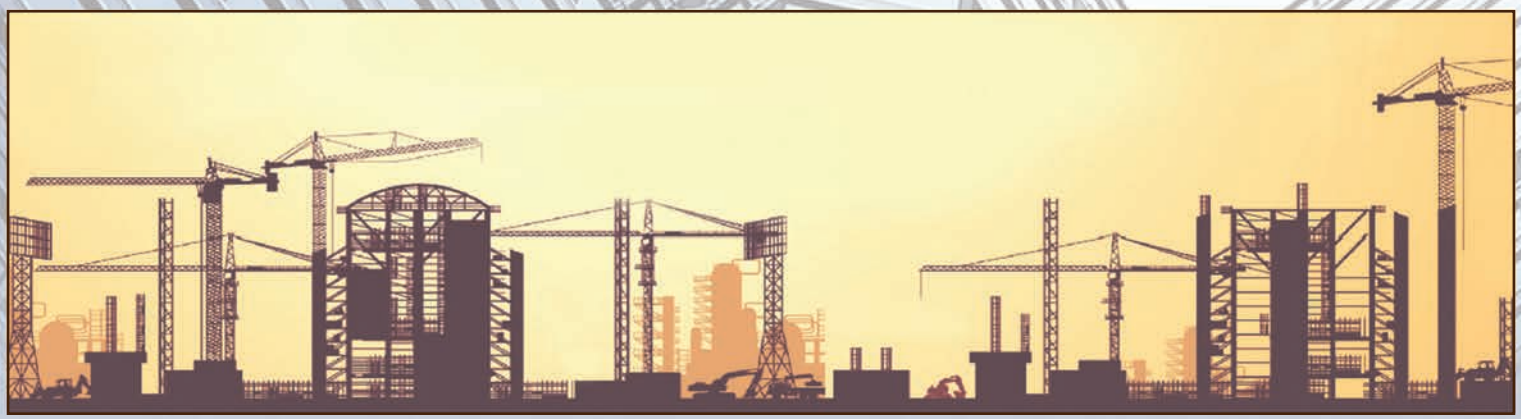
150 YEARS OF CELEBRATING THE MAHATMA

सत्यमेव जयते

स्वच्छ भारत
एक कदम स्वच्छता की ओर

USE OF INNOVATIVE TECHNOLOGIES & MATERIALS IN CONSTRUCTION



CPWD

CENTRAL PUBLIC WORKS DEPARTMENT
Ministry of Housing and Urban Affairs

Proceedings of Seminar on

USE OF
INNOVATIVE TECHNOLOGIES
&
MATERIALS IN COSTRUCTION

June 14, 2019

(The views expressed are purely of the authors and not of the editor or their organizations)

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MESSAGE

I am happy to know that Central Public Works Department is organizing one day Seminar on "**Use of Innovative Technologies and Materials in Construction**" on June 14, 2019 in Vigyan Bhawan, New Delhi.

Indian economy has been on a steady high growth path in the past several years. Construction Sector has played a stellar role in putting India on the path of rapid economic development. There has, however, been an increasing appreciation that full potential of the construction sector in India's economic development has not been realized due to various challenges.

There is a great challenge of mass housing projects to be completed by the year 2022; simultaneously there is a need to use of innovative technologies and materials for eco-friendly, quality and speedy construction. A rapid usage of new construction technologies is being recognized as one of the keys to achieve India's ambitious infrastructure goals.

I congratulate Shri Prabhakar Singh, Director General, CPWD for organizing this much needed Seminar for promotion of Housing for All Mission of the Government the during the year of construction technology.

I hope that day long Seminar will give an opportunity to the participants in knowledge sharing and achieving the goal of quality and speedy construction.

(Durga Shanker Mishra)

New Delhi
07 June, 2019



PRABHAKAR SINGH
Director General

सत्यमेव जयते

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MESSAGE

In the Construction and Infrastructure Sector, use of innovative technologies and materials has become most important to increase the productivity and efficiency at worksites. In the present day context, it has become essential to adopt "Use of Innovative Technologies and Materials in Construction for faster, ecofriendly and quality construction.

Central Public Works Department being a Principal Engineering Organization of Government of India has accorded highest priority for use of innovative technologies and materials at its project sites.

CPWD has approved sixteen new and emerging technologies for use in its construction and various field units have adopted using them in construction of new projects.

I am happy to note that as a part of knowledge sharing and experiential learning in the field of Innovative Technologies and materials at work sites, CPWD is organizing a one- day Seminar on June 14th, 2019 in New Delhi. The Seminar will give an opportunity to the participants to deliberate on the various aspects of use of innovative technologies and materials in the construction sector.

I congratulate Dr. K.M. Soni, Additional Director General (Tech), CPWD and his team of officials for their untiring efforts in organizing this Seminar and bringing out this useful publication.

Place: New Delhi

(Prabhakar Singh)

सत्यमेव जयते

डॉ. के. एम. सोनी
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CPWD



Foreword

CPWD has approved sixteen new and emerging construction technologies related to civil and one air conditioning for implementation in new works. These technologies are for speedy and/or environmental friendly construction. To propagate use of these technologies, this seminar is being held in which discussion will be held on use of such technologies and innovative materials.

The seminar is being attended by experts and senior officers of various central government organisations including CPWD. Hence, the proceedings of the seminar will prove to be a milestone in taking these construction technologies to the field for speedy, quality and environment friendly construction.

I thank my team lead by Shri M.K. Mallick, CE(CSQ) and Diwakar Aggarwal, SE(TAS) for arranging this seminar and bring out this publication.

Place: New Delhi
June, 2019

(Dr. K.M. Soni)
ADG(TD)

CONTENT

1. **NEW CONSTRUCTION TECHNOLOGIES APPROVED BY CPWD** 1
   by Dr. K M Soni & Divakar Agrawal

2. **USE OF GLASS FIBRE REINFORCED GYPSUM (GFRG) BUILDING SYSTEM FOR RESIDENTIAL BUILDINGS AT IIT TRANSIT CAMPUS AT TIRUPATI** 11
   by P K Naidu & CN Suresh

3. **MONOLITHIC CONSTRUCTION METHODOLOGY IN HIGH RISE BUILDINGS: CASE STUDY OF "IT BUILDING AT ANNA NAGAR CHENNAI."** 22
   by Dharmesh Chandra Goel, Dharanidaran Selvarajan & Lakshmipathy Suresh Kumar

4. **INNOVATIVE MATERIAL AND TECHNOLOGY IN THE FIELD OF ENERGY EFFICIENCY MEASURES** *by Rajiv Gupta* 34

5. **AUTOCLAVED AERATED CONCRETE –A SUSTAINABLE CONSTRUCTION TECHNOLOGY** *by D S Adhikari & Rajdeep Chowdhury* 43

6. **MONOLITHIC CONCRETE CONSTRUCTION WITH ALUMINIUM FRAMEWORK FOR CONSTRUCTION OF 76 NO. MULTISTORIED HOUSES FOR HON'BLE MPS OF LOK SABHA AT DR B D MARG, NEW DELHI** *by Rajeev Singhal* 50

7. **CONFINED MASONRY IN BUILDING CONSTRUCTION** *by D.S. Panwar* 59

8. **CONFINED MASONRY** *by Manu Mittal & Ajay Kumar Agrawal* 67

9. **PRECAST CONCRETE PAVEMENTS – A SMART SOLUTION FOR INDIAN ROADS** 80
   by Ravi Shankar S

10. **A SUSTAINABLE APPROACH TO FLOOD DAMAGE REPAIR OF HILL ROADS IN TRIPURA USING SOIL FILLED GABIONS – A CASE STUDY** *by D.Roychowdhury* 88

11. **MONOLITHIC ALUMINUM FORMWORK CONSTRUCTION FOR SPEEDY CONSTRUCTION** *by P K Singh & Dr. K M Soni* 101

12. **3S PREFAB BUILDING TECHNOLOGY** *by V G Jana & Col Sanjay Adsar (Retd)* 109

13. **ADOPTING NEW TECHNOLOGIES FOR FASTER CONSTRUCTION** *by Harnam Singh* 120

14. **POST TENSIONED CONSTRUCTION TECHNOLOGY FOR MULTI-STOREYED BUILDINGS** *by Dr. K M Soni & Bharat Kataria* 130

15. **V-INFILL WALL (LIGHT WEIGHT EPS WALL)** *by Narashima Rao* 139

16. **POLYISOCYANURATE (PIR) DRYWALL PRE-FAB PANEL SYSTEM TECHNOLOGY FOR HOUSING AND CONSTRUCTION** *by Saumya Anand* 156

17. **PRECAST TECHNOLOGYIN CONSTRUCTION: ELEMATIC – FINLAND BASED TECHNOLOGY PARTNER** *by Shrikant Luktuke* 161

18. **BUILDING INFORMATION MODELLING** *by Usha Batra & Dr. K M Soni* 165

19. **NEW TECHNOLOGIES USED IN EXPANSION OF NEHRU HOSPITAL PROJECT (334 BEDDED) AT PGIMER CHANDIGARH.** *by Rajeev Kumar Sao* 173

20. **EPS (BEADS) CEMENT PANELS** *by Ratan Singh* 179

21. **INTRODUCTION TO PRECAST TECHNOLOGY** *by N.N.S.S.Rao* 184

22. **IBS Industrialised Building Systems to IBS (INTERMEDIATE BUILDING SYSTEMS)** *by Pramod Adlkaha & Saket Mehra* 206

23. **NEW MATERIALS AND TECHNOLOGIES ADOPTED IN CPWD AT MUMBAI** *by Dr. K M Soni & Usha Batra* 215

24. **PRECAST PAVEMENTS – FUTURE ROAD CONSTRUCTION** *by G Sreenivasa* 225

25. **FAST TRACK BUILDING CONSTRUCTION USING LGSFS WITH EPS INFILL - FERRO CONCRETE PANEL TECHNOLOGY** *by Dr. R.Gopalan* 235

26. **ROBOTICS IN CONSTRUCTION: A DISTINCT TECHNOLOGY OPTION** *by C.K.Varma* 241

27. **INNOVATIVE CONSTRUCTION MATERIALS: FOR SUSTAINABLE CONSTRUCTION** *by C.K.Varma* 247

28. **INSULATED CONCRETE FORMWORK TECHNOLOGY** *by M.M. Roy* 254

29. **COMPOSITE STEEL STRUCTURE CONSTRUCTION** *by Varun Thareja* 261

30. **MIVAN FORMWORK USING IN MONOLITHIC CONSTRUCTION** *by A.K. Sharma & V.K.Gupta* 269

31. **INNOVATIVE TECHNOLOGIES AND MATERIALS IN CONSTRUCTION** *by P. K. Dixit* 279

NEW CONSTRUCTION TECHNOLOGIES APPROVED BY CPWD

Dr K M Soni, Addl. Director General (Tech), CPWD
Divakar Agrawal, Superintending Engineer (TAS), CPWD

Abstract

CPWD has been approving and adopting use of new materials and construction technologies for use of its engineers which are even adopted by other engineers. CPWD has approved 16 new technologies related to civil engineering and one to electrical.

Speed, quality, environmental issues and durability are considered to be governing the construction process due to large requirement of housing. Construction technologies which perform better in speed of construction, quality and durability will last longer and others may not. Though large numbers of construction technologies are available with different names, but most of them are with slight innovation or using some component or application used in material or construction methodology and RCC and steel still remain main construction materials.

CPWD also incorporates new materials and technologies in its Schedule of Rates for wide adoption and adoption in its contracts.

Introduction

Many organizations now arrange the financial resources through loans or grants which are provided for a fixed period. Hence, such funds are limited and mostly not carried forward during next financial year. Such organizations are asked to construct the buildings or create infrastructure within the time allotted to them. Any cost or time overrun puts them in difficulty as either they do not get funds or are required to pay additional interest on the loans taken by them. Hence, completion of works in time or before time has become priority of such organizations and so of the government also. Technologies using precast elements, innovative shuttering, and industrial components save considerable time of construction.

Some materials like recycled C&D waste materials, flyash based materials and technical textiles are required to be used due to environmental considerations hence CPWD is promoting their use.

CPWD has approved new and emerging technologies which help in faster construction and are environment friendly. Such technologies are in different fields like materials, formwork, components, or processes. Some technologies contribute to faster construction and some to utilizing waste materials and few use innovative and new materials or processes. Overall

17 technologies have been approved by CPWD for construction in CPWD works.

Apart from the technologies approved by CPWD, many other technologies are available, some of which are briefly discussed.

Technologies Approved by CPWD

The following technologies have been approved by CPWD;

1. Monolithic construction using aluminium formwork
2. Monolithic construction using plastic aluminium formwork
3. Pre fab or pre cast construction
4. LGFS construction
5. Hybrid construction
6. Expanded polystyrene core panel system
7. Speed floor system
8. GFRG panel building system
9. Non asbestos fibre reinforced aerated sandwich wall/roof/floor light weight solid core panel
10. EPS cement sandwich wall/roof/floor light weight solid core panel
11. Block masonry using AAC blocks
12. Block masonry using Flyash bricks
13. Reinforced soil technology using technical textiles
14. Use of self compaction concrete
15. Use of confined masonry
16. Use of C&D recycled waste products in construction
17. VRF system in air-conditioning

Above technologies can be grouped broadly in the following categories;

i. Monolithic construction

ii. Pre fab/pre cast RCC construction

iii. LGFS construction

iv. Hybrid construction

v. Pre-fabricated sandwich panel system

vi. Masonry with recycled waste technology

vii. Reinforced soil technology

viii. High Performance concrete

ix. Energy efficient technologies

Monolithic construction has RCC walls and as such it is similar to RCC framework construction except it uses new type of formwork than the traditional steel shuttering in which RCC walls, beams and slab are casted insitu and monolithically using different type of formwork such as tunnel formwork, aluminium formwork, jump formwork, plastic or plastic - aluminium formwork. Pre fab or pre cast construction is carried out at factory or off site in the yard where structural components are casted, transported at site, and assembled with or without any cast in situ construction. LGFS uses light gauge steel structure which is then covered with different types of materials and buildings erected. Hybrid construction uses two different types of materials like LGFS and steel particularly to suit design requirements. Pre cast sandwich panels are used for walling which can be made with different materials. As they are to be transported from the factory to site, they are made of lighter materials for ease of transportation and erection. Recycled waste materials like flyash bricks, AAC blocks and C&D waste blocks being environment friendly are used for masonry works. Reinforced soil technology is used for retaining walls, roads and slope stabilization which saves considerable space, requires less excavation and can be used for erection of almost vertical walls. Confined masonry is similar to RCC construction and reduces column sizes and performs better under seismic conditions. VRF is used for air-conditioning, normally in place of window or split air-conditioners.

