1	10 Maximum	6.0	
d)	Accelerated Pozzoloniz Activity Index at 7 days % of control.	1	85 Minimum	86.1	
c)	**Furniture**				
1.	**Teak Veneered Ply 3.5 mm Thick**				**As per IS: 1328-1982**
a)	Resistant to Water	102	To pass the test	Passes the test	
b)	Moisture Content	90	5 to 15%	7.93%	
2.	**Leather Colour Fastness**				
a)	Wet to and fro Rubbing Test				As per IS 577-1986 Appendix 'B'
i.	Material	1	3 after 300 rubs	4	
ii.	Felt Pad	1	3 after 300 rubs	3	
b)	Adhesion of Finish	1	3 min	4	Bally Procedure of IS: 577- 1986.
c)	Test for Resistance to Blocking	1	There shall be no visible damage to the surface and the sample shall separate without lifting the weight	There is no visible damage to the surface and the sample separates without lifting the weight	As per IS:577:1986

10.0 INDIAN BUILDING CONGRESS AWARD

Indian Building Congress during 9th Convention on July 6, 2003 awarded IBC Trophy to CPWD for Construction of Parliament Library Building for Excellance in Built Environment for the year 2002.



Shri K. Srinivasan Chief Engineer, Receiving IBC Trophy

COMPLETION COST

1.0 The Original Preliminary Estimate for the Project for Rs. 88.41 Crores was sanctioned in August, 1993 with a period of completion of 4 years. As the Project progressed, the Lok Sabha Secretariat kept adding to their requirements from time to time. These were

1.1 Additional Requirement for Special Services :

A/A & E/S for special services for Rs. 8,79,42,000/- was communicated by Lok Sabha Secretariat on August 14, 1996. The detailed provisions for special services could not be finalized and number of meetings were held with Lok Sabha Secretariat & Consultant Architect and following changes were made in use of spaces in the Building.

a) Committee Rooms were increased from four to ten numbers.

b) Private dining rooms were deleted.

c) Computer Centre was enlarged and shifted from first floor to first basement.

d) Technological improvements were required making the originally proposed equipment obsolete.

e) Wiring support/floor trunking for computer networking was reduced.

f) In view of technological explosion during last three years Lok Sabha Secretariat desired that system should be updated and state of art technology should be provided by upgrading the specifications.

The decision for special services to be provided in Auditorium & 10 nos committee rooms was taken during meeting held on January 14, 1999. Lok Sabha Secretariat also decided that video system of broadcasting quality is to be provided. The video camera, control & recording system would be provided by Doordarshan as in the case of Parliament House, whereas necessary support for power & cable routing etc. was to be provided by CPWD. A lumpsum provision was made for power supply system, lighting, wiring and cable path provisionally as details were to be received from Doordarshan after they finalize the equipment.

The revised preliminary estimate having provision for sound reinforcement system, simultaneous language interpretation system, audio-visual system, large screen display, film projection, stage Equipments, stage lighting including special lighting for coloured TV coverage, conferencing system, CCTV (Display), UPS & floor-trunking was approved by Lok Sabha Secretariat for Rs. 15,04,07,740/- during June, 1999. However, the estimate did not include the work of video cameras, Control & recording equipment for video recording in various areas which was to be done by Delhi Doordarshan as per decision of Lok Sabha Secretariat. As per the estimate period of completion for this work was one year.

1.2 Additional Work of Interior Decoration, Furniture & Furnishing

The provision for Interior Decoration, Furniture & Furnishings was not included in original preliminary estimate sanctioned for the work. The decision was taken subsequently to provide interior decoration, furniture & furnishings in the building.

M/s Raj Rewal Associates was appointed as consultant for this work during November, 1997 after approval of Lok Sabha Secretariat. The nodal officers for finalzing the requirements were appointed by Lok Sabha Secretariat vide letters dated January 1, 1998 & October 10, 1998. The plans/ requirements were finally approved on February 3, 1999 & preliminary estimate submitted in March, 1999. The A/A & E/S for Rs. 35,56,00,000/- was received in June, 1999 with a period of completion as 18 months i.e. Decemer, 2000.

1.3 These two additional provisions alone cost Rs. 51 Crores i.e. 55% of the cost of the sanctioned estimate.

2.0 Apart from these additional requirements the scope of the work too was changed substantially from technical and architectural considerations specially relating to work in Foundations and the Domes. These, along with other changes in specifications brought about in the Superstructure items, accounted for an additional cost of Rs. 32 Crores.

3.0 Put together these additional works cost Rs. 83 Crores – as much as the original estimate, with the time of completion also increasing proportionately.

4.0 Adding to our woes certain delays occurred which was caused by agencies beyond our control. They were :

4.1 Delay due to NIC & Doordarshan Works

The work of cabling for computers was to be done by NIC and for Video recording by Doordarshan. The work was entrusted to NIC & Doordarshan by Lok Sabha Secretariat very late and the work of false ceiling in corridors was held up for the same for about six months during 2001.

4.2 Less Allotment of Funds

Less allotment of funds as compared to requirement for various financial years also affected the progress of work.

5.0 But in spite of these hindrances it goes to the credit of the Project Team that the time for completion did not exceed beyond what was justified by the cost of additional works as mentioned in paras 1 & 2.

Thus the project was completed within the proportionately enhanced time at the following cost:

a)	Revised Sanctioned Cost of Building	Rs. 141.31 Crore
b)	Special Services	Rs. 15.04 Crore
c)	Interior Decoration, Furniture & Furnishing	Rs. 35.56 Crore
	Total	Rs. 191.91 Crore
	Actual Expenditure	Rs. 202.00 Crore
	Cost Over Run	Rs. 10.09 Crore
		which is within the permissible variation

PRO ACTIVE ROLE OF CPWD

A mammoth project of this size cannot be credited to one man or even one team. Millions of manhours both on the drawing board as well as at site have gone into creation of this Parliament Library Building. But certainly the key players of this Project have been the CPWD, M/s Raj Rewal Associates and major contracting agencies like M/s Cem India Ltd., Larsen & Toubro Ltd., Voltas etc.

M/s Raj Rewal Associates certainly deserve credit for the architectural concept (a concept which would make Sir Lutyens proud) and the detailed architectural drawings which followed. But it fell upon CPWD to convert his dreams into brick-and-mortar reality. Thus, CPWD had to sometimes supplement and sometimes moderate the drawings and details given by M/s Raj Rewal Associates, in order to ensure functional viability of some of the features planned by the Architect. Some examples are.