Monolithic Construction Technologies

Monolithic construction means in situ casting of slab, beams and columns/walls simultaneously. Such construction is carried out by specialized shuttering/formwork after placement of reinforcement and service lines hence all the designs and drawings must be

available before taking up the construction. As the construction of the structure is with RCC walls, wall thickness is less than masonry members or columns resulting into higher carpet area. Also, it has few construction joints and even does not require cement plaster on the walls. It provides better seismic resistance due to monolithic action. Main advantage is speed and quality. It is highly suitable for repetitive multi-storeyed construction which may compensate to the extra cost due to economy of scale.

Limitations of such construction include limited modular sizes in some cases, high cost in case of non-repetitive units, high initial cost, skilled labour requirement, changes not feasible after casting or during life time of the building, feasibility of limited architectural features, less energy efficient due to external walls having low insulation properties, and difficulty and higher cost in repair and rehabilitation of services and structure during its life time. Due to advantage in repetitive type of construction, such technique is being adopted in residential units, hostels and hotels having similar modules.

Monolithic construction can be adopted using various types of shuttering as given in the following;

Jump form shuttering

In this technique, central core generally for housing lifts or staircase is constructed first using a climbing or jump formwork system and thus the name. A frame is constructed over the central core and steel formwork hung from it. Once the climbing form work is in position, the formwork panels are closed and concrete wall casted. After the walls are casted, the formwork is released. Jacks then lift the whole frame up to next level. All the form work panels are then attached to the frame and the process continued. The form work gets supported on the concrete casted earlier and thus does not rely on supports or access from other parts of the building or permanent works. This is suitable for multi-storeyed vertical concrete such as shear walls, core walls, lift shafts and stair shafts in buildings. Advantage in high rise construction is that central core can be effectively used for other activities.

With little difference in operations, three types of such form work are in general use known as normal jump form in which units are individually lifted off the structure and relocated at the next level using a crane, guided climbing jump form in which units remain guided by the structure also using crane, and self climbing jump form, which does not require crane as it climbs on rails by means of hydraulic jacks. Guided form work also known as slip form work is similar to self climbing formwork but moves continuously when pouring/casting is being done instead of periodically static self climbing form work.

Such form work has the advantage of faster construction and can be used only for central

core while for other parts of building, normal RCC construction can be taken up.

Aluminium form work

Monolithic construction is also carried out by using aluminium formwork system (Fig. 1) which allows casting of a floor in single operation. Mivan is the name of Malaysian company who invented it first in 1990. Advantage of such formwork is that architectural features like projections, cornices, planters, curved beams etc can also be casted in one operation though it cannot be combined with other formwork materials such as plywood and steel. The formwork is largely hand held and does not need the services of a crane for movement either vertically or horizontally. These can be effectively used for repetitive works like multi-storeyed construction or row houses (Fig. 2).



Figure 1: Aluminium formwork



Figure 2: Multi-storeyed construction

Limitation of the technology may be holes caused by wall ties which are to be taken care to avoid leakage/seepage. Number of times such formwork can be used is less than tunnel formwork. It is said that it can be used 250 times while tunnel formwork can be used for more than 500 times though being aluminium, it can be recycled. Suppliers of such formwork are available in the country.

Tunnel Formwork

Tunnel formwork was invented about 50 years back in Turkey for multi unit residential apartments and is said to be useable from 500 – 1000 cycles. It comes in half units in the form of an inverted "L". When two halves are bolted together at the top, they form the tunnel (Fig. 3) hence the name. The inbuilt wheels and the jacks help the formwork move in and out of the position and adjusted to the final height to cast walls and slabs in one operation in a daily cycle. In casting process, prefabricated wall reinforcement is placed by crane along the entire wing prior to casting the kickers used to position wall formwork then two and a half tunnel placed in position also by crane, bolted together and ties added. The formwork

system provides for a pour to be wrapped in tarpaulins and for the use of butane heaters to maintain a sufficiently high temperature for the concrete to reach its desired strength overnight for removal of formwork next day thus working on 24 hours cycle. The process is repeated for the next two bays. Apart from limitations described earlier, in tunnel formwork, walls are to be planned in same alignment of the formwork (Fig. 4), external projections avoided and shaft openings to be provided from inside. CPWD has taken up such construction in Chennai (Fig. 5).



Figure 3: Tunnel formwork



Figure 4: Alignment of walls



Figure 5: CPWD construction

Monolithic construction can also be achieved using plastic, aluminium-plastic and formwork of similar other materials. Such formwork is cheaper but cannot be used for those numbers of repetitions as aluminium or tunnel formwork and has to be checked for uniform surface without any bulging. Maini scaffold stsems, MFS formwork systems Pvt. Ltd., Bajaj products, Uday structural & engineeres Pvt. Ltd., Prime Steeltech (I) Pvt. Ltd., RGVR constructions India Pvt. Ltd., Royal technocrafts, Wonder moldplast Pvt. Ltd., and Global industrial suppliers are some of the suppliers of different formworks for monolithic construction.

Pre Fabricated Construction

Pre-fabricated construction may be with pre-cast concrete or steel. Precast concrete buildings use precast RCC structural members such as beams, slabs, columns, walls, staircases, individual isolated footings etc (Fig. 6). Normally such members are fabricated at the casting yard or in the factory with in-situ jointing. Connectivity of pre fabricated members is to be ensured and members designed suiting to seismic/ lateral loads, if any. Advantage of such construction is in pollution and dust control, quality assurance, faster construction and less storage space required at the site. Limitations are of module sizes, limited architectural features, constraints of service lines and assurance of monolithic action during lateral loads. CPWD has recently constructed multi level car parking block for SBI data centre at Hyderabad (Fig. 7) in which precast external and internal wall panels, precast parapet wall

panels, precast pre-stressed beams, precast hollow core slabs, precast staircase, precast columns and precast solid slabs for ramp landings have been used. Cost analysis indicated that such construction is costlier than conventional in situ construction for individual buildings however for large number of buildings, the cost may be comparable. Also, the speed of construction is faster compared to conventional construction. Such technology is recommended upto seismic zone IV however analysis of seismic loads may be made before adopting such technology.



Figure 6: Precast slab



Figure 7: Building with precast members

Some of the technology providers are M/s B G Shirke construction technologies Pvt. ltd, Moducast Pvt. ltd, Magicrete Building Solutions, Elematic India, P G Setty construction pvt. Ltd., Teemage, Nordicflex, William Ling, and Adalakha associates Pvt. Ltd.

Light Gauge Frame System (LGFS)

LGFS technology uses cold formed steel as the construction material for wall, floor and roof system. LGFS cold rolled steel sections are galvanized for corrosion resistant property, have less weight, and helps in faster construction. Since inside structure is with LGFS, external panels both from outside and inside are used like pre cast concrete panels and polyurethane based panels. Since the system is light, it can be used for low rise structures though with steel structures, LGFS can be used in high rise structures i.e. with hybrid structures. LGFS construction is recommended for G+3 structures. Advantage is that the structure is light, construction is faster and chances of corrosion are less compared to RCC structures. Precautions are to be taken in design and connections of foundation with LGFS components, their maintainability and durability. Impact resistance to such structures may also be less compared to conventional ones.

In hybrid steel structure, a combination of LGFS and steel structure can be used and then any number of storeys can be constructed however cost may not be economical substantially but speed is faster than conventional RCC structures. Since, LGFS structures are light, load on the structure is also less compared to conventional construction.

Some of the agencies in this technology are Mitsumi housing Pvt. Ltd., Everest industries Ltd., MGI infra Pvt. Ltd., RCM prefab Pvt. Ltd, Visakha industries Pvt. Ltd., Jindal Steel & Power Ltd, and HIL Ltd.

Stay in Place Formwork system

Stay in place formwork, as the name suggests, stays with the structure. Monolithis construction can also be achieved in same technology. It is of light weight like EPS. J K structure, FACT RCF building products Ltd., Coffor construction technology Pvt. Ltd., Reliable insupack and FTS buildtech Pvt. Ltd. are some of the technology providers. Due to precast components, speed and quality can be achieved in such construction.

Prefabricated Sandwich Panel System

Sandwich panels are used for walling and can be made from different materials such as EPS, cement based materials, fibre glass, or any other light suitable material. Such panels are sometimes used for load bearing construction, which are used for low rise structures varying from as G+1 to G+3 structures. Such panels can also be used in conventional RCC framed construction and walls made of such panels in place of brick/block work. Such construction needs to be ensured for seepage and connectivity when used in RCC construction. Such technology for high rise construction is only for wall panels and as panels are precast, they save the time of construction.

Some of the agencies providing such technologies are Worldhaus, Rising Japan infra Pvt. Ltd., Bau panel systems India Pvt. Ltd., B K chemtech engineering, Beardshell Ltd., and Covestro India Pvt. Ltd.

Confined Masonry Construction Technology

Concept of confined masonry construction (Fig. 8) is similar to Assam walling or ekra walling construction used long time back in semi permanent buildings in north eastern part of India, difference being that in place of wooden vertical and horizontal members of ekra walling construction, members in confined masonry construction are casted in reinforced concrete while infill walls are replaced with masonry work in place of bamboo mat. Such construction has higher seismic resistance and provides higher carpet area due to lower sizes of columns.



Figure 8: Confined masonry construction in IIT Gandhinagar

High Performance Concrete (HPC)

HPC is a high strength concrete made by lowering the water-cement (w/c) ratio than 0.35, utilizing fine pozzolanic materials. Low w/c ratio and the use of silica fume makes concrete mixes significantly less workable. To compensate the reduced workability, super plasticizers are commonly added to high-strength mixtures. Thus, HPC has high workability, high durability and high strength. Self compaction concrete is normally used in post tensioned construction, and even in monolithic construction which is also HPC and does not require compaction.

Reinforced Soil Technology

Reinforced soil concept is based on the principle of friction between soil and the reinforcement. Geosynthetics are being used in various applications like separation, reinforcement, filtration and drainage, moisture barrier. Government is giving a lot of emphasis on use of technical textiles. Geosynthetics are now being used in reinforced soil of retaining walls and approaches of bridges/flyovers.

Other Technologies

There are many emerging technologies being used in different components of building construction. There are few which are in research stage and being experimented and may be adopted after they become technically and economically viable.

3 D construction printing technology is another technology being researched for implementation in building construction which is going to be the integration of owner's design acceptability, architect's vision with on site but mainly off site fabrication enabling one to get house in less than 24 hours and as per the demand. Thus, robotics and AI are the future technologies for use in civil engineering fields, both in construction and maintenance.

Trenchless technology largely avoids cutting of roads and paths to pass through utility services in soils avoiding disruption of traffic and also helping in pollution control and uses micro tunnelling, horizontal directional drilling, pipe ramming, auger boring, moling etc.

Large numbers of energy efficient technologies are available now for E&M services also such as LED technology, solar power generation, regenerative lifts, IBMS, occupancy and other sensors, smart meters, energy efficient chillers and geo thermal heat exchange system for energy efficient air-conditioning.

Technologies are also available for time saving and quality work in flooring, paneling, false ceiling, painting, plastering, slab casting, anchoring etc.

Conclusions

New and emerging technologies helping in execution of structures with speed, quality and durability have become essential for the development of the country hence are going to come in India from all over the world due to large scale requirements in the country. At present, limited technologies with limited entities are available but with the government's support, such technologies will not only be available but will be developed suiting to country's requirements.

CPWD has approved new and emerging technologies for speedy construction and also the technologies which are green and sustainable. These technologies are also being included in Delhi Schedule of Rates (DSR) for the benefit of engineers in the construction industry.

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USE OF GLASS FIBRE REINFORCED GYPSUM (GFRG) BUILDING SYSTEM FOR RESIDENTIAL BUILDINGS AT IIT TRANSIT CAMPUS AT TIRUPATI

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Introduction:

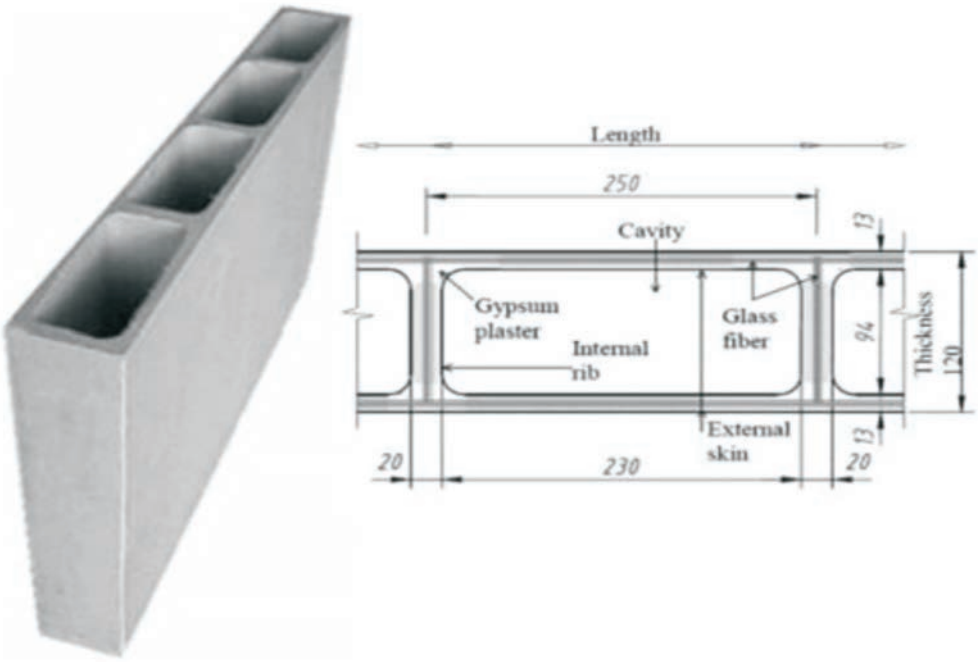
Glass fibre reinforced gypsum (GFRG) panel, which is commercially known as Rapid wall, is a wall panel made of high quality calcined gypsum plaster, reinforced with glass fibres. This modern building element was devised by the GFRG Building System Australia in the year 1990 for mass-scale construction of houses in a very short span of time. In recent times, these panels are being produced in India and the technology is gaining popularity in the construction industry in India.

Gypsum is abundantly available in India which is a by-product waste of fertilizers industry. Gypsum plaster has been used extensively in the building industry worldwide to provide high quality architectural and decorative finishes, and also in the production of plasterboard for interior partition walls. Until recently, gypsum plaster was considered to be too weak to be used for load bearing walls. The Australian technological breakthrough of combining glass fibre strands with gypsum plaster, resulted in GFRG wall panels, which had the desired properties of strength and water resistance.

GFRG can be manufactured out of any kind of gypsum such as flue gas gypsum, mineral gypsum, phosphor-gypsum or marine gypsum, the production process requiring relatively low energy. Natural gypsum was used as the raw material in Australia. It was reported that India has almost 64 million tonnes ofstockpiled gypsum waste generated at various fertilizer plants, with an addition of almost 2.5 million tonnes every year, and hence in India, the panels are made from processed phosphor-gypsum

The GFRG Panels are manufactured in semi-automatic plants using slurry of calcined gypsum plaster mixed with certain chemicals including water repellent emulsion and glass fibre rovings, spread and embedded uniformly into the slurry with the help of screen roller. The panels are dried at a temperature of 275oC before shifting to storage area or the cutting table. The wall panels can be cut as per dimensions and requirements of the building planned for construction. GFRG panels have a smooth finished surface and do not require any plaster. They can be whitewashed or painted with or without application of putty. In India, the panels are manufactured at Rashtriya Chemicals and Fertilizers (RCF) Mumbai, and Fertilizers and Chemicals Travancore (FACT) Ltd Kochi, to fixed dimensions of 12 m length, 3 m height and

124 mm thickness.



Details of a GFRG Panel

Thus, GFRG panels for building construction promotes the reuse of industrial waste by-products, thereby reducing the dependence on conventional energy-intensive and increasingly scarce building materials. The product is not only eco-friendly but also resistant to water and fire.The panels, which are extremely strong yet lightweight, compared to other building materials, are ideal for a wide range of building applications for residential, commercial and industrial buildings etc., and are extremely useful for cost effective mass construction of large-scale affordable housing.

GFRG panels, infilled with reinforced concrete (RC), can be used in the construction as structural members such as walls, slabs, staircases, parapet walls, etc. Use of such structural elements with high strength to weight ratio in building construction ensures reduction in volume of construction compared to conventional buildings. Thus such constructionsentails far less embodied energy in comparison with the conventional construction using burnt clay brick and reinforced concrete. Therefore the buildings with such technologies are highly energy efficient and qualify for better Green ratings and Sustainable building category.

GFRG panels are gaining popularity in the construction sector across the globe, especially in India. These panels, with the advantages of Speed, sustainability and affordability, have been identified as a potential solution to address the problem of mass housing requirement of economically weaker sections. So far, more than 800 GFRG buildings have been constructed

in India.

Extensive experimental and theoretical studies on GFRG panels have been carried out by IIT Madras for over a decade. Building Materials & Technology Promotion Council (BMTPC) under MoHUA has approved the GFRG wall panel technology for adoption in building construction. The panels have been tested and approved by Structural Engineering Research Centre of CSIR for the construction of buildings in earthquakeprone areas.

Building Materials & Technology Promotion Council (BMTPC), with the support of IIT Madras, has already published 'Structural Design Manual', and 'Manual on Waterproofing for GFRG/Rapidwall Buildings' to aid architects, structural engineers, construction engineers and builders in the structural design, planning and estimation of GFRG buildings.

A BIS code on design and construction of GFRG building systems is reported tobe in circulation and may be expected shortly for guidance of architects, structural engineers and construction engineers on the design and construction of GFRG buildings in India.

Model building was constructed at IIT Madras to demonstrate the long term durability and sustainability of these building systems. Further studies were carried out by the researchers in the country to establish the Fire and water resistance of these wall panels.

Transportation of GFRG Panels:

GFRG panels can be easily transported from factory to site via trucks or trailers. It must be ensured that the panels are put in a vertical position (using stillages) to avoid any damage during transportation.



GFRG Panels in Stillages and loading in truck

3. Applications of GFRG Panels:

a. As vertical and shear load bearing wall

b. As roof slabs/horizontal floor

c. As partition wall

d. As pitched roofing

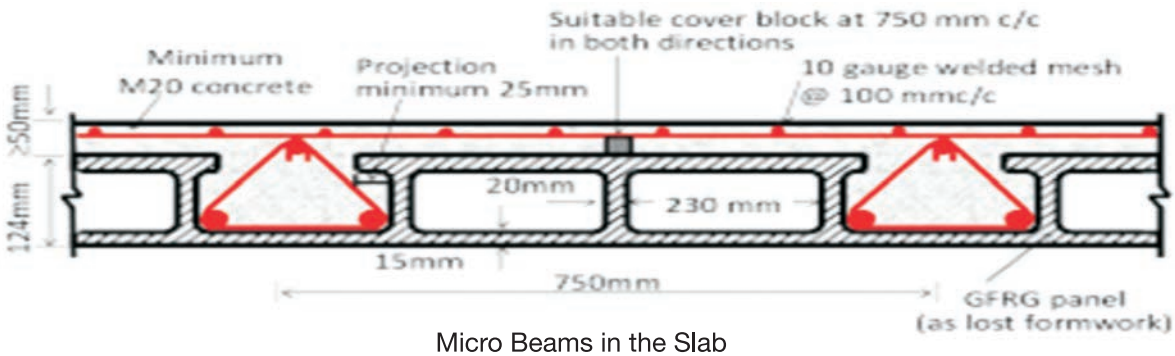
e. As compound wall/Security wall

f. As cladding in industrial structures

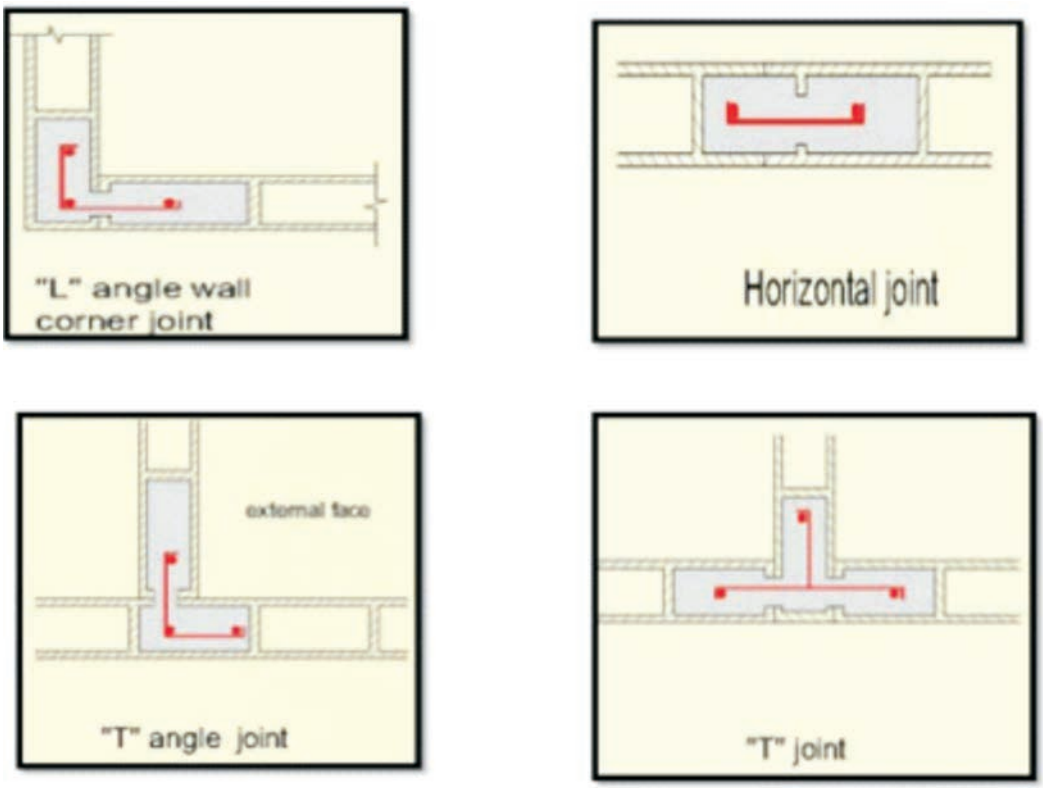
4. Construction & workmanship:

GFRG / Rapid-wall for rapid construction of Building shall be designed on the basis of Design Manual by a qualified structural Engineer. As per the building plan and design, each wall panel shall be cut at the factory using an automated cutting saw. Door/window/ventilator and openings for AC unit etc., shall also be cut and panels for every floor marked as per the building drawing.

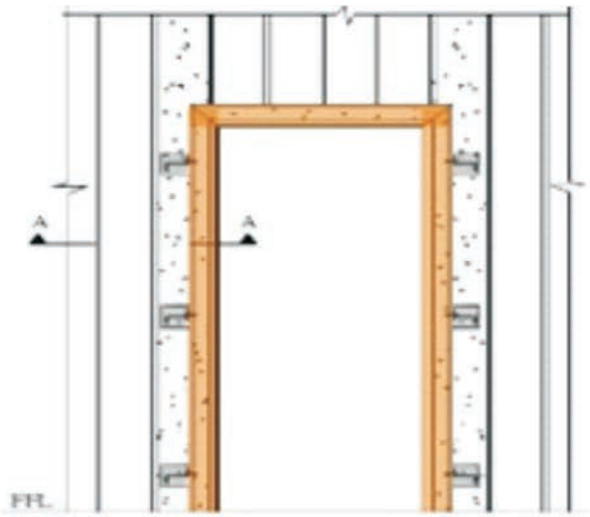




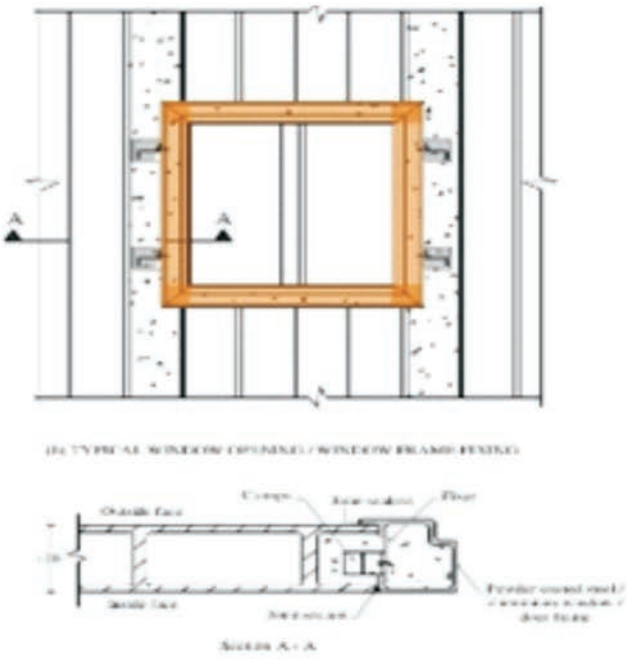
Micro Beams in the Slab



Jointing system of Wall panels



Typical door opening / door frame fixing



The construction process up to the plinth level is similar to that of conventional loadbearing building construction. No special foundation system is required for the installation of GFRG panels.

An RCC band is provided at the plinth level with steel reinforcement dowel bars protruding

above plinth beam which are lapped with additional steel bars and taken into the cavities of the vertical wall panels

Wall Panels shall be erected over the RCC plinth beam using a crane and concrete is infilled from top. All the panels shall be erected as per the building plan by following the notation. Each panel shall be erected level and plumb and shall be supported by lateral props to keep the panel in level, plumb and secure in position. Embedded RCC lintels shall be provided wherever required by cutting open external flange. Reinforcement for lintels and RCC sunshades shall be provided with required shuttering and support.

After inserting vertical steel reinforcement as per the structural design and clamps for wall corners are in place to keep the wall panels in perfect position, ready mix concrete with 12mm aggregate shall be poured from the top into the cavities using a boom pump. For small building construction, concrete can be poured manually using a funnel. Filling the panels with concrete shall be done in three layers of 1m height with an interval of 1 hour between each layer. There is no need to use vibrator because gravitational pressure acts on the concrete inside the water tight cavities.





POURING OF CONCRETE IN WALL PANELS





An RCC tie beam is provided all around at each floor/roof slab level as an essential requirement. Web portion of the panel to required beam depth at top shall be cut and removed for placing horizontal reinforcement with stirrups and then concrete to be filled.

GFRG panel for floor/roof slab shall be cut to required size and marked with notation. First, wall joints, other cavities and horizontal RCC tie beams are in-filled with concrete thereafterAcro spans shall be provided to room span between the walls with supports wherever embedded micro beams are there and then roof panels shall be lifted by crane. Each roof panel shall be placed over the wall in such a way that there will be a gap of at least 40mm. This is to enable vertical rods to be placed continuously from floor to floor and provide monolithic RCC frame within Rapidwall. Wherever embedded micro-beams are there, top flanges of roof panel shall be cut leaving at least 25mm projection. Reinforcement and weld mesh is placed for micro beams and then concrete shall be poured for micro beams and RCC slab.

Vertical reinforcement of floor below shall be projected above the floor level with extra length so as to protrude by 0.45m above the floor level to serve as start-up rods and lap length for upper floor bars. Once the wall panels are erected on the upper floor, vertical reinforcement rods, door/window frames fixed and RCC lintels shall be casted. Then concrete where required and joints shall be filled. Thereafter, RCC tie beams all around shall be concreted.









Once concreting of ground floor roof slab is completed, Acro Spans supporting the slabs shall be removed after 4th day. Finishing of internal walls and ceiling corners shall be done using wall putty. Simultaneously, electrical conduits, water supply and sanitary lines, floor tiling, mosaic or marble works, staircase work etc. shall also be carried out for each upper floor. Water proofing treatmentis required at different levels of construction such as foundation, sunshade and flooring/roofing etc.

The GFRG building system has been successfully used by CPWD and IIT Tirupati for construction of four nos. of Hostels for Boys and Girls (G+3 structures) and for construction of staff quarters at Transit campus of IIT Tirupati. The four storeyed hostel building was completed in a time span of 6 months. The structures being four storeyed every alternate cavity in the GFRG panel was filled with RCC. Similarly every alternate cavity in the slab panel was filled with RCC to form micro beams in the slab.The cost of construction was Rs 1600/- per s-ft excluding foundation cost.

Weight- light weight 40 Kg/ sqm	Axial load capacity 160 kN/m{ 16 tons/ m}	Compressive strength 73.2 Kg/cm2
Unit Shear strength 50.90 kN/m	Flexural strength 21.25 kg/cm2	Tensile Strength 35 KN/ m
Ductility 4	Fire resistance Can withstand 4 hours 1000 degrees	Thermal Resistance R=0.36 K/W
Thermal conductivity 0.617	Elastic Modulus 3000-6000Mpa	Sound transmission[STC] 40
Water absorption < 5%	Coefficient of Thermal Expansion 12 x 10-6 mm/mm/0 C	Sound transmission coefficient 45

Mechanical Properties of Panels

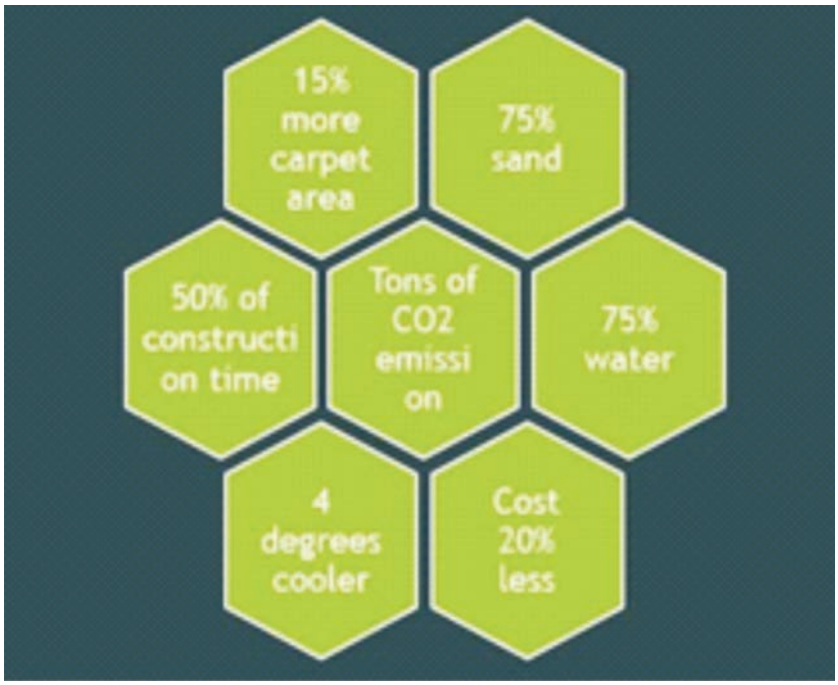
Advantages GFRG Panel Construction:

I) Faster Construction

Conventional buildings with Ground + one that are usually constructed in about 6 to 10 months can be constructed in a months' time with GFRG panels.

ii) Economical

GFRG reduces the consumption of cement by almost 50%, steel by 30% ,sand by 76%, Labour by 62 per cent and construction time by 82 percent apart from substantial reduction in water usage.