- The Architect had proposed initially three basements which were later got reduced to two basements from structural considerations. The idea of providing diaphragm wall was hit upon by the design team of CPWD after carrying out intensive studies of similar works done elsewhere in the country. The method of excavating 93255cum of rock without blasting was also devised by CPWD after making a number of trials with various kinds of equipments and methods.
- The structural design for the building was totally done by the CPWD design team.
- The same applies for all electrical, mechanical and electronic services which were designed by CPWD team at site; as also water supply and drainage services.
- The details for waterproofing of the basement was developed by the site engineers of CPWD and a false floor was added at the second basement, with provisions for drainage of any water due to seepage.
- Innovative methods of circular stone cladding and vertical cladding on filler walls without use of any clamps or pins, was developed by the site engineers.
- M/s Raj Rewal Associates were requested to modify the width of the marble slats in the Auditorium and also provide a serrated finish to the circular walls of the Auditorium, keeping the acoustics of the auditorium in mind.
- M/s Raj Rewal Associates were requested to make modifications taking into account the accessibility of the various services for the purpose of maintenance. Such examples are - access for corridor lighting, access in the catwalk above the auditorium and access to the services in the various halls provided in the building.
- Last but not the least, the structural designing, detailing etc. of the Domes was done by CPWD, while the Architect had only given the form or shape of the domes. The casting of the joints, the casting of the bubbles, the erection of these elements, maintenance of geometrical precision, waterproofing the entire dome

assembly etc. were details which were worked out by the CPWD to produce the exact form envisaged by the Architect.

In a similar manner, even though we were fortunate to have M/s Larsen & Toubro Limited who is a leading construction agency in the country to do the superstructure and domes work, still there were many instances where we needed to play a pro-active role in supplementing their efforts to ensure a defect- free construction. Examples are-

- Guidance in the shortlisting of agencies for specialized works like waterproofing, internal services, production of castings etc. was given by CPWD after doing intensive market surveys.
- Insisting on preparation of mock up for the domes, cladding and other finishes and sorting out deficiencies.
- Laying out method statements, test requirements etc. in great detail followed by thorough and timely checks at site so that defective material or construction are identified and removed forthwith.
- Timely advice for expediting the progress. For example by increasing the number of moulds for coffers, insisting on steam curing of coffers to reduce the time of the casting cycle, advice for pre-casting the RCC chajjas for domes to save time etc.
- Identifying agencies and methods of waterproofing and helping in making corrections to the materials or methods used in the case of expansion joints, roof treatment etc.
- Last but not the least, monitoring the project at frequent intervals and sorting out coordination problems relating to other agencies involved in the work.

This Project has thus shown how the different members of the team could complement each other's efforts in order to produce a building which would be aesthetic, robust and functional, all at once.

MAINTENANCE & HOUSE KEEPING

1.0 MAINTENANCE

The maintenance is required to keep, restore or improve various facilities including every part of building & services to an acceptable standard. The objectives are :

a) To preserve the building and services in good operating conditions and

b) To maintain its original specifications & finishes, and where necessary upgrade them.

Apart from day to day services the maintenance can be divided into two categories i.e. Periodical Maintenance and Preventive Maintenance.

1.1 Periodical Maintenance

The periodical maintenance is proposed to be done for various exposed surfaces as per specifications & frequencies given below.

Sl.No.	Building Element	Specifications	Frequency
A.	**BUILDING**		
1.	Burma Teak Wood		
a)	Panelling, False Ceiling	French Spirit Polish & Melamine Coating	Once in Five Years
b)	Flooring (Auditorium & Committee Rooms)	French Spirit Polish & Melamine Coating	Yearly
c)	Doors	French Spirit Polish & Melamine Coating	Once in Three years.
2.	Cedar Board Panelling	Wax Polish	Yearly
3.	Cedar Wood		
a)	Battened False Ceiling below Auditorium Balcony	Wax Polish	Yearly
b)	Auditorium (Cross Combed & Battened Ceiling), Other Areas (Cross Combed in Coffers), BPST, VIP & AV Domes (Cross Combed)	Wax Polish	Once in Five Years
4.	Shisham Wood Cross Combed in Core Domes (2 nos) & Services Dome	Synthetic Enamel Paint (By Spray Method)	Once in Five Years
5.	Painting Ceiling in Kitchen/Canteen, Sound Control, Light Control Room etc.	Synthetic Enamel Paint	Yearly
6.	Plastered Surface (Parking, Service Area, Space below Auditorium, Offices etc.)	Oil Bound Distemper	Yearly

7.	Gypsum Board False Ceiling/Drop Ceiling including in Coffers	Plastic Emulsion	Once in Two Years
8.	Parking Demarcation & Numbering	Road Marking Paint & Black Japan Paint	Yearly
9.	Sand Stone Work including Jali	Silicon Water Repellent	Once in Three years
10.	Drain Cleaning (Peripheral Second Basement & Third Level Parking)	Cleaning of Silt etc.	Once in Six Months
11.	Manhole (about 860nos) & Connecting Channels (False Floor)	Cleaning of Silt etc.	Yearly
12.	Sewage Sumps (Second Basement–5nos) (Water & Sludge being Pumped by Automatic Pumps Regularly)	Removal of Sludge etc. (Generally will not be required)	As and when required
13.	Folding/Sliding Partition (Auditorium Stage) of Modern Fold (US Based Company) under Annual Maintenance Contract to M/s Consolidated Services upto April 4, 2007.	Regular Checking by the Agency	Once in Two Months
14.	Water Supply		
a)	Cleaning & Disinfection of Underground & Overhead Water Tanks	Dewatering, Silt Clearance, Fungus Removal, Scrubbing, Washing by Pressure Jet, Chemical Treatment and Ultra Voilet Radiation to Kill Bacteria & Germs.	Once in Three Months
b)	Testing of Water	For IS Conformity for Human Consumption	Monthly
15.	Strainer Pipes Connecting to Spouts at Terrace.	Cleaning	Weekly in Rainy Season Otherwise Monthly.
16.	Spouts/Drain along Glass Blocks	Cleaning for Blockage	Weekly
17.	Space on Both Sides of Expansion Joints	Pit & Drainage Cleaning	Weekly in Rainy Season otherwise Monthly.
18.	Carbon Steel for Domes	Epoxy Painting	Once in Five Years
19.	Stainless Steel for Domes	Lacquer Polish	Once in Five Years