Factors	Conventional	GFRG
Cost	Higher than GFRG	Can save 20-30%
Time(for G+1)	Approximately 6 months	30 days
Eco friendly	No	Yes
Fire resistant	Melts in 1000 degrees	Can withstand 1000 degrees for 4 hours
Earthquake resistant	Cannot resist earthquake unless designed separately	Can resist earthquake (Panels itself acts like a shear wall)
Cooling effect	No cooling effect	Cooler up to 4 degrees
Life	50 Years	80 Years
Water resistant	No unless water proof coating is made	Water proof
Carpet area	9" wall thickness, hence less carpet area	5" wall thickness, hence more carpet area
Strength	Less stronger	5X stronger than conventional

iii) Fire Resistant

In the event of any fire accident, GFRG panels release 15-20% moisture of its own weight which largely reduces the surface temperature and fire damage.

iv) Earthquake Resistant

GFRG panels have been found to be successful in resisting the impacts of Earthquakes even in seismic zone-V as the panels function as shear walls as well.

v) Cooler than a Conventional building:

When compared with the conventional building construction, GFRG construction can keep the indoor temperature cooler by up to 4 degrees.

vi) Water Resistant:

Certain chemicals are added to the mix during the manufacture of GFRG panels which make them impervious.

vii) More Carpet Area:

Since the thickness of the walls made with GFRG panels is hardly 5 inches when compared with the conventional 9 inches brick walls, more carpet area will result in a GFRG building for a given built-up area.

viii) Conservation of natural resources:

As GFRG construction uses most energy efficient building materials & industrial wastes and least amount of conventional building materials are used,this will lead to conservation of country's Natural resources.

6. Limitations of GFRG Panels:

a. The panels are required to be handled with extreme care and specialised machinery is needed for their handling.

b. GFRG panels are not useful for walls with circular or curved profile.

c. The panels need to be stacked properly in order to avoid any damage.

d. The shorter span of slab - generally limited to 5m.

e. Service life is less than normal building life.

f. Subsequent changes in construction is not possible.

7. Conclusion:

GFRG system was proved to be very effective in all the aspects of construction especially time and cost of construction. The system is ideally suited for mass construction of residential buildings where same floor plan is repeated several times and live load on the slab is not much unlike Non-residential buildings.

Acknowledgements:

The authors are thankful to IIT Madras and IIT, Tirupati, Building Materials and Technology Promotion Council (BMTPC), Rashtriya Chemicals and Fertilizers (RCF) Ltd., Mumbai, India, FACT-RCF Building Products Ltd. (FRBL), Kochi, India and Rapid Buildings Systems (RBS), Australia, for their valuable contribution.

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e. Use of glass fibre reinforced gypsum panels with reinforced concrete infills for construction of walls and slabs. Shinto Paul, Philip Cherian, Devdas Menon and A Meher Prasad

MONOLITHIC CONSTRUCTION METHODOLOGY IN HIGH RISE BUILDINGS: CASE STUDY OF "IT BUILDING AT ANNA NAGAR CHENNAI."

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Lakshmipathy Suresh Kumar, Assistant Engineer, CPWD, Chennai Zone, Chennai

Abstract

A form work system which holds temporally the cast concrete till it attains self-supporting and required strength is becoming a pivoting-role in the Construction arena. High repetitive cycles, lesser impact on environment, speed, high productivity at site is the focus of any new methodologies of Construction field of India. Our Country being one of the fastest growing economy demands Speed, Safety, Durability, and High range Mass production systems with the Proven technology solutions for its exponential growth and to comply with the demand a case study has been conducted on the various formwork methodologies.

This study focus mainly on the tunnel formwork advantages during execution and ease over the regular form work for framed structure and the edge over the various other Monolothic technologies.

Index Items: High flow Concrete, Surface vibrators, Floor Cycle, Kickers, Stripping time, Curing Compound, Conventional Plywood form work, De-shuttering time and Safety.

Introduction

Ever increasing Urban population and increased demand on dwelling units leads to finding most appropriate solutions for the urban dwellers which are cost effective, lower maintenance cost, more eco-friendly solutions. Form work systems plays a very important role in project time, cost and recurring maintenance expenditure. Various Form work systems and methodologies are available world-widewhereas intricate and in-depth analysis of suitability of the form work system for the project centric approach is very much sought before adoption of any such systems.

Objective

The aim of this paper is to provide the construction methodology and technical challenges involved in Tunnel form Construction during the following Stages

a. Vertical wall Reinforcement Caging.

b. Laying of Electrical /Fire service Conduits.

c. Tunnel Box shutter placement.

d. Floor slab reinforcement Caging.

e. Quality Control and Pouring of free flow, de-shuttering and Shifting of Tunnel Form work.

f. Surface Curing.

g. Application of Curing Compound.

3. Changing Scenario of Form Work in India

The adoption of new technologies in Construction Industry is the latest trend in our country due to the following facts.

A. Faster Completion.

B. Less labour intensive solutions.

C. Economic aspects.

D. Better Quality finishes.

E. Green Rated solutions.

4. Components in Tunnel Form Work

1. Half Tunnel is an inverted “L type” Steel shutters when two inverted L bolted forms one Full tunnel.

2. Back Panel is the end shutter attached to form one side closed tunnel.

3. Outside Wallformis the end external shutter along with safety/working platform at ends.

4. Lifting Beam is to distribute handling stresses more uniformly in the top horizontal panel which is place inside the top panel.

5. Lifting Triangle is the device used to connect the half tunnel with the crane during handling

6. Roller for ease of movement of tunnel form on the platform till it is lifted by lifting triangle.

7. Kicker Form is primarily to create exact image of the below walls to the upper floors.

8. Slab Stopend is used to indicate the end for slab.

9. Slab/DoorBlockout is used as openings for various services.

10. Window Blockout is used as opening for window.

12. Stripping needle platform(Fig. 14) is to roll the tunnel horizontally till half way out of the box structure to be lifted by crane.

13. Gable End Framefor providing access all-round the structure soas to facilitate movement during construction.

14. Tie-rod(Fig.7) and release sleeve is placed at appropriate time before concreting is done. This is to be ensured for dimensional accuracy , proper distribution of stresses and to avoid leakage of Concrete.

15. Collapsible strut provides highly accurate de-shuttering method with less disturbance to shutter.

16. Tower Crane and other lifting equipmentto transit the forms from one floor to other.

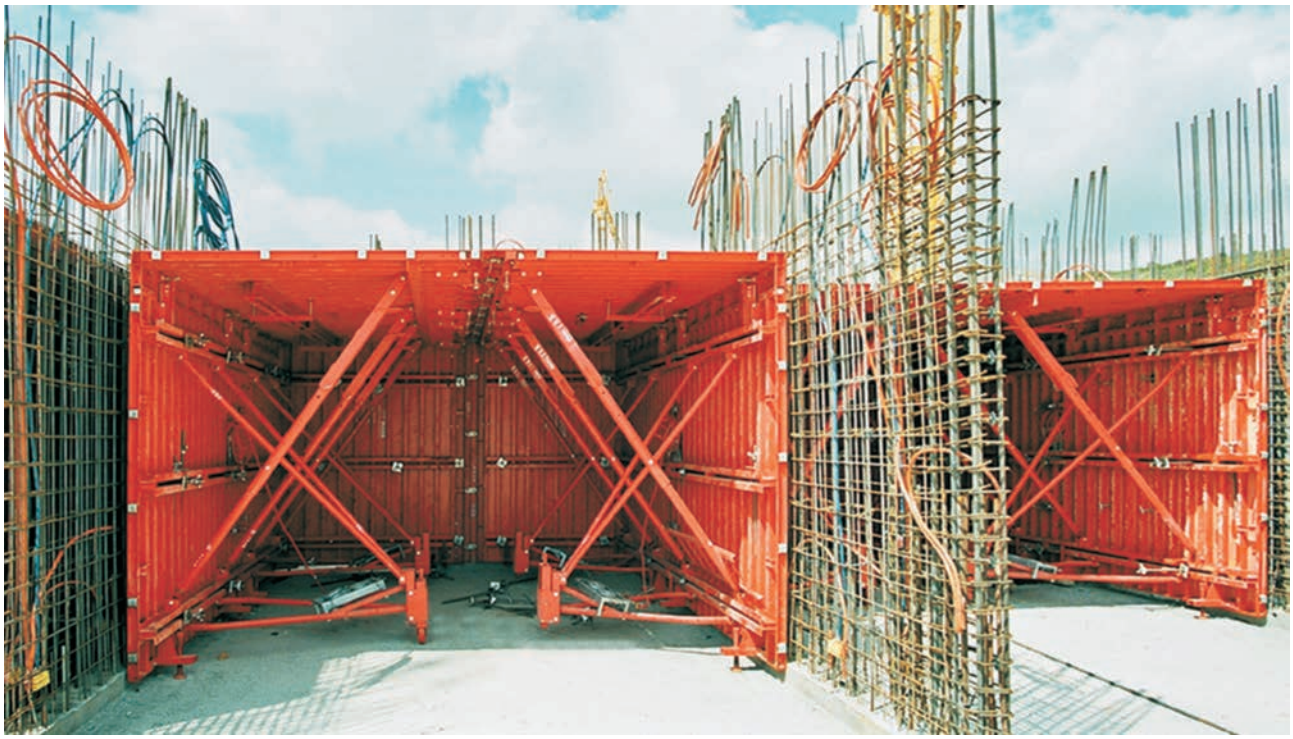


Fig.1 Typical Tunnel Form Arrangement along with wall reingorcement and services
Courtsey: https://www.mesaimalat.com.tr/en/products/formwork-systems/tunnel-formwork



Fig.2 Type-2 Quarters, G+18 Tower at Anna Nagar,Chennai.Tunnel form System



Fig.3 North & South Towers Type-3 Quarters,G+18 Tower at Anna Nagar,Chennai.Tunnel form System

5. Methodology

5.1 Wall Reinforcement Caging

All the wall vertical reinforcement including boundary elements, spandrels, beams and non-boundary mesh reinforcement are placed with proper shear links and hoops loops(Fig.4) and as pre relevant ductile detailing codes and as pre structural drawings.

Care should be taken all these vertical reinforcements are to be provided with temporary lateral support to prevent sway during high winds and distortion of the vertical cages.

5.2 Laying of Electrical /Fire service Conduits.

All the electrical conduits and metal boxes are to be placed (Fig. 6) before placing the tunnel form.

care should be taken only mental boxes are to be used.

PVC conduits are preferred. Switch Box and DB location is to be discussed and located at Non-Boundary Structural Zones.

However under unavoidable circumstances these are to be treated as opening in structural system.

Before giving clearance to placement of tunnels by Electrical team the metal boxes and conduits in the tunnel walls are to be plugged with Expanded Polystyrene(Fig.5) or other suitable material so as to prevent slurry incrustation in to the metal boxes and conduits.



Fig.4 Boundary Element Reinforcement with Relevant Ductile Detailing (circular Cover Blocks)



Fig.5 Electrical DB fully covered with Expanded polystyrene (EPS)



Fig.6 Tunnel wall with Block out Electrical Services

5.3 Tunnel Box Shutter Placement

Every half tunnel when lowered to position should be immediately placed with tie rod and sleeve cone.

But tightening of the tie rod shall be done after complete placement of all the tunnel and then levelled to the desired level. Once when the Tie rods (Fig.7) are placed back to back through the holes the tunnel is already in level because without levelling the tie rod holes won't match.

Care should be taken for any corrections after tightening tie-rods fine tuning of the tunnel form is not possible.

5.4 Floor Slab Reinforcement Caging



Fig.7
Tunnel Shutter
Tie-Rod



Fig.8 Lay out of top of Tunnel Form Floor Slab showing Horizontal conduits,Kickers, Block Outs for services and Top layer cage on spacers

No cranking of reinforcement are permitted in slabs.



Fig.9 Kicker's Image Spacers

The bottom mesh reinforcement has to be laid after the electrical and other service line locations are marked with permanent ink or paint.

Necessary spacers with high accuracy are to be tied to the bottom mesh reinforcement before placement of second layer.

Proper development length shall be provided for the top steel and bottom mesh reinforcement as per relevant IS codes.

Electrical conduits (Fig. 8) and other services are to be place without disturbing the reinforcement layers.

Necessary cover for Bottom and top mesh has to be ensured.

The Kickers are to be Placed on special Spacers (Fig.9) so that perfect imaging of the below floor walls are ensured.

5.5 Quality Control And Pouring of Free Flow De-shuttering And Shifting of Tunnel Form Work.

Quality of Concrete is Checked in various stagesi.e in Green and Hardened phase.

During Green Concrete Stage all relevant RMC & Concrete Specification as per CPWD specification holds Good except the following

1.High range water reducing admixture (HRWRA) Polycarboxylate Ether @ 0.50 to 1.00% on weight of Cement is being used for Workability (Fig.10 & 11) and Durability perspective with a w/c ratio of 0.38 achieving free flow slump of 600mm as per ASTM C1611-C1611M 14 standard test on Self -Consolidating Concrete. The Power content including fly ash is

480kg/cum with a upper limit resection of 25% on fly ash.

2.The concrete is pumped and placed and surface vibrators are used like ordinary RMC.

Care should be taken to avoid excess or less vibration of shutters. It is to be understood that these shutter Vibrators are only for better Mobility of Concrete alone.

As the depth of wall is 3m and the anular space available is 160mm(thickness of wall).

These Shutter vibrators(Fig.13) are placed at 1.50m so as to ensure that self moving concrete dosent get hanged at mid height while the lower layers are still mobile to avoid cave-in.



Fig.10 Work ability Test based on ASTMC 1611/C 1611-M14 Procedure-B



Fig.12 Typical Tunnel Form Arrangement after Half Tunnel removed
Courtsey: https://www.mesaimalat.com.tr/en/products/formwork-systems/tunnel-formwork



Fig.11 Work ability Measurement based on ASTMC 1611/C 1611-M14



Fig.13 Variable Frequency Shutter Vibrator



Fig.14 Cantliver Needle Platform for Tunnel Movement and Workers safety

3. De-shuttering/stripping Strength as per IS:456:2000 stripping Strength requirements of Concrete based on Compressive Strength from 18 hours from the time of production of concrete and at every multiple 6 hours is

checked on achieving the desired strength the tie-rods and collapsible struts are released to de-shutter the tunnel(Fig.12) for the next cycle. Normally this stripping time for de-shutter never exceeds more than 24 hours. Under very cold climatic conditions heaters can be used to heat up the tunnels.

5.6 Surface Curing

Top Horizontal surface is always moist cured (Fig 15 &16) with gunny bags.Ponding is not apreferred method of curing because it will affect the Tunnel Cycle time as no labour or materials can be placed.

5.7 Application of Curing Compound

Membrane Curing on the overall concrete surface immideatly after deshuttering with water based Membrane Curing Compound

complaing with ASTM : C 309 is applied as per manufacture specification.

Care should be taken it should be white pigment based to have better supervisory control on application of Curing Compound(Fig.17) and for heat reflection on the fresh green concrete.



Fig.15 Moist Curing with Gunny Bags after 6 hours to check shrinkage cracks



Fig.16 Kickers being removed after 8 hours and holes Grouted



Fig.17 Moist Curing with Gunny Bags sustained till vertical cage erection

7.0 Case Study

Name of organisation	Central Public Works Department
Name of Client	Income Tax Department
Name of Agency	M/s DEC infra
Name of project	532 Nos of Type-2,3&4 Quarters for Revenue Department.
Location	Anna Nagar,Chennai.
Type of project	EPC Mode
Construction Area	61,068 Sqm.
Type of formwork	Tunnel Form work,Plasti-Tech Form work, Aluminum Form Work & Conventional Form work.
Contractor hired for Tunnel Form Work	MESA Imalat,Turkey.

A case study has been conducted at Income Tax Quarters at Anna Nagar Chennai. Where various Form work technologies are used for its advantage by M/s DEC infra Working under CPWD,Chennai Zone.

As this Project of G+18(Fig 2 and Fig 3) has to be constructed at the very busy Premium Residential/Commertial Hub of Chennai Metropolitan City. Three different unconventional Form work technologies are adopted in this project for harnessing very specific advantages of those form work

methodologies. However its relative merits and demerits are listed after being

sessfully implementing those form work methodologies.various merits and demerits are debated with field engineers and planning team and its relative comparision has been analysed and recorded.

6.0 Comparative Study

Comparision on various methodologies of Shear wall construction with Conventional form work system is tabulatated.

S.No.	Attributes	Conventional Form work	Tunnel Form work	Aluminium Form Work	Plastic form work
1	Pre-Planning with BIM	Not required	High degree of Planning required	Moderate Planning required	Complex system
2	Planning and Coordination Control required	Moderate Degree of Control	High Degree of Control	Moderate Degree of Control	High Degree of Control
3	Floor Cycles	Min. cycle time is of 21 days.	One day's cycle per floor.	Four days cycle per floor.	Min. cycle time is of 21 days.
4	Type of frame	Framed Structure	Open Box Structure	Box Structure	Box Structure
5	Dimensional Accuracy	Moderate	Very High	High	Moderate
6	Surface Finish	Plastering required	Direct painting after putty	Plastering reqd.	Gypsum plaster reqd.
7	Use of Wood	largely with wood and Ply Boards	Nil	Nil	Nil
8	Economical Aspects	Moderate fund flow	Huge fund flow required	Moderate fund flow	Moderate fund flow

9	Seismic Stability/Wind Loads	Good	Very High	Very High	Very High
10	Basement Stories	Yes	Not Possible	Yes	Not Possible
11	Number of Labours required	Very High	Low	Large	Large
12	Skilled Labour	Not required	Highly skilled	Highly skilled	Highly skilled
13	Tower Crane	Not required	Required	Not required	Required
14	Scope of Change in design	Yes	Not Possible	Not Possible	Not Possible
15	Project Production Speed	Very slow	Fastest	Medium	Low
16	Safety during execution of work	Vulnerable	High standards	Moderate safety	Vulnerable
17	Waste Production	Very High	Low	Medium	Moderate
18	Embodied Energy saving	--	Very High	Moderate	Moderate
19	Initial Investments	Low	Very High	Moderate	Very High
20	Complexity of Tools	Local tools	Available on demand	Available on demand	Inventory to be maintained
21	Accelerated Curing	Page 23 of 28 Not Possible	Provision is Available	To be custom made	Not Possible

7.0 Conclusion

Innovation is not invention. It is change from mundane. We at Chennai Zone are still using RCC Monolithic Construction for developing builtenvironment,however we have just migrated to innovative shutter form works which are already established in

construction industry world wide and harvested following in return

(a) Speedy Construction

(b) Safe Construction

(c) Skilled labour at site

(d) Uncompromising Quality

(e) Motivated staff who are eager to be associated with new and change.

(f) Energy efficiency, both natural energy by the way of imbibed energy of materials and artificial by the way of thermal comfort of interiors.

(g) Efficient use of materials

(h) Conservation of water in construction

(i) Clean development

(j) Green building

(k) Curious peers

(l) Supportive and appreciative management

(m) Ready to learn and gain,followers in fellow professionals and everyday vendors for associating with the project.

(n) "WOW" factor in finished product and last but not the least,

(o) A satisfied client, Customer and the user.

8.0 Acknowledgement

TheauthorsacknowledgeDirector General, CPWD, Special Director General (PR) Chennai, Additional Director General (SR-1) Chennai, for their constant and persistent support in thisMonolithic Construction Technology project, Anna Nagar Chennai andpermitting the authors to share their experience in this forum through this paper for adopting the technology and usage in live project.

The authors have relied upon numerous technical literatures pertaining to tunnel form work, monolithic construction and other form works for the comparative study in this paper. The case study and comparative analysis projected in this paper based on the experience in the project reinforces the established literature and is therefore thankfully acknowledged in general.

INNOVATIVE MATERIAL AND TECHNOLOGY IN THE FIELD OF ENERGY EFFICIENCY MEASURES

Rajiv Gupta, EE (E) Energy Conservation Cell

CPWD has taken an initiative of energy efficiency measures in existing buildings and New Construction. There is a continuous technical development in the field to conserve energy for buildings sector to make the building towards net zero building and energy plus building.

Following are the few new market practices and innovative material, technology, which are continuously upgrading to lower the energy demand in the building sector. The following is the tentative list(actual list is endless) of innovations as given below;-

1. Use of evaporative cooling:-

This is used in food court, kitchen ventilation, Malls, Pre Cooling of Intake air using heat recovery wheel. Due to this cycle energy requirement dropped drastically. Figure 1.

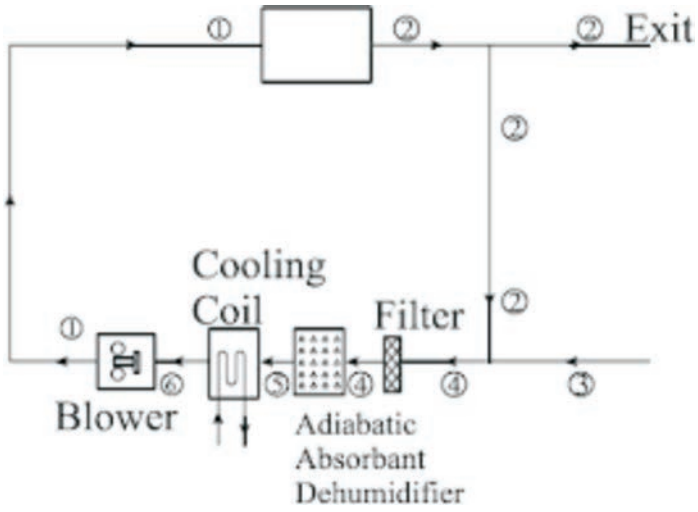


Figure 1

2. Use of phase changing material in automotive refrigeration transport sector and concrete walls and roofs.

These days use of phase changing material is videly used to store thermal mask storage in transport refrigerator sector and concrete walls and roofs to reduce peak demand of HVAC equipment. Figure 2.

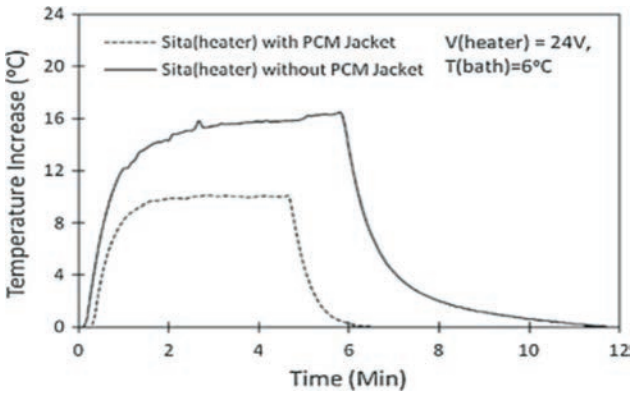


Figure 2

3. Use of Bamboo on the rooftop of buildings to reduce the heat load through roof and sustainability:-

Bamboo is a very good building material if treated properly, which gives good aesthatics and having good tensile strength, insulation property, which is recently incorporated in CPWD DSR 2019 due to its innovative property. Figure 3 & 4



Figure 3



Figure 4

4. Use of reflective white tile on rooftop of building to reflect the solar heat energy partially to reduce solar heat gain through roof and thus reduce the heat load of the building. Figure 5 & 6



(A)

Figure 5



(B)

Figure 6

5. Use of Double Glass with vaccum in Window is used to reduce heat load of the building. As plain glass is 25 times more absorbent of heat than brick wall hence DGU (double glass with vacuum) is used to reduce heat intake in the building and thus reduce heat load of the system. Figure 7

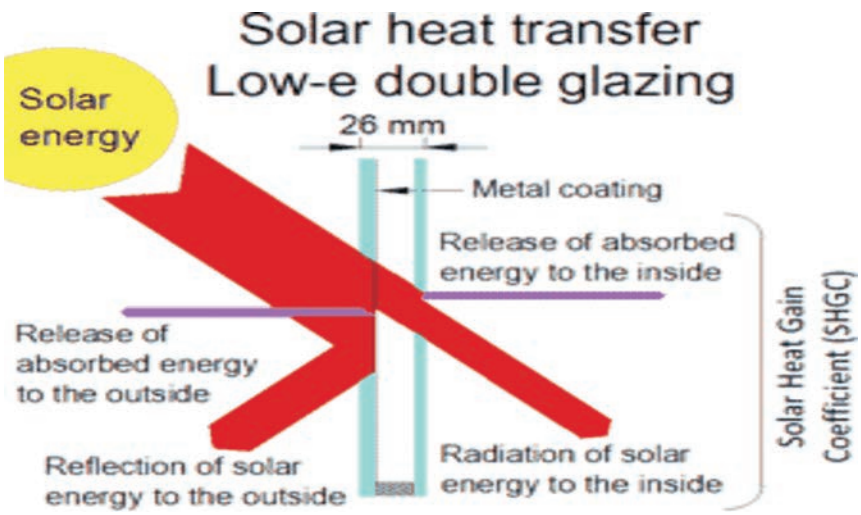


Figure 7

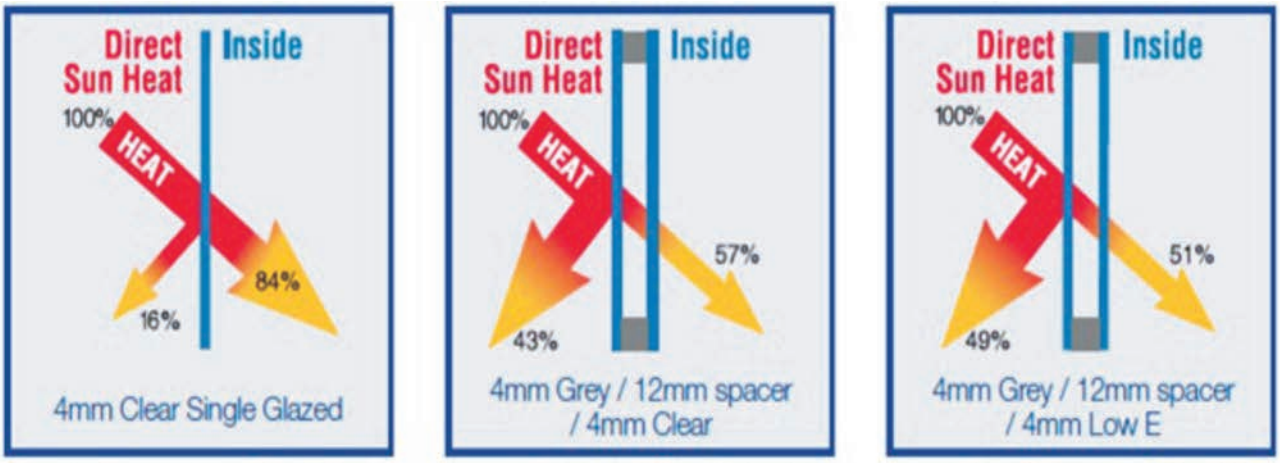
6. Use of Sandwich insulation wall on outer surface of building to reduce heat load.

Use of thermal sandwitch insulation panel between walls increase the thermal resistivity & thus reduce heat load of the system.

Thermal insulation system

“Thermal insulation system” is a term used to cover the entire combination of materials and endeavoured provisions which together perform thermal barrier duty. Often, it is misunderstood that only the material (insulant) is of consequence for design. However, the way it is applied, the ancillary provisions that are needed to keep it in place, protective coverings that are necessary and compatibility with other provisions such as water proofing etc. determine its final effectiveness.

In warm locations such as India, the predominant insulation duty pertains to summer ambient conditions and the concurrent requirement for cooling of the air in the building interior. The major obstacle in achieving comfort conditions within the enclosure on a summer day is the enormous amount of solar heating to which the roof is subject, apart from heat inflow from the high ambient air itself. The principal offender is always the roof apart from the walls which, if not properly insulated can allow large quantities of heat to enter in the building and thus increase heat load of the system. Figure 8



Standard 4mm glass offers little resistance to heat gain.

SHGC 0.84 (solar impact)

Insulated Glass Unit using toned glass can reduce heat gain by 27%.

SHGC 0.57 (solar impact)

Low E Insulated Glass Unit using Low E glass on the inside pane can reduce heat gain by 33%.

SHGC 0.51 (solar impact)

Figure 8

7. Use of under deck/over deck insulation on rooftop.

Enter the building envelope and thereby cause the following:-

a) Increase the temperature of air within the enclosure beyond permissible limits.

b) Greatly increase the load required on the HVAC equipment to remove the above ingress of heat which means

- High energy cost for running the HVAC System and
- Higher running time and hence wear and tear of the HVAC equipment

c) Insufficiently or poorly insulated roofs would also mean necessity to install HVAC equipment of much higher capacity than what would be adequate if proper thermal insulation had been provided.