B.	FURNITURE		
1.	Mobile Closed Stacks		
a)	Guard Rail Channel	Cleaning of Dust etc.	Monthly
b)	Powder Coating	Touching by Spray Paint (Wherever Required)	Yearly
2.	Open Stacks		
a)	Powder Coating Hot rolled Seamless Tubular Frame & CRCA Sheet Shelves	Touching by spray paint (Wherever Required)	Yearly
b)	Stainless Steel with Block Board Shelves		
i.	Block Board Shelves	French Spirit Polish & Melamine Coating.	Once in Two Years
ii.	Stainless Steel	Polishing	Once in Five Years
3.	Wooden Furniture with or without Stainless Steel Structure viz. Workstation, Study Carrels, Office Tables, Banquet Hall Tables & Chairs, Canteen Chairs, Committee Room Tables, Wooden Racks etc..		
a)	Wood Work	French Spirit Polish & Melamine Coating	Once in Two Years
b)	Stainless Steel Work	Polishing	Once in Five Years
4.	Sofa Sets		
a)	Leather Upholstery & Cushion Foam	Renewal	Once in Five Years
b)	Stainless Steel	Polishing	Once in Five Years
c)	Leather	Wax Polishing	Yearly
5.	Office Chairs , Auditorium Chairs (Upholstery & Cushions)	Renewal	Once in Five Years

1.2 Building Preventive Maintenance

The various complaints as lodged by the occupants needs to be attended. Also regular inspection needs to be done for cleaning and replacement of damaged/ broken and non-functional items. Some of the important items are high- lighted as per details given below :

a) *Doors* : The doors provided needs to be checked regularly for ease of closing and functioning of various fittings provided. The fittings of generally 'd'–line & 'Dorma' company have been provided and should be replaced by fittings of same specifications. As far as aluminium glazed shutters are concerned 6mm thick heat strengthened float glasses have been provided & should be replaced with same specifications in case of breakages.

b) *Windows* : The aluminium windows provided needs to be checked for proper functioning and breakage of glass etc. Glass if broken needs to be replaced with same specifications i.e. hermetically sealed double glass units.

c) *Marble Slats Wall Lining & Sand Stone Jali* : Polished Banswara marble slats 75mm/ 150mm wide & 18mm thick and sand stone jali screwed to sal wood frame have been used with sand stone horizontal bands. In case of breakage of marble tiles/ sand stone jali the same can be replaced by first removing sand stone bands which have to be removed very carefully since they are fixed with dash–fasteners & cement mortar backing.

d) *Stone Work* : The stone work needs to be checked regularly to ensure that the same is not disturbed and becomes loose. The bank guarantee for proper fixing of stone has been furnished by M/s Larsen & Toubro Ltd. for a period of five years from the date of completion for both the works i.e. superstructure and domes.

e) *Vineratex* : Any crack or waviness appearing in the surface or any portion emitting hollow sound needs to be rectified. Vineratex done is guaranteed for a period of ten years from date of completion. M/s Larsen & Toubro Ltd. has submitted the guarantee bond for this purpose for both the works i.e. superstructure and domes.

f) *Cedar Cross Combed Panels* : Cedar cross combed panels provided in the false ceiling in coffers bear a guarantee for seven years from the date of completion. Twenty percent of security deposit has been withheld for this purpose.

g) *Fire Check Doors* : The staircases & some other areas have been provided with fire check doors having locking arrangement. The very concept of providing locking arrangement for fire-check doors goes against the rationale of having the FCDs themselves, in the first place. However, locking arrangement have been provided from security consideration. In normal circumstances, when the space is inhabited by people, FCDs should remain unlocked so that there is a clear escape route available for people in case of fire in that compartment. All the fire check doors are guaranteed for a period of seven years from the date of completion . Ten percent of security deposit is lying with the department for this purpose. The door fittings of "Dorma" Company except locks have been used, whereas locks of Cavalier make have been used.

h) *Portable Fire Extinguishers* : The portable fire extinguishers provided bears five years guarantee for ABC type and two years guarantee for CO_2 type from date of completion. Guarantee bond to this effect is available with the department. Ten

percent of security deposit shall be refunded after completion of the said guarantee period.

i) *Fire Pillows* : Opening in EDBs have been sealed with fire pillows of 3 hours fire rating to check the spread of fire from one floor to another. It should be ensured that these pillows are not disturbed from their position during repairs to electrical installations etc. However two sleeves have been kept in EDBs to pass electrical cables etc. for future additions which may be used as & when required.

j) *Floor Cleaning* : In view of provisions of floor trunking the building is planned to be cleaned regularly by wet mopping only. Washing of floor should not be done at all otherwise same is likely to reach at undesired locations through floor trunking.

k) *GI Spouts in Sunken Floor of Toilets* : The water proofing has been done in slope and spouts of GI Pipe of 50mm dia have been left at top of water proofing layer in sunken floors of toilets before laying lean concrete for draining out of seepage water (if any) to the shafts. The seepage water dripping from these spouts into shaft will help in giving advance warning for any leakage in pipes/fittings etc.

l) *Glass Blocks–Light Well* : Glass blocks with drain have been provided along outer periphery of the building at ground floor. Though water proofing treatment has been done for the drain, at the junction of wall & glass blocks, the sand stone is just over lapping the glass block panels and sand stone being porous, there is possibility of water leakage with water flooded on glass blocks. However, this situation is not likely to crop up, provided the drains including its spouts are regularly cleaned.

m) *Removal of Stainless Steel/Perforated Aluminium Planks in False Ceiling* : The stainless steel/perforated aluminium planks in false ceiling needs to be removed for attending various services above the false ceiling. Three to four grills in continuation are snap fitted and needs to be removed before opening of the false ceiling planks. While replacing these it must be ensured that the lines and levels are restored as per the original.

n) *Sanitary Fittings* : The chinaware sanitary fittings such as urinals, wash basins water closets etc. of Neycer make have been provided & should be replaced with fittings of same specifications in case of breakage.

o) *Water Supply Fittings* : The water supply fittings such as CP Brass bib cock, pillar cock, angle valve etc. of Jaquar make have been used & should be replaced with fittings of same specifications.

p) *Glass Blocks/Glazing* : The details for glass blocks & hermetically sealed glazing provided are covered in chapter of Glass work, which should be replaced with material of same specifications in case of damages . However glass blocks & hermetically sealed glass units for domes are guaranteed for manufacturing defect for a period of five years & ten years respectively from date of completion.