Choices available for Roof insulation are:-

Provision of thermal insulation as a contact treatment to the inner surface of the roofing. This is normally termed as “Underdeck” insulation. Figure 9 & 10.

Provision of thermal insulation over a suspended ceiling (False ceiling) system.

And finally insulation provided over the roofing structure-normally reffered to as “Overdeck” insulation.



Figure 9



Figure 10

8. Use of solar rooftop PV panel on the building as well as use of solar PV film on window of building to generate clean solar energy.

These days solar PV Panel and solar film are used to gernate solar energy not only from rooftop but film on window also to generate maximum clean solar energy. Figure 11.



Figure 11

9. Upsizing of Cables and copper Electricals wires for Energy Efficiency

Now a days a new concept (i.e.) is introduce by using cable or wires with cross sectional area one size above than normally utilized. It has already been mentioned that minimum size to be used should be 1.5 sq, mm cable, in order to be able to withstand short circuit condition. ICAI in effect is suggesting one higher size i.e. upsized cable. The logic for upsizing is more sound

and gives economic benefits.

Most of the households do use two way/three way plugs for connecting through a single outlet. A minimum recommended size cable permissible can thus get overloaded. Further, a minimum recommended size cable carrying its rated full load current will get heated up to temperature. The resistance of the cable will be the highest permissible if next higher size of cable is used, it will be much less heated. Its resistance and loss will be considerably lower. The life expectancy of cables and therefore of house wiring becomes longer. (In general, a reduction of temperature rise by 80c /100c doubles the life.) There is also energy saving and therefore, saving in electricity consumption bill, arising from using one higher size conductor. This is further illustrated in the following example(see Table 2.14).

CASE STUDY CALCULATION OF ENERGY SAVING THROUGH USE OF HIGHER SIZE CABLE:

Particulars	Value/Quantity
Equipment used	Air Conditioner
No. of equipment considered	1
Equipment capacity (tones)	1.5
Power Input (Watts)	2050
Running current(A)	9.5
Normal cable size used (sq. mm)	1.5
Length of cable, assumed (meteres)	25
Resistance of cable @ 20^0 C (ohms/km)	12.10
Resistance at 65^0 C (ohms/km)	14.278
Resistance at 65^0 C for 25m at 65^0 C(ohms)	0.357
12R loss for 25m at 65^0C (watts)	32.2
Next higher size cable (sq. mm)	2.5
Resistance of cable @ 20^0 C (ohms/km)	**7.41**
Resistance of cable @50^0 C (corresponding Final temperature as current is ½ of rated current) (ohms/km)	**8.30**
Resistance for 25m cable (ohms)	**0.207**
1^2R loss (watts)	**18.68**
Saving in 1^2R Loss	**13.52**

Energy saving	Domestic Use	Commercial use
No. of hours A/C used (per day)	8	10
No. of days used per year	180	300
No. of hours used in a year	1440	3000
Saving in energy (kWh)	19.5	40.6
Value of energy saved @ Rs. 4 per unit (Rs.)	78	162
Additional cost for higher size cable (Rs.)	85	85
Cost recovered in no. of years	1	6 months

(-Courtsy Building Wiring Handbook Second Edition 2016 by ICAI Page-27)

It is seems from above calculation that by going in for cable of one size hire additional cost of cable can be recovered in six months to year depending upon tariff structure of Discoms, no. of hours used per year, weather consumer is domestic or commercial one.

10. Use of earth AIR tunnel for pre cooling of fresh air.

Fresh air in building is pre cooled by passing through earth air tunnel which is created below the earth level to get benefits of lower temperatures below the earth and thus reduce heat load of the systems. Figure 12.

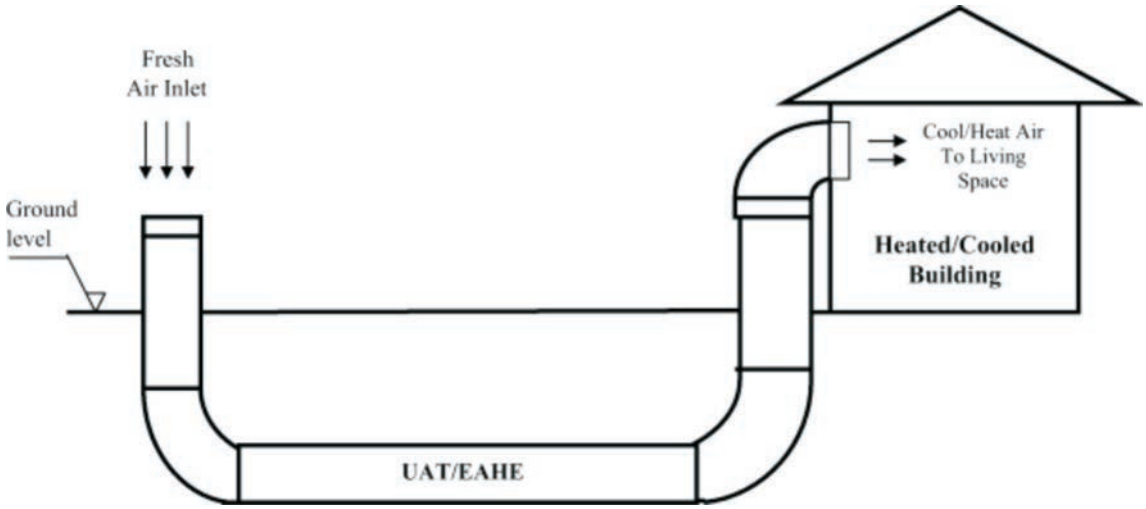


Figure 12

11. Use of sewer treatment plant generated water for horticulture and makeup water of cooling tower in centre AC plant.

These days the water generated from STP is being used for horticulture and makeup water of cooling tower in centre AC plant to reduce water requirement of buildings. Figure13.



Figure 13

12. Use of auto clean condenser tube to reduce chocking of tube in water cooled chiller. Figure 14.



Figure 14

13. Blow down of dissolved solids from cooling tower basin to reduce concentration of dissolved solids in the condenser tube for reducing scaling in the condenser tube.

It is a normal practice to bleed off the water from cooling tower basin to reduce the concentration of dissolved solids to reduce scaling in the condenser tube from time to time.

14. Use of thermal storage plant to produced additional thermal mass where electricity is cheaper in no load or partial load of power plants. Figure 15 & 16.

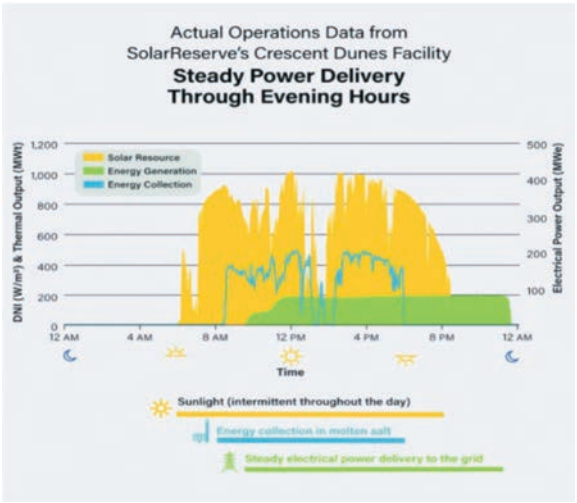


Figure 15

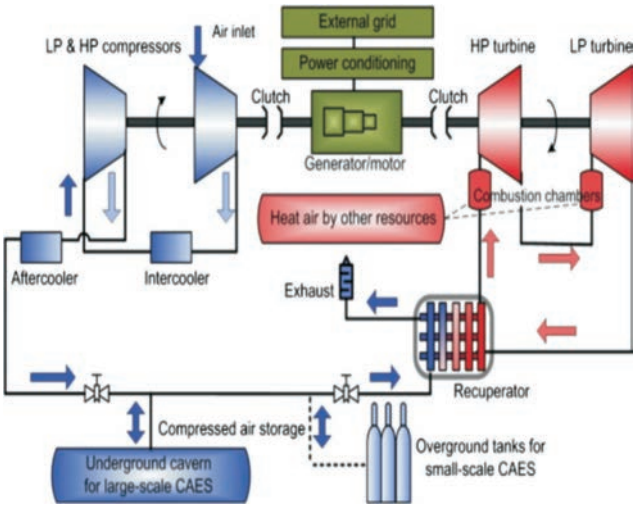


Figure 16

15. To increase the set point of room temperature up to 26 OC in consultation with client to conserved energy.

It is found that increase in 10 C set point of room temperature saves sufficient amount of energy i.e. decrease in heat load. Bureau of Energy Efficiency has already issued direction for the same.

16. To allow formal dress code in office in place of coat and pant to reduce human heat load requirement.

By allowing formal dress code is spite of coat & pant reduces the comfort temperature requirement and thus reduced heat load. Japan has already made a law on this (link given below).

https://qz.com/465327/ditch-the-tie-and-reduce-the-ac-japans-cool-biz-gets-summer-hell-just-about-right/

The list is endless. But we can save energy by combined efforts of civil, electrical, architectural and horticulture wing to save energy at design stage, construction stage and

best Operation and maintenance practices. This shall lead us on the path of building our future brighter shiner and self sustaining to give our children a better atmosphere to live in.

Here is one word lines which I want to share in the end

एक कदम आप उठाएँ

एक कदम मैं उठाऊँ

आओ मिलकर ऊर्जा बचाएँ

देश को ऊर्जा संरक्षण में आत्मनिर्भर बनाएँ

न व्यर्थ होने दें अब वायु जल और विद्युत

आओ हम सब मिलकर अपने बच्चों के लिए इस पृथ्वी

और पर्यावरण को बेहतर बनाएँ

अब न होगी कोई क्षति ओज़ोन परत में

और न होगा अब अंधेरा किसी भी घर में

कदम से कदम मिलाकर हम सब देश को प्रगतिशील बनाएँ

और ऊर्जा के क्षेत्र में आत्मनिर्भर बनाएँ

AUTOCLAVED AERATED CONCRETE –A SUSTAINABLE CONSTRUCTION TECHNOLOGY

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Rajdeep Chowdhury, Head -Specification & Application Engg.,
Biltech Building Elements Ltd.

Introduction

Now a days, the demand of AAC as construction material is continuously increasing with the increase in buildings for housing and commercial purposes in both urban and rural areas. Due to properties like light weight, durability, toughness, heat insulation, AAC is more relevant sustainable building system. Micro pores in AACprovides high acoustic insulation and thermal insulation function. It is low weight than the conventional walling and roofing material.

On the basis of method of curing, aerated concrete can be of two types which are Autoclaved Aerated Concrete (AAC) and Non Autoclaved Aerated Concrete (NAAC). In this paper focus has been through on Autoclaved Aerated Concrete.

Autoclaved Aerated Concrete (AAC) is an ultra-light concrete product that is used as an alternative construction material in modern world. It can weight as little as 1/5 as much as ordinary concrete due to its distinct cellular structure featuring millions of tiny pockets of trapped air. AAC is formed by using fly ash or sand, cement, lime, gypsum, aluminium powder, water and an expansion agent. Fly ash is the waste material that generates from burning of coal used in thermal power Stations that can be utilized in substantial quantity in AAC. The raw material used to manufacture large amount of conventional construction materials have the adverse effect on environment and human health , also depleting the natural resources. These AAC blocks & AAC reinforced products like roof panel, lintel & wall panel developed by using fly ash will help in reducing the problem of disposing fly ash.

Further these light weight Autoclaved Aerated Concrete products helps in transporting more material in single trip ,productivity , reduces dead load of the structure . AAC is a green building material, possess excellent thermal insulating properties, good sound absorber and can also be used as decorative material.

In the last decade, construction industry has been conducting various researches on the utilization of easily available alternate raw materials in construction. The high consumption of raw materials by the construction sector, results in chronic shortage of raw materials and the associated environmental damage. AAC is one of the materials which can cope up with the

shortage of building raw materials and produce a light weight, energy efficient and environmentally friendly concrete.

Construction of a building requires different building materials like bricks, steel, Cement etc. Use of these materials leaves environment footprints. It is therefore becomes prudent to adopt new substitute/alternate building materials which can provide a sustainable alternative to the consumers/end users. Autoclaved Aerated Concrete (AAC) is one such building material which contributes towards sustainability of the structure &the environment.

This paper shares salient details of AAC technology and its benefits as well as its advantage compare to the normal concrete while used in a structure.

At present there are around 90 AAC plants are operating across India . Total installed capacity approx.15 million cum/annum.Biltech Building Elements Ltd. (BBEL) is the first Manufacturer of Autoclaved Aerated Concrete (AAC) building material in India. BBEL is operating AAC business in India for more than 3 decades with it's two brands “Biltech” & “SIPOREX”. BBEL having 7 AAC manufacturing plants in India. Apart from non-load bearing AAC blocks, BBEL is also having capability to produce light weight AAC Reinforced Products i.e.WallPanel, Roof Panel & Lintel.

What is Autoclaved Aerated Concrete ?

Autoclaved Aerated Concrete (AAC) is formed by a chemical reaction between finely divided calcareous and siliceous material.AAC with its characteristic structure comprising millions of tiny pores, offers optimum solidity at low weight. As air has a low heat conductivity, aerated concrete provides excellent thermal protection.

AAC has been used extensively in Europe, Asia & USA. In India AAC is in use for last 40 years

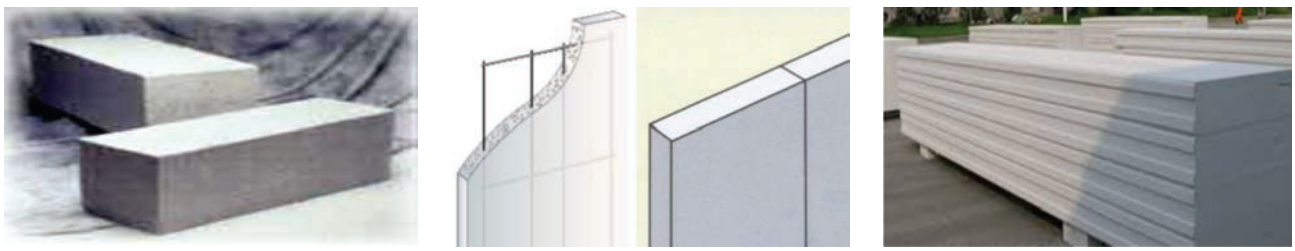


Figure-1:- AAC Product Details

Type	Length	Height / Width	Thickness
AAC Block	600, 625, 650 mm	240mm, 250 mm	100 ,125,150,200,225,250 & 300 mm
AAC Panel (Roof & wall)	1000 to 4000 mm	600 mm	100 ,125,150,200 mm (depending upon Span and superimposed load)
AAC Lintel	700 to 2000mm	100, 150 , 200mm	150 , 200 mm

Properties of AAC Material

S. No.	Properties	AAC Block	AAC Wall & Roof Panel
1	Density (Oven Dry)	551-650 Kg/Cum	551-650 Kg/Cum
2	Compressive Strength	Minimum 30 Kg/cm2	Minimum 35 Kg/cm2
3	Thermal Conductivity (K Value)	0.162 W/mK (avg.)	0.22 W/mK
4	Resistant to Fire	2 - 6 hrs depending on thickness	2 hrs depending on thickness
5	Design Gross Density	800 Kg/Cum. (approx.)	850 Kg/Cum. (approx.)

Relevant B.I.S Standards

BIS - 2185 (III) –1984 : Autoclaved Aerated Concrete Block.

BIS - 6041 –1985 :Construction of Autoclaved Aerated Concrete Block Masonry.

BIS - 6072 & 6073 : Autoclaved Aerated Concrete wall & Roof Panel

BIS - 6441 –1972 :Methods of Test for Autoclaved Cellular Concrete Produc

The Manufacturing Process.

Various raw materials – fly-ash, quicklime, cement, gypsum and aluminum powder are tested, graded and stored in their respective silos. These are then metered and conveyed in a programmed sequence into the batch mixer. This mixture is poured into moulds, allowed to rise and set, trimmed and cut to shape and size and loaded into autoclaves. In the autoclaves they are steamed, as per the process requirements, for up to 12 hours, unloaded, palletized and sent for dispatch.In case of reinforced Products steel cages treated with anti-corrosive paint are prepared and placed before pouring of mix in the Mould . Profiling of panels can be done at the green stage or after Autoclaving.

Why AAC in place of conventional structure ?

- **Structural savings:**

AAC is structurally more stable as compared to bricks. The quantity ofcement and plaster required for an AAC block masonry is significantly lower than that for bricks. Further,larger size blocks lead to faster masonry work. On the structure, there will be a benefit in cost for AAC based system over conventional systems on account of AAC's light weight.

- **Speed in construction:**

AAC based systems shall provide a time benefit of over 30% vis-à-vis conventional construction due to reduction in number of joints and better labour Productivity in the masonry because of its bigger size.In case of structural products like AAC Panel no shuttering , curing is required leading to substantial saving in project timeline.

- **Operation & Maintenance Benefits:**

The insulating property of AAC provides improved thermal efficiency thus reduces the heating as well as the cooling load of a building.AAC based system shall provide substantial saving in energy costs , due to reduced Air-conditioning load in AAC vis-à-vis conventional walling system. There is no affect of efflorescence in AAC products so the durability of rendering coat including painting increases.

- **Properties to counter seismic sensitivity:**

AAC material reduces the impact of earthquake forces on fixed structures. The base shear experienced in various experimental models with AAC blocks was significantly smaller than with conventional clay bricks which results in reduction in member forces which leading to reduction in required amount of Steel to resist this forces. So economy in construction can be achieved by using AAC blocks instead of conventional clay bricks. The performance of AAC block infill was superior to that of Conventional brick infill in RC frame.

- **AAC is a Green energy efficient Building Material**

AAC material conforms to the requirements of IGBC –LEED , BEE -ECBC & TERI-GRIHA

Comparison with Normal Concrete

S. No.	Autoclaved Aerated Concrete (AAC)	Normal Aggregate Concrete
1	AAC is a versatile light weight construction material and usually used as blocks.	Normal concrete has very heavy density compared to the AAC.
2	A low density and excellent insulation properties	High density and lower insulation property.
3	The low density is achieved by the formulation of air voids to produce a cellular structure. These voids are typically 1mm to 5mm across and give the characteristics appearance.	The concrete so formed has a high density and compact structure .
4	Densities range from 551 to 650 Kg/m3	Medium density concrete blocks have a typical density range of 1350-1500 Kg/m3 and dense concrete blocks a range of 2300-2500 Kg/m3.
5	High resource efficient as thefinished product is upto five times the volume of the raw materials used, with an air content of 70% to 80% (depending on the required strength and density)	No resource efficiency , the finished product is compact and dense .
6	Easily workable .Can be sawed, nailed and drilled easily like than wood.	Cannot be sawed, nailed or drilled as easily as AAC blocks.
7	Very less curing required-Labour cost, water is saved for curing.	High Curing is required and labour intensive.

AAC &CPWD's proposed Sustainability Parameters

Sl. No.	Proposed Sustainability Parameters	AAC Performance potential
1	Recycled content	High in the range 65 % - 70%
2	Embodied Energy	Less
3	Rapidly Renewable	NA
4	Locally Available Material	Yes , more than 100 plants are operational
5	Capital Cost	Medium
6	Functional Life Period	As compared to Conventional
7	Maintenance Cost	Low
8	Construction Waste Management	Wastage very low
9	Flyash Content	minimum 55% to 65%
10	Reduced Weight	Vey less Density reduces dead load
11	Reduced Time of Construction	High potential minimum 20%
12	Toxicity/Indoor Air Quality/Safety	No Efflorescence and higher Fire resistance

AAC Reinforced Panels

AAC Reinforced wall and Floor panels are light weight, fire resistant, provides high thermal insulation fast and easy to install. The interior steel reinforcement cage is covered with an anti corrosion coating. Theses Panels are used in residential, Hotels, Hospital and industrial buildings. Panels have good load-bearing capacity, the static hanging weight in a single point is approx. 120kgs. AAC internal panels are the thinnest among those with the same capacity in sound insulation and fire protection.



Figure-2: Typical Joinery methods of AAC Floor & Wall Panels



Figure-3: Erection of AAC vertical Wall Panels

Design Considerations :

- Autoclaved Aerated Concrete (AAC) wall / Floor Panels can be used as load bearing systems and shall be designed in order to comply with strength and serviceability requirements.
- The Panel thickness and the span will determine the allowable service load.
- Floor and roof panels can be supported by AAC Masonry Walls,reinforced concrete, steel beams.
- The longitudinal bars of reinforcement develop their tensile stress using mechanical anchorage provided by cross bars.
- In case of AAC Floor Panels minimum support bearing to be provided of 100 mm
- In case of AAC Wall panels proper anchorage to be provided at the top and base of panel

Energy Conservation Potential of AAC:

ECBC code of practice for energy conservation in buildings sets several requirements to limit the peak loads for space cooling. The enforcement of limits(voluntary) on the thermal resistance for exterior walls gave way to the introduction of AAC as an efficient material that can provide the requisite thermal Insulation without adding any other specific thermal insulating material.

AAC provides useful thermal inertia because it possesses an advantageous combination of mass, thermal conductivity and specific heat properties. This means that AAC can reduce the extremes of internal temperature compared with buildings made of lighter structures (which have minimal thermal capacity) or heavier structures (providing less thermal insulation).

Building Envelope Performance Factors of AAC

AAC contributes significantly in limiting Residential Envelope Transmittance Value (RETV) which helps in reducing heat gains from building envelope, thereby improving thermal comfort and reducing the electricity required for cooling. For e.g. AAC Block of 300 mm thk with 2 coat of plaster in 12.5 mm both sides provides thermal transmittance U: 0.55 W/m2.k.



Figure-4: Typical use of AAC in Building :

Conclusion

Conventional construction materials and techniques are energy intensive and time consuming. Already nation is witnessing pressure from shortage in economic and quality dwelling units so it's a pressing need to explore alternate building materials and construction process.

AAC Building system can contribute substantially not only in developing a sustainable habitat but also optimizing the cost and speed of construction. Already AAC based building system being used in Housing Industrial and Institutional applications for last more than 45 years across India and has high potential to meet sustainability challenges in Construction.

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MONOLITHIC CONCRETE CONSTRUCTION WITH ALUMINIUM FRAMEWORK FOR CONSTRUCTION OF 76 NO. MULTISTORIED HOUSES FOR HON'BLE MPS OF LOK SABHA AT DR B D MARG, NEW DELHI.

Rajeev Singhal, Chief Project Manager, New Delhi Project Zone

Background:

There is a growing focus on affordable homes and housing for all which necessitates the use of new and innovative construction technologies. The Ministry of Housing and Urban Affairs has also issued directions vide OM No. 28012/7/2016-W-3 dated 20.03.2018 that CPWD shall adopt new and emerging technologies in its projects. Eight new technologies were to be adopted.

1. Monolithic concrete construction system using aluminium formwork.
2. Monolithic concrete construction system using plastic aluminium formwork.
3. Expanded polystyrene core panel system
4. Light gauge steel framed structure (LGSF) system
5. Industrialized 3-s system using RCC precast with or without shear walls, columns, beams, cellular light weight concrete slab/ semi precast solid slab.
6. Speed floor system.
7. Glass fiber reinforced gypsum (GFRG) panel building system.
8. Factory made fast track modular system.

One such technology is monolithic concrete construction by use of Aluminium formwork noted for its ability to aid mass construction activity with good quality and durability. This technique is being used for the titled project.

Introduction of Project:

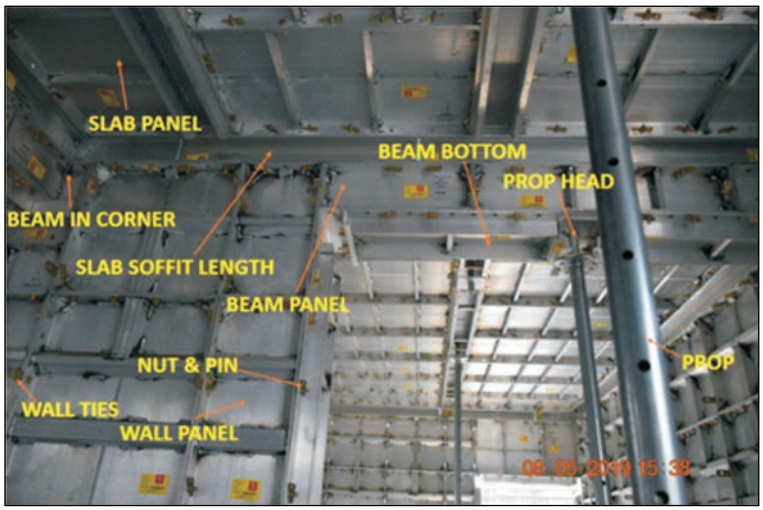
The project pertains to construction of 76 flats in 3 towers, with basement, stilt and 13 upper floors. Each tower shall have two flats on each floor. In the middle tower, the top floor shall be used as recreational area.



The project was sanctioned on 10.07.2017 for Rs. 218.72 crores to be completed in 40 months i.e.by November, 2020. However the project is expected to be completed by June 2020.

Introduction of Technology:

All the components of the building like columns, beams, slabs, walls, stairs and balconies are cast in one go with concrete using lightweight, specially designed aluminium formwork, hence the name “monolithic construction” avoiding the use of brickwork, plaster etc leading to faster construction. A typical arrangement of aluminium formwork in a room is shown below.



(Main components of aluminium form work)

Design of framework:

The shuttering is custom made for the project. The building plans, structural design and layout of all the services should be available for design of shuttering. In this particular project, it was stipulated in the contract that the contractor shall procure aluminium formwork sufficient to cast 3 flats along with the intermediate lift lobby so that construction could be completed within the stipulated time of 22 months.



(Plan of a typical tower with 2 flats and intermediate lift lobby)



(Shuttering being fixed for a flat)



(Top View of Shuttering)

Design of Concrete for monolithic construction

The concrete sections in monolithic construction are thin as compared to conventional construction. In this particular project, shear walls are 200mm thick and non shear walls are 100mm thick.

Also, entire floor/ flat is to be cast in one operation. The conventional concrete is not suitable for such a use as it will not spread uniformly over the entire area of walls and floor. Hence self compacting concrete, ie, concrete that can flow under its own weight and completely fill the voids within the formwork, even with dense reinforcement without any vibration is being used.

Grade of concrete is M-30 with flow of 600mm after 3 hours.
Design Mix for M30 adopted:

Mix Constituent	Qty for 1cum. in Kg
Cement (OPC 43)	368
Fly Ash	157
Water	210
Fine Aggregate	834
Coarse Aggregate 10-20mm (40%)	292
Coarse Aggregate <10mm (60%)	438
Chemical Admixture @ 0.9% by weight of cementitious content	5
Water Cement Ratio	0.4

Work cycle of Formwork:

Casting of one flat is being done in 10 days which can be compressed to 8 days by reducing the time for reinforcement and conduit laying.

1st& 2ndDay - Fixing of reinforcement of shear wall.

2nd& 3rd Day - Laying of electric conduits and fixing of junction and switch boxes.

3rd& 4thDay - Fixing of formwork of wall.

5th Day - Fixing of formwork of slab.

6th Day - Laying of reinforcement of beam.

7th& 8thDay - Laying of bottom layer reinforcement of roof slab.

8th&9thDay - Laying of electric conduits and top reinforcement.

10th Day - Casting of complete structure.

Comparison of Aluminium Formwork with Conventional Formwork with reference to-

1. Cost of construction
2. Time taken for construction
3. Maximizing Usable area

1. COMPARISON OF COST FOR STRUCTURE OF ONE HOUSE

Construction with Conventional Formwork					
Sl. No.	**Description of Item**	**Unit**	**Quantity**	**Rate**	**Amount**
1.0	Centering and shuttering including strutting, propping etc. and removal of form for :				
1.1	Suspended floors, roofs, landings, balconies	Sqm	370	693.05	2,56,428.50
1.2	Lintels, beams, plinth beams, girders	Sqm	340	552.05	1,87,697.00
1.3	Columns, Pillars, Piers, Abutments, Posts and Struts	Sqm	240	733.70	1,76,088.00
2.0	Providing and laying RCC - M-30	Cum	140	9,871.95	13,82,073.00
3.0	Steel Reinforcement	Kg	17136	83.50	14,30,856.00
4.0	Brick Work with cement mortar 1:6	Cum	107	7,590.45	8,12,178.00
5.1	6mm cement plaster on ceiling 1:3	Sqm	370	227.35	84,119.50
5.2	12mm cement plaster on wall 1:6	Sqm	600	254.25	1,52,550.00
5.3	15mm cement plaster on wall 1:6	Sqm	650	292.85	1,90,353.00
				Total	**46,72,343.00**

Construction with Monolithic Aluminium Formwork					
1.0	Providing and laying RCC M-30	Cum	180.00	9,871.95	17,76,951.00
2.0	Extra for M-30 Self Compacting Concrete	Cum	180.00	650.00	1,17,000.00
3.0	Steel Reinforcement	Kg	26100.00	83.50	21,79,350.00
4.0	Aluminium Formwork	Sqm	1615.00	202.45	3,26,957.00
				Total	**44,00,258.00**
				SAVING IN COST =	**2,72,085.00 (6% savings)**

There is a saving of 6% in cost of construction of structure by using monolithic construction as compared to conventional construction.