M/s Larsen & Toubro Ltd. have furnished guarantee bond for the same.

q) *Elastomeric Bearings* : The elastomeric bearings provided for domes are guaranteed for a period of ten years.

r) *Junction of Aluminium Glazing & Sill/Floor Level* : The junction of aluminium glazing and sill/floor level have been treated with silicon sealant and needs to be checked regularly & treated with silicone sealant wherever required to avoid leakage through these joints. Pressure washing along these joints should not be done while washing the sand stone cladded/paved area.

s) *Water Proofing* : All the water proofing works done for superstructure and dome are guaranteed for a period of ten years from date of completion.

t) *Level of Stone Cladding/Earth* : Extensive plantation & grassing have been provided at the terrace. The walls of depressed portion for grass/planter area have been treated by cement plaster with water proofing compound upto a height of 450mm/750mm and cladded with sand stone strips at top. The level of earth should be 3" to 4" below bottom level of sand stone strip so that in case of accumulation of water it does not reach untreated surface/dash fasteners location due to capillary action resulting in seepage in building.

For example, the bottom strip of stone cladding was removed for Auditorium terrace garden and level of earth was lowered which solved the problem of seepage at these locations. The junctions and remaining exposed areas were treated with water based ferro–seal compound.

u) *Cleaning Terrace Drains & Strainer Pipes* : The strainer pipes connecting to spouts & drains on the terrace gets blocked frequently by leaves/cut grass etc. & needs to be cleaned regularly, accumulation of water on the terrace is likely to result in leakage/seepage in building.

v) *Expansion Joints* : Clear, vacant space has been created by erecting walls & water proofing the same on both sides of expansion joints through which pipes/cables are crossing. These spaces need to be cleaned regularly including removal of chockage from connecting drain provided in this space to avoid stagnation of water. Though the holes for pipes/cables have been treated but with the passage of time these are likely to become loose. In case of water level in these vacant spaces reaching upto the level of pipes/cables, the same is likely to result in leakage through expansion joint.

w) *Drainage in Focal Area at Terrace* : The drainage channels have been provided below path ways in focal area i.e. from Focal to Library, Focal to Audio-Visual Museum, Focal to VIP Block for draining surface water of the focal dome & nearby area. As far as auditorium block side is concerned the provision has been made for drain in the grassing area of 'J' Block for draining out water from focal to courtyard. These drains needs to be inspected and cleaned regularly specially

before on set of Monsoon.

x) *Maintenance & Repair of Irrigation & Sprinkler System* : The external landscape and terrace garden is being irrigated by irrigation line connected to tube well . There is a supplementary agreement for annual maintenance contract with M/s Surge Systems (India) Pvt. Ltd. for three years. As per the terms and conditions of the agreement, the annual maintenance mentioned above for the first year is free of cost for which nothing is payable to the agency. For the remaining two years the contractor is to be paid annually @ 3% of the tendered value, which is only labour charges and the cost of material replaced is to be borne by the department. The popup sprinklers, bubblers etc. are of "TORO" make of USA and should be replaced by material of same specifications in case of breakage.

The minor adjustment i.e. setting the sprinkler to the desired angle of sweep in plantation area can be done with the help of special key which is available with horticulture wing. At least one loop of Irrigation line must remain open when any one of the tube wells is in running condition and two loops must remain open when both the tube wells are in running conditions.

1.3 Furniture–Preventive Maintenance :

Furniture of all categories have been guaranteed for a period of five years against faulty manufacturing, workmanship , material, finishing and operation.

a) *Mobile Closed Stacks* : The following needs to be checked for mobile closed stacks regularly.

i. Mobile units sometime get derailed due to improper use and bearings if damaged needs to be replaced.

ii. The chain need to be checked periodically for tension since it gets expanded or contracted with temperature variation.

iii. Teeth of sprockets get damaged with continuous use and need to be replaced at an interval of 3 to 5 years.

iv. Shelves to be checked regularly at least once in a year and clips etc. to be refitted as and when required.

b) *Open Stacks Type 'B' and 'C'* : The open stacks type B are powder coated stacks including shelves whereas open stacks type C are made of stainless steel tubes and block board shelves with Burma teak wood veneering. The various items like pin, welding etc. needs to be checked regularly.

c) *Workstations, Study Carrels, Office Tables, Banquet Hall Tables & Chairs, Canteen Chairs, Committee Room Table and Open Stacks Type 'A', Wooden Racks* : These furnitures items are generally made by using frame work of stainless steel pipes, universal joint connector and block board of grade-I, type-2, BWR ply and laminated with 3.5 mm thick Burma teak veneering. The following needs to be

checked regularly.

i. Welding of various joints

ii. Lamination over block board.

iii. Neoprene pad provided for stainless steel shoe.

iv. Locks, roller channels, isolated wood panels, wooden moulding/lipping/block board/ply boards etc.

v. Fibre board with fabric upholstery for Workstations.

d) *Sofa Set* : Though the life of leather upholstery is considered about five years, the same needs to be checked regularly for cracks, damage etc.

e) *Standard Model Chairs and Auditorium Chairs* : The arm rest, foam, upholstery, castor, gas lift & tilting arrangement needs to be checked regularly.

2.0 KITCHEN EQUIPMENTS

Kitchen equipments/deep freezer etc. as per details below have been provided for which annual maintenance contract (AMC) has been drawn for a period of five and three years respectively w.e.f. April 21, 2002 with M/s Continental Equipment India (P) Ltd. , New Delhi .

Sl.No.	Description of Items	–	Total No.
A.	**KITCHEN EQUIPMENTS (Five Years AMC)**		
1	Hot bain marie (Elect) with hot case underneath	–	3 nos
2	Tee/coffee/milk dispenser (elect) table top type	–	9 nos
3	Four door vertical referigerator	–	2 nos
4	Ice cream freezer of 165 ltrs capacity	–	2 nos
5	Bottle cooler of 165 ltrs capacity	–	3 nos
6	Planetary mixer electrically operated of 40 ltrs capacity	–	1 no
7	Potato peeler of 5kg per charge capacity	–	1 no
8	Storage type water cooler 120 ltrs per hour cooling	–	1 no
9	Wall mounted Aquaguard	–	14 nos
10	Microwave ovan	–	3 nos
11	Wet masala grinder	–	1 no
12	Mixer (blender) double spindle.	–	1 no
13	Hood type dish washing machine	–	2 nos
14	Pre-rinse sink with jet spray unit	–	2 nos

15	Heavy duty vegetable cutting machine	–	1 no
16	Meat mincer	–	1 no
17	Vegetable/meat gravity slicer.	–	1 no
18	Pressure cleaner	–	1 no
19	Five door vertical referigerator	–	1 no
20	Water boiler of 50 ltrs capacity	–	1 no
21	Milk boiler of 30 ltrs capacity	–	1 no
22	Storage type water cooler of 40 ltrs/hour capacity	–	10 nos
23	Ice cube making machine of 60 kg per day capacity	–	1 no
24	Clean dish table	–	1 no
25	Two door vertical referigerator	–	9 nos
26	Water boiler of 30 ltrs capacity	–	1 no
27	Milk boiler of 20 ltrs capacity	–	1 no
28	Geyser of 100 ltrs capacity	–	1 no
29	Insectocuter wall mounted	–	1 no
30	Geyser of 50 ltrs capacity	–	12 nos
31	Kitchen aid mixer	–	2 nos
32	Soup warmer	–	4 nos
33	Water cooler of 150 ltrs capacity	–	3 nos
B.	**DEEP FREEZER (Three Years AMC)**		
1	Walk in vegetable cold store of size 2700mm x 2400mm x 2100mm	–	1 Set
2	Walk in dairy product cold store of size 2100mm x 2400mm x 2100mm	–	1 Set
3	Walk in deep freezer cold store for mutton & chicken of size 2700mm x 2400mm x 2100mm	–	1 Set
4	Walk in multi-purpose cold store of size 3000mm x 2400mm x 2100mm	–	1 Set
5	Garbage cold store	–	1 Set

3.0 HOUSE KEEPING

The building was completed and inaugurated on May 7, 2002. The work of housekeeping was started by traditional methods of cleaning i.e. by manual cleaning that too with the barest minimum number of workers, as a time gap arrangement

before handing over housekeeping to Lok Sabha Secretariat. However, subsequently it was decided in October, 2002 that housekeeping work will be done by CPWD. Shri Shivraj V. Patil, Hon'ble MP (former Speaker Lok Sabha) had visited the Parliament Library and suggested that the Parliament Library Building should be cleaned by vacuum cleaners and other modern gadgets and further suggested mopping/cleaning should be done by machines instead of manually. The proposal was accepted by Hon'ble Speaker, Lok Sabha on November 27, 2002.

There are no established guidelines for automated housekeeping. Keeping in view the observations of Hon'ble Speaker a detailed study has been done. The various agencies and manufactures dealing in housekeeping machines and the agencies executing the work of housekeeping with automated machines were called for discussions and demonstration of various machines. After detailed discussions it was decided that machines of M/s Nilfisk marketed by M/s Eureka Forbs Ltd. and of Taski marketed by M/s Johnson Diversey are of standard make and have a strong backing of after-sales service. As proposed by M/s Eureka Forbs Ltd. and M/s Johnson Diversey the chemical of M/s ECO Lab–Henkel and M/s Johnson Diversey were found to be most suitable cleaning material for this building. The terms and conditions were finalized by keeping the provisions of machines either of Taski or Nilfisk and chemicals of M/s ECO Lab–Henkel and M/s Johnson Diversey.

3.1 List of Chemicals Required for House Keeping Work

The provision of following chemicals for cleaning of various areas have been made:

Sl.No.	Chemicals	For Cleaning of
A.	M/S JOHNSON AND DIVERSEY	
1.	R1	Bathroom Items
2.	R2	Rooms, Offices Items, Laminated Furnitures, PC, Marble, Granite Floors
3.	R3	Glass Surfaces
4.	R4 Shine UP	Wood Polish Furniture
5.	Good Sense Freshner	Room Air (Spray)
6.	R6	WC Urinals
7.	R9	Bathroom (Hard Water)
8.	TR 101	Carpet Shampoo
9.	TR 103	Carpet (Deep Cleaning)
10.	R20+	Floor Stripers
11.	Complete	Kota Stone Polish
12.	Nobile	Marble Floors-Polishing
13.	Spiral	Kota Stone and Hard Floor

14.	Snapback	Kota Stone Floor
15.	Lever Star	Hand Disinfectant before/after going into Critical Areas
16.	Emerel	Restorative Product for Fixtures

AND/OR

B. M/s ECO Lab- Henkel

1.	The following chemicals should be of Oasis Compac Range and these chemcials are to be dispensed through a sleek Oasis compac dispensor.	
	* OC Bath Room Cleaner	Bath Room fittings & Fixtures
	* OC Glass Cleaner	Glassess
	* OC Air Fresh	Air-Freshener
	* OC Neutral Cleaner	All Purpose Stain Remover
	* OC Counter Act	Bad Odour Remover
2.	Sigla	Floor Mopping & Scrubbing
3.	Nettoklar	Marble Crystallization
4.	Bendurol	Stripping of Floor
5.	Polli	Regular Buffing of Granite
6.	Sapur Dud	Carpet Cleaner
7.	Sapur A&P	Carpet Spotting
8.	Helios	Stainless Steel/Chrome Shining
9.	Lodisin	Hand Soaps
10.	Opti	Wooden Furniture Polish

3.2 Manpower & Machines/Equipments

The provision of minimum manpower and machines/equipments as per details given below have been made:

A. Manpower

Sl.No.	Designation	Numbers
1.	Manager	1
2.	Supervisor	3
3.	Labour/Operator	30

B. Machines & Equipments

Sl.No.	Machines/Equipments	Model No.	Numbers
1.	Walk Behind Sweeper (Petrol Driven)	Nilfisk SW 700 P or Taski Balimat-65 T	1

2.	Walk Behind Sweeper	Nilfisk SW 655 or Taski Ballmat-45 T	2
3.	Single Disc Scrubber	Nilfisk N421 A or Taski DS 42*	2
4.	Floor High Speed Burnisher	Nilfisk SDH- 5120 or Taski Ergodisc 1200.	1
5.	Walk Behind Automatic Scrubber cum Drier	Nilfisk CA 340 or Taski Combimat 300 E	2
6.	Walk Behind Automatic Scrubber cum Drier	Nilfisk CA 530 or Taski Combimat 1000 E	2
7.	High Pressure Water Jet	Nilfisk NF-410 with Detergent(tank) or Taski High Pressure TX-12-100	1
8.	Back Mounted Dry Vacuum Cleaner	Bakuum of Nilfisk or Taski Dorsalino Back-Vac	2
9.	Dry Vacuum Cleaner	Nilfisk GD-930 or Taski Bora-12	8
10.	Dry & Wet Vacuum Cleaner	Nilfisk WD-225 or Taski Vacuumate 22	3
11.	Upholstery/Carpet Injection Extraction Machine	Nilfisk ZP 3 in-1 or Taski aquamat 10.1	2
12.	Glass Cleaning Telescopic Kits with Detergent Squeezee Provision	As Approved by Engineer-in-Charge.	As per Requirement
13.	Mopping Trolley with Double Bucket System	As Approved by Engineer-in-Charge.	As per Requirement
14.	Wheel Mounted Garbage/ Waste Disposal Trolley	As Approved by Engineer-in-Charge.	As per Requirement
15.	Ride on Sweeper (Petrol Driven)	Nilfik- SR-1000 P or Taski-Ballmat 98 T	1
16.	Ride on Scrubber/Drier (Battery Operated)	Nilfisk- BR-700B or Equivalent Model of Taski	1

3.3 Areawise Frequency of Cleaning

The minimum frquency of cleaning required alongwith machines to be used are given below

Sl. No	Area	Job	Frequency	Machines to be deployed
1.	Boundary wall (Stone and Grills)	i. Dry dusting in security rooms at gates. ii. Pressure washing entire compound wall	Fornightly Quarterly	• Dry Vacuum Cleaners • High Pressure Water Jet

2.	Parking.	i. Vacuum Sweeping	Daily before 9 AM	• Ride on/Walk Behind Sweeper
		ii. Pressure washing	Monthly	• High Pressure Water Jet
		iii. Drain & Drainage sump cleaning	Monthly	• High Pressure Water Jet and manually
3.	Outside Area	i. Vacuum Sweeping (paved area)	Daily	• Ride on/Walk Behind Sweeper
		ii. Cleaning peripheral glass blocks & drain	Weekly	• Manually
		iii. Pressure washing of paved area	Monthly	• High Pressure Water Jet
		iv. Washing peripheral glass blocks & drain.	Monthly	• Mopping with Water & High Pressure Water Jet
4.	External Façade of Building	i. Pressure washing	Quarterly	• High Pressure Water Jet
5.	Terrace	i. Cleaning	Weekly	• Dry Vacuum Cleaner
		ii. Pressure washing	Quarterly	• High Pressure Water Jet
		iii. Spouts cleaning	Monthly/or as required earlier	• Manually
6.	Outer Surface of Domes	i. Cleaning of hard surface.	Once in Two months	• High Pressure Water Jet
		ii. Horizontal glass cleaning (except Focal dome).	Once in Two months	• Glass Cleaning Telescopic Kit
		iii. Cleaning of vertical glazing and glass brick walls.	Once in Two months	• Glass Cleaning Telescopic Kit
		iv. Focal Dome Horizontal Glass wash cleaning	Once in Two months	• Glass Cleaning Telescopic Kit
7.	Courtyards (Paving & Glass Blocks)	i. Vacuum sweeping	Daily	• Walk Behind Sweeper
		ii. Pressure washing & scrubbing	Fornightly	• Walk Behind Scrubber cum drier & High Pressure Water Jet
8.	Kota/Marble/ Granite Floor in Corridors, Public Areas including Committee Rooms, Library etc.	i. Wet & dry cleaning	Daily before 9.00 AM & as per site requirement.	• Walk Behind Scrubber cum drier
		ii. Buffing of floors	Fortnightly	• Floor High Speed Burnisher
		iii. Scrubbing of floors	Fortnightly	• Single Disc Scrubber

9.	Kota/Marble Floor in Rooms & Canteen Area	i. Wet & dry cleaning	Daily before 9.00 AM & as per site requirement.	• Walk Behind Scrubber Cum Drier
		ii. Buffing of floors	Fortnightly	• Floor High Speed Burnisher
		iii. Scrubbing of floors	Fortnightly	• Single Disc Scrubber
10.	Internal Wall/ Column Surfaces with Wall Panelling/ Cladding of Stone, Wood, Marble Slats, Stone Jalis etc. (excluding Auditorium)	i. Dry dusting including spot cleaning upto 6ft. Height.	Daily	• Dry Vacuum Cleaner
		ii. Dry dusting upto roof including ledges	Weekly	• Back Mounted Dry Vaccuum Cleaner
		iii. Wet mopping signages & display	Weekly	• Manually
		iv. Vacuum cleaning all wall surfaces i/c. grooves etc.	Quarterly	• Dry Vacuum Cleaner
11.	Ceilings	i. Cleaning of Electrial lights & frames etc.	Fortnightly	• Dry Vacuum Cleaner & Manually
		ii. Vacuum cleaning of non metallic ceilings.	Quarterly	• Dry Vacuum Cleaner
		iii. Wet/moist cleaning of mettalic ceilings	Quarterly	• Manually
		iv. Cleaning of ceiling of domes, dome structure including glass from inside using suitable cleaning agents.	Half yearly	• Special equipments to reach large heights.
12.	Doors	i. Cleaning ii. Stain removing	Weekly Monthly	• Dry Vacuum Cleaner • Manually
13.	Stainless Steel/ Metal Surfaces such as Door/ Window Hardwares Furniture Frames etc.)	i. Dusting ii. Polishing	Weekly Quarterly	• Dry Vacuum Cleaner • Manually
14.	Staircases	i. Cleaning ii. Scrubbing of steps and railings etc.	Daily Monthly	• Dry Vacuum Cleaner • Scrubber cum Drier
15.	Skirting	i. Scrub cleaning	Monthly	• Hand scrubber & Manually

16.	Door/Window Glasses	i. Cleaning finger marks/ spots & entrance doors.	Daily	• Glass Cleaning Telescopic Kit
		ii. Internal side	Weekly	• Glass Cleaning Telescopic Kit
		iii. Outer side	Weekly	• Glass Cleaning Telescopic Kit
17.	Toilets	i. Re-filling of toiletries such as freshners, hand soap etc.	Daily before 9.00 AM & subsequently as per requirement.	• Manually
		ii. Floor wet & dry cleaning	Daily before 9.00 AM	• Scrubber cum Drier
		iii. Wall cleaning	Daily before 9.00 AM	• Manually
		iv. Cleaning WC/ Wash Basin/ Urinals etc.	Daily before 9.00 AM & afterwards as per requirement	• Manually
		v. Mirror cleaning for keeping dry & stain free.	Daily	• Manually
		vi. Other fittings & fixtures.	Daily	• Manually
		vii. Check cleaning	Every 60-90 minutes	• Manually
		viii. Complete washing including wall tiles etc.	Fornightly	• Telescopic Kit
18.	Dustbins only in Toilets and at Open Area within Building	i. Complete cleaning from inside and outside.	Weekly	• Manually
		ii. Emptying garbage bags	Daily as and when required	• Manually
		iii. Dustbins to be provided in Ladies toilets only	As per requirement	• Manually
19.	Library Stacks Area	i. Cleaning of floor under compactors/mobile stacks	Monthly	• Scrubber cum Drier & Manually
		ii. Vacuum cleaning of compactors including top surface.	Monthly	• Dry Vacuum Cleaner
		iii. Dusting of Book/ Newspaper shelves in reading areas.	Weekly	• Dry Vacuum Cleaner
20.	Fire Exinguishers & Wall Hangings etc.	i. Dry dusting	Daily	• Manually
		ii. Removing wall hangings etc. and cleaning behind.	Fortnightly	• Dry Vacuum Cleaner

21.	Switch Buttons	i. Dry/Wet wiping	Weekly	• Manually
22.	Telephones & Computers	i. Dusting	Daily	• Manually
		ii. Vacuuming of key boards etc.	Weekly	• Dry Vacuum Cleaner and Manually
		iii. Cleaning with deodorizer	Monthly	• Manually
23.	Table/Cabinets & Other Furniture Items	i. Dry dusting, Spot cleaning/stain removing	Daily before 9.00 AM as per site requirement	• Manually
24.	Auditorium Carpet	i. Dry vacuum cleaning	Monthly	• Dry Vacuum Cleaner
		ii. Spot cleaning	As and when required	• Carpet Injection/ extraction machine
		iii. Cleaning by injection extraction	Quaterly	• Carpet Injection/ extraction machine
25.	Auditorium Wall Lining	i. Dry Dusting upto 6ft height	Daily	• Dry Vacuum Cleaner
		ii. Vacuum cleaning for full height of cladding upto roof.	Quarterly	• Back Mounted Dry Vacuum Cleaner
26.	Venetion Blinds	i. Vacuum cleaning/ Dusting	Once in Two months	• Dry Vacuum Cleaner
27.	Upholstry	i. Dusting of Chairs/Sofas.	Daily	• Manually
		ii. Vacuum cleaning	Monthly	• Dry Vacuum Cleaner
		iii. Spot cleaning	As and when required	• Carpet Injection/ extraction machine
		iv. Cleaning and shampooing	Half yearly	• Carpet Injection/ extraction machine
28.	Leather	i. Dusting of Chairs/ Sofas.	Daily	• Manually
		ii. Vacuum cleaning	Monthly	• Dry Vacuum Cleaner
29.	Cobwebs	i. Check for cobwebs & removal	Daily as required	• Dry Vacuum Cleaner and Manually
30.	Door Mats	i. Dusting & cleaning	Daily	• Dry Vacuum Cleaner and Manually
31.	Removal of Garbage	i. At NDMC Garbage Dump Pit	Daily	• Trollies

The automated housekeeping in Parliament Library Building is being done w.e.f April 1, 2003.

EPILOGUE

All good things must come to an end. That applies to this documentation too. It is likely that the magnitude of the Project and its unlqueness have been lost in the maze of technical details contained in the document. For the lay reader, therefore, the following facts may be interesting.

The Central PWD has been involved in constructing monumental and heritage buildings since its inception (the year 1854), the most prominent among them being the Parliament House, the President's Estate, the North Block and the South Block. CPWD has been privileged to be called upon once again to build this heritage structure viz. the Parliament Library Building, which compares favourably with its illustrious neighbours.

The Project has been unique in that it is for the first time that rock-anchored diaphragm walls and basement raft have been used for a building; it is for the first time that stainless steel has been used in such a large quantity as structural elements; and the first time that cast steel joints have been used in a space frame in place of conventional tube-to-tube welding. How gigantic the Project was would become clear from the following data.

- 1,19,190 cum of Excavation in Soil
- 93,255 cum of Excavation in Rock without Blasting
- 410 m of Diaphragm Walls
- 2112 nos of Pre-Stressed Rock Anchors
- 253 t of High Tension Wires for Rock Anchors
- 28572 t of Cement
- 9123 t of Reinforcing Steel
- 34,20,000 nos of Bricks
- 3645 cum of Red Sand Stone
- 945 cum of White/Pink Sand Stone
- 3026 sqm of Sand Stone Jalis
- 6594 sqm of Marble/Marble Tiles/Slats
- 27622 sqm of Kota Stone
- 13710 sqm of Granite
- 20610 kg of Aluminium Sections for Doors & Windows
- 2729 sqm of Vertical Glazing for Windows

- 478 sqm of Vertical Glazing for Domes
- 533 sqm of Horizontal Glazing for Domes
- 33500 nos of Glass Blocks
- 380 cum of Burma Teak Wood
- 20136 sqm of Gypsum Board
- 129 t of Structural Steel for Domes
- 368 t of Carbon Steel (including weight of castings)
- 6024 nos of Carbon Steel Castings
- 70 t of Stainless Steel for Dome Structures (including weight of castings)
- 876 nos of Stainless Steel Castings
- 40 t of Stainless Steel for Glazing of Domes
- 75 t of Stainless Steel for Super Structure
- 86000 nos of Stainless Steel Dash Fastners
- 42 t of Stainless Steel for Furniture
- 474 t of CRCA Sheets for Mobile Stacks
- 80 t of HR Sheets for Mobile Stacks

The total built-up area of the Parliament Library Building is 60460sqm, about 1½ times the size of the Parliament House itself. Taken along with the Parliament House and the Parliament House Annexe, the Indian Parliament Complex is one of the largest in the world. CPWD is proud that it was given an opportunity to be associated with the construction of this complex.

THE TEAM

CIVIL WING

Chief Engineers & Project Managers

1 Shri Jag Mohan Lal
2 Shri Krishan Kumar
3 Shri K. Srinivasan

Superintending Engineers

1 Shri Bipin Chand
2 Shri Anil Kumar Bajaj
3 Shri Ravi Kant Soni
4 Shri Anil Kumar Garg

Executive Engineers

1 Shri Ravi Kant Soni*
2 Shri Sudhir Kumar
3 Shri N.K. Garg
4 Shri Jitendra Kumar
5 Shri R.K. Duggal
6 Shri Rakesh Kumar Shami
7 Shri Sanjay Gupta

Assistant Engineers/Assistant Executive Engineers

1 Shri J.K. Bansal
2 Shri P.K. Dixit
3 Shri Jitendra Kumar*
4 Shri Ram Diya
5 Shri Ajay Kumar
6 Shri Krishna Maheswari
7 Shri Devender Prakash
8 Shri Madan Pal
9 Shri Anil Trehan
10 Shri Om Narayan Awasthi
11 Shri Manish Kumar
12 Shri Apurb Anand
13 Shri Rajesh Kumar Rastogi
14 Shri Satya Prakash Bajpai
15 Shri Suresh Chand
16 Shri Shiv Singh Meena
17 Shri Ram Adhar Yadav
18 Shri Hari Om Sharma

Junior Engineers

1 Shri Satya Prakash Sharma
2 Shri M.K. Mathur
3 Shri Ram Adhar Yadav*
4 Shri Baldev Raj
5 Shri Hari Om Sharma*
6 Shri V.K. Sharma
7 Shri Sharan Singh
8 Shri S.P. Jain
9 Shri V.K. Arora
10 Shri B.N. Niyogi
11 Shri V.K. Gangwal
12 Shri Inder Pal Singh
13 Shri Bhuwan Chandra Kandpal
14 Shri R.K. Gupta
15 Shri Rajesh Taneja
16 Shri Shashi Kant Mishra
17 Shri P.K. Aggarwal
18 Shri Chander Shekhar
19 Shri N.K. Srivastava
20 Shri Satya Pal Singh

Draughtsmen

1 Shri Hari Singh
2 Shri Jitendra Kumar
3 Shri O.P. Thakkar
4 Shri Rajesh Kumar

ELECTRICAL WING

Chief Engineers

1 Shri J.N. Bhavani Prasad
2 Shri K. Keshvan
3 Shri K.A. Ananthanarayanan

Superintending Engineers

1 Shri S.C. Khurana
2 Shri Mohan Swaroop
3 Shri N. Nagrajan

Executive Engineers

1 Late Shri I.J. Malhotra
2 Shri M.M.L. Chibba
3 Shri G.L. Kapoor
4 Shri S.P. Sehgal

Assistant Engineers

1 Shri S.P. Sehgal*
2 Shri A.K. Roy
3 Shri Manjit Singh
4 Shri D.V. Gupta
5 Shri N.K. Malik
6 Shri V.K. Seth
7 Shri B.M.L. Gupta
8 Shri Vishesh Swamiwal

Junior Engineers

1 Shri S.R. Saini
2 Shri Puran Singh
3 Shri Kanhaiya Sah
4 Shri Vishesh Swamiwal*
5 Shri B.S. Bisht
6 Shri Binesh Chandra
7 Shri C.B. Singh
8 Shri Subroto Burman

Draughtsmen

1 Shri P.K. Khatri
2 Late Shri Radhey Shayam Kaushik
3 Shri Sriniwas

DESIGN TEAM (CIVIL)

Chief Engineers

1 Shri S.C. Gupta
2 Shri S.L. Karunakaran
3 Shri S.K. Khanna
4 Shri Deepak Narayan
5 Dr. A.V. Chaturvedi
6 Shri R. Subramanian

Superintending Engineer

1 Shri Jose Kurian

Executive Engineers

1 Shri Sudhir Kumar**
2 Shri Shailendra Sharma
3 Shri Neeraj Mishra
4 Shri Balraj Chadha
5 Shri Sanjay Gupta**
6 Shri P.Gopalakrishnan

Assistant Executive Engineers

1 Shri Ramesh Mishra
2 Shri Dev Roy Choudhary
3 Shri Niamuddin
4 Shri Rajeev Singhal
5 Shri Tarkeshwar Tiwari
6 Shri Mumtaz Ahmed
7 Shri R.P. Yadav
8 Shri Shailender
9 Shri M.V. Rao

Junior Engineers

1 Shri Piyus Aggarwal
2 Shri D.S. Bora
3 Shri Praveen Aggarwal

Draughtsmen

1 Shri S.K. Duggal
2 Shri R.K. Mannan
3 Shri M.K. Sharma
4 Shri Rajan

HORTICULTURE WING

Assistant Director

1 Shri Mahendra Prakash Nim

Section Officer

1 Shri Shivpal Singh Sishodia

CONSULTANT ARCHITECT

M/s Raj Rewal Associates

Team

1 Shri Raj Rewal
2 Shri Arvind Mathur
3 Shri Anshu Mahajan
4 Shri H.S. Sandhu
5 Shri Sanjeet Bose
6 Shri Vipin Thakur
7 Shri Ankur Mathur
8 Shri Sumit Maity
9 Shri Pratap Talwar
10 Shri Arun Rewal
11 Shri Raoul Rewal

MINISTERIAL STAFF

Private Secretary to Chief Engineers

1 Shri Surender Singh
2 Shri C.M.K. Thakur
3 Shri Charanjit Singh
4 Shri Raj Kumar

Assistant Accounts Officers

1 Shri P.S. Pardeshi
2 Shri H.P. Gupta
3 Shri Alok Moti Lal
4 Shri A.P. Dubey
5 Shri Satish Chander Sharma

Office Superintendents

1 Shri D.S. Rawat
2 Shri C.P. Singh
3 Shri Ram Mehar
4 Shri R.A. Mahato

Head Clerks

1 Shri S.D. Joshi
2 Shri Ram Kanwar
3 Shri Rattan Singh

Stenographers

1 Shri Mohan Singh Nabiyal
2 Shri D.K. Gosain
3 Shri Prabal Kumar Sutradhar
4 Shri Sudarshan Lal Wadhwa
5 Shri Hardesh Kumar
6 Shri Amarjeet Kapoor

Upper Division Clerks

1 Shri Gulshan Kumar
2 Shri Umed Singh Rawat
3 Shri Ramesh Chander Sati
4 Shri Vashisth Dev
5 Shri Kishan Mansukhani

Lower Division Clerks

1 Shri Santosh Kumar
2 Shri Sandeep Jain
3 Shri Ravinder Kumar
4 Shri Babu Lal
5 Shri Narender Kumar
6 Shri Krishan Kant
7 Shri Rohtash Singh

Staff Car Driver

1 Shri Durga Bahadur

Peons

1 Shri Babu Lal*
2 Late Shri Deep Chand
3 Shri Miser Pal
4 Shri Jai Narayan
5 Shri Vijay Pal
6 Shri Lalit Mohan

WORKCHARGED ESTABLISHMENT

Motor Lorry Drivers

1 Shri Shambhu Prasad Singh
2 Shri Beer Pal

Beldars

1 Shri Brahm Prakash
2 Shri Krishan Bahadur
3 Shri Gopal
4 Shri Nanak Singh

Head Gardner

1 Shri Ramyagya

HAND RECEIPT WORKERS

Motor Lorry Drivers

1 Shri Padam Bahadur Thapa
2 Shri Devender Bahadur
3 Shri Om Nath

Messengers

1 Shri Rambir Singh
2 Shri Rajpal Singh Yadav
3 Shri Devender Singh Negi
4 Shri Heera Ballabh Bhatt
5 Shri Balbir Singh
6 Shri Mahesh Chand

** Subsequently promoted and posted in the Project itself.*
*** Subsequently transferred from Design Team to Project.*