2. COMPARISION OF TIME TAKEN FOR CONSTRUCTION

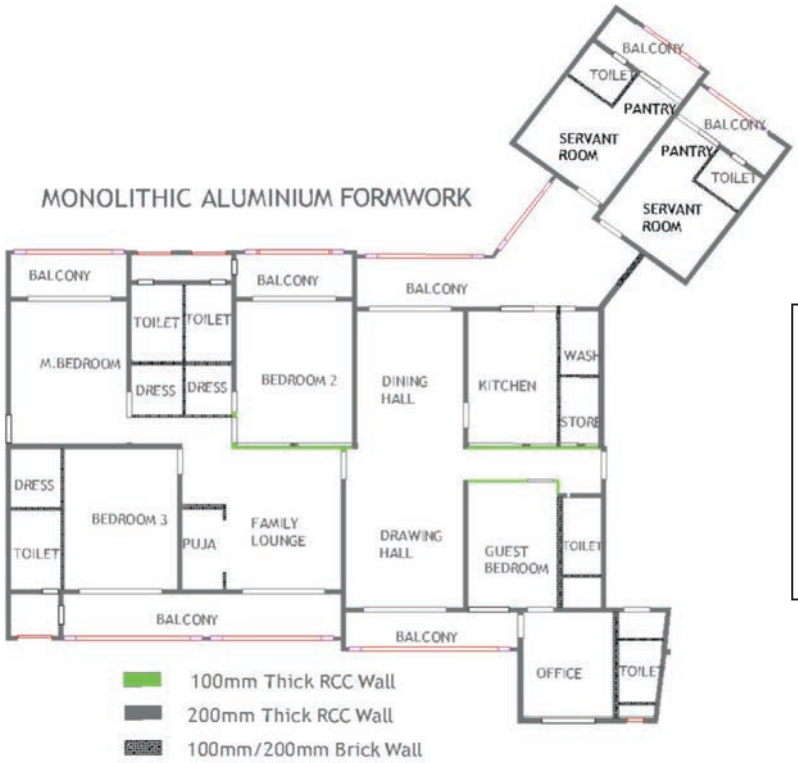
Considering shuttering procurement for one and half floor				
		Aluminium Formwork		**Conventional Formwork**
S No	**Activity**	**Time (Days)**		**Time (Days)**
1	Mobilisation	30		30
2	Earthwork and Raft	75		75
3	Basement	60		60
4	Stilt Floor	45		45
5	Completion of structure of one and half tower	1 x 30 =30 12 x10 =120	150	13X18= 234
6	Completion of structure of remaining one & half tower	1 x 20 = 20 12 x10 = 120	140	13 X18 =234
7	Completion of structures above 13th(top) floor with conventional formwork	30		30
8	Completion of brick work and plaster after completion of structure	Nil		30
9	Completion of finishing work like painting, flooring, sanitary etc after brickwork and plaster	60		60
10	Development work, horticulture and misc. work	30		30
	Total Time	620 Days		828 Days

Time saving in Project =208 days

% Saving in Time =25%

There is a saving of about 25% in time by using monolithic construction as compared to conventional construction.

3. COMPARISON OF USABLE AREA



Total Plinth area= 408 Sqm

Usable area = 368.68 Sqm

Percentage of usable area=90.36%



Total Plinth area= 408 Sqm

Usable area = 350 Sqm

Percentage of usable area=85.78%



(View of shuttering for balcony)



(View of wall brackets for upper floor casting)

Merits over conventional formwork:

1. Faster construction with approx. 25% savings in time as all the building components are cast together.
2. Smooth finish, hence no plastering of surface is needed.

3. Thinner wall sections giving higher usable area. The usable area is found to be increased by about 5% by adopting shear wall system.
4. Lesser joints, hence less chance of seepage.
5. Uniform quality of construction.
6. Eco friendly as shuttering can be used for more than 100-250 times.
7. Dimensional accuracy of door and window openings and all the building components.
8. Lower maintenance cost because of better quality and avoiding brickwork and plaster.
9. Better aesthetics. In the case of RCC structural framework of column and beams with partition brick walls, the columns and beams show unsightly projections in room interiors.
10. Lesser cost of construction of structure.
11. No need for chase cutting for electrical conduits and cutting for switch boxes.

Limitations:

1. Initial investment for the formwork is high.
2. Large number of formwork components to be handled.
3. Higher repair cost for aluminium.
4. Probability of theft due to higher cost.
5. Suitable for multistoried structures with repetitive type of work.
6. Lead time of about 3 months required for initiation of work, as the formwork are designed and manufactured.
7. Post construction alterations are not possible.
8. All the services are to be pre-planned in advance.

Conclusions:

Monolithic Concrete Construction system using Aluminium Formwork is advisable for mutistoryed construction of flats where a large number of flats are to be constructed in a short period of time. Even though initial investment is higher as compared to conventional formwork, the same is offset by getting more usable area, less cost of structure and less maintenance cost.

CONFINED MASONRY IN BUILDING CONSTRUCTION

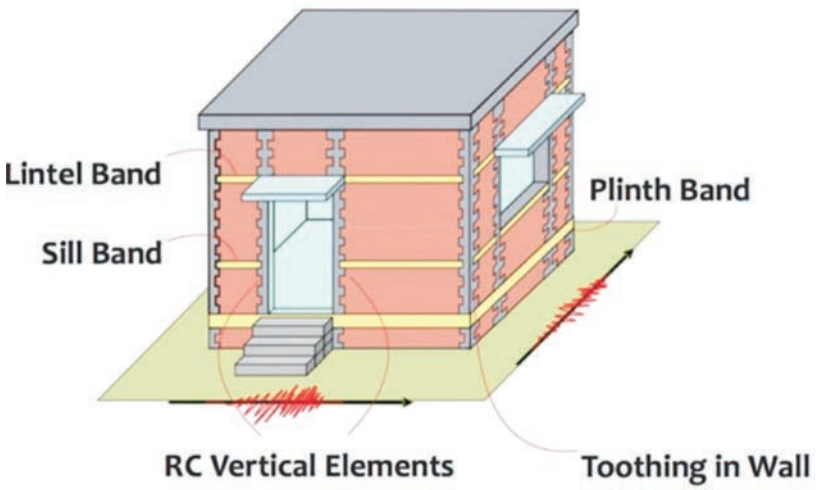
D. S. Panwar, Executive Engineer, CPWD, Guwahati

Abstract:

Over the past 30 years, hundreds of thousands of people all around the globe have been needlessly killed by the collapse of their own homes during earthquakes. Typically, concrete frame buildings with masonry infills perform very poorly when subjected to strong ground shaking, as do buildings of unreinforced brick masonry, if not designed and built well. Poor performance of unreinforced masonry prompted a need for developing and promoting alternative building technologies. An alternative construction technology, using the same construction materials, is CONFINED MASONRY construction. Confined masonry is a construction system where the masonry walls are built first and the concrete in columns and beams are poured in afterwards to confine the wall. It has typically performed well in past earthquakes worldwide, when built according to the general design guidelines.Satisfactory performance of confined masonry in earthquake is due to the joint action of masonry walls and their confining elements.The goal is to achieve enhanced seismic performance using technologies which require similar (preferably lower) level of construction skills and are economically viable.

Key Components of a confined masonry building:

Confined masonry construction consists of masonry walls and horizontal and vertical reinforced concrete (RC) confining elements built on all four sides of a masonry wall panel. Vertical elements, called tie-columns, resemble columns in RC frame construction except that they tend to be of far smaller cross-sectional dimensions. Most importantly, these RC members are built after the masonry wall has been completed. Horizontal elements, called tie-beams, resemble beams in RC frame construction but they are not intended to function as conventional beams since confined masonry walls are load-bearing. Alternative terms, horizontal ties and vertical ties, are sometimes used



instead of tie-beams and tie-columns.

The key features of structural components of a confined masonry building are as below:

- Masonry walls transmit the gravity load from the slab(s) above down to the foundation (along with the RC tie-columns). The walls act as bracing panels, which resist horizontal earthquake forces acting in-plane. The walls must be confined by RC tie-beams and tie-columns and should not be penetrated by significant openings to ensure satisfactory earthquake performance.
- Confining elements (RC tie-columns and RC tie-beams) are effective in improving stability and integrity of masonry walls for in-plane and out-of-plane earthquake effects. These elements prevent brittle seismic response of masonry walls and protect them from complete disintegration even in major earthquakes. Confining elements, particularly tie-columns, contribute to the overall building stability for gravity loads.
- Floor and roof slabs transmit both gravity and lateral loads to the walls. In an earthquake, floor and roof slabs behave like horizontal beams and are called diaphragms. The roof slabs are typically made of reinforced concrete, but light-weight roofs made of timber or light gage steel are also used.
- Plinth band transmits the load from the walls down to the foundation. It also protects the ground floor walls from excessive settlement in soft soil conditions and the moisture penetration into the building.
- Foundation transmits the loads from the structure to the ground.

A comparison of Reinforced Masonry and Confined Masonry:

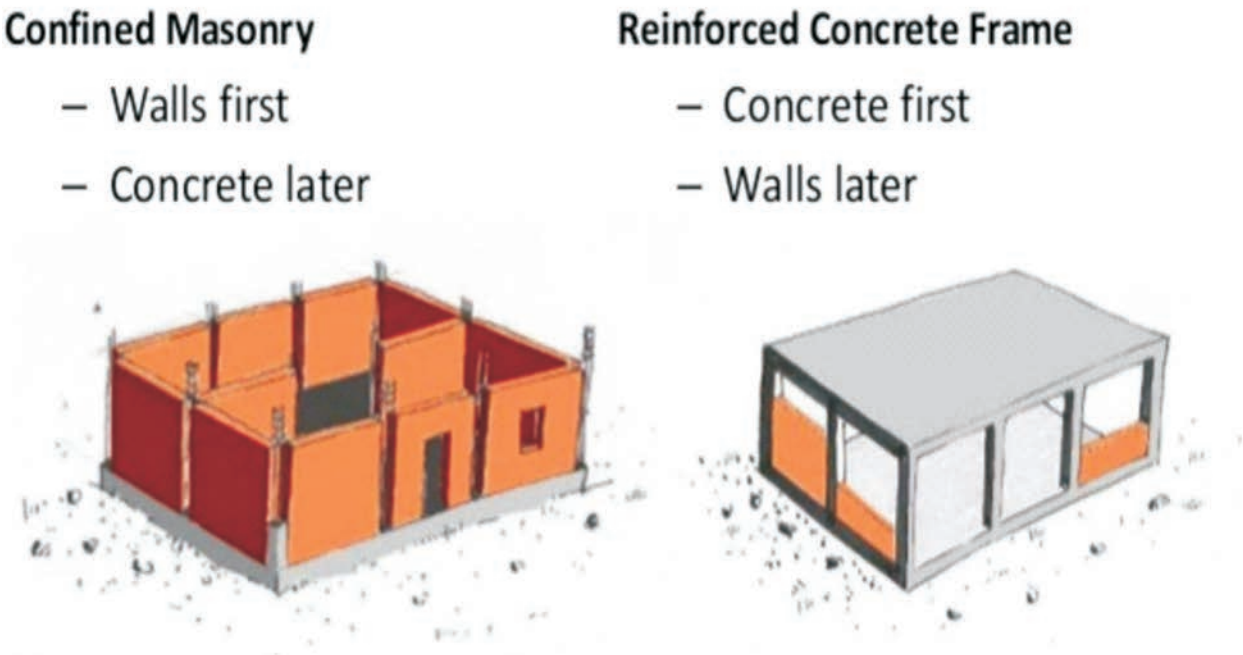
Reinforced masonry:

- In reinforced masonry Vertical and horizontal reinforcing bars are provided to enhance the strength and ductility (deformability) of masonry walls.
- Masonry units are usually hollow and made either of concrete or clay.
- Vertical reinforcing bars are placed in the hollow cores, which are subsequently grouted with a cement-based grout to anchor the reinforcement and protect it from corrosion.
- Vertical reinforcement is placed at the wall corners and intersections, around the openings, and at additional locations depending on expected seismic loads.
- Horizontal reinforcement is provided in the form of ladder-shaped wire reinforcement

placed in horizontal joints, or deformed reinforcing bars placed in bond beams, typically located at floor and/or lintel levels.

Confined Masonry:

- In confined masonry, the reinforcement is concentrated in vertical and horizontal RC confining elements whereas the masonry walls are usually free of reinforcement.
- Advanced construction skills and inspection at different stages of construction are necessary to ensure quality of reinforced masonry. Horizontal reinforcement is placed into bond beam blocks which also need to be grouted.
- Specialized equipment is used for pumping grout into masonry.
- Confined masonry technology falls in between that of unreinforced masonry and RC frame construction; however, due to its smaller member sizes and the lesser amount of
- Reinforcement it is more cost-effective than RC frame construction
- The quality of RC confining elements in terms of reinforcement detailing and concrete construction can be verified with more confidence compared to similar components of reinforced masonry construction (e.g. placement of reinforcement and grout in hollow block cores).



KEY DIFFERENCE BETWEEN CM & RC FRAME CONSTRUCTION

General requirements of Confined Masonry:

a. Architectural Guidelines:

- The building plan should be of a regular shape.
- The building should not be excessively long. Ideally, the length-to-width ratio in plan should not exceed 4.
- The walls should be built in a symmetrical manner to minimize torsional effects.
- The walls should be continuous up to the building height.
- Openings (doors and windows) should be placed in the same position on each floor.
- Tie beams should be placed at every floor level at a vertical spacing not to exceed 3 m.
- Tie columns should be placed at a maximum spacing of 4 m.
- At least two confined walls should be provided in each direction.
- Since the earthquake performance of confined masonry buildings largely depends on the shear resistance of masonry walls, it is essential that a sufficient number and total length of walls be provided in each direction.
- The walls should always be placed continuously, directly over one another.

b. Construction Guidelines:

Basic requirement is good quality materials and good workmanship.

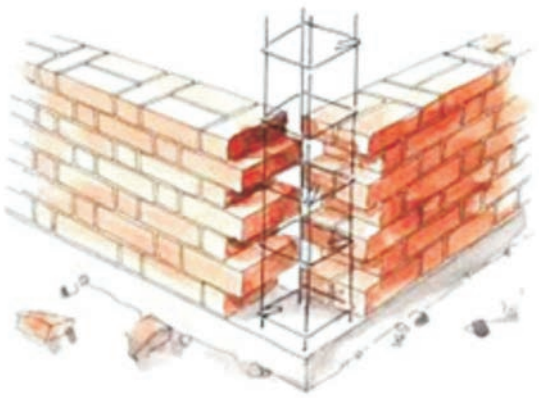
b.1 Tie Columns:

- The first storey tie columns reinforcement should be assembled first before foundation construction takes place.
- The reinforcement of tie columns should consists of four 10 mm diameter deformed bars for longitudinal bars, and 6mm ties at 200 mm spacing.
- Vertical bars should be lapped by a minimum of 500 mm or by at least 40 times the bar diameter.
- The minimum tie -column dimensions are 100mmx 100 mm.

b.2 Wall Construction:

- Minimum wall thickness be 100 mm
- Wall height to thickness ratio should not exceed 30
- Toothed edge should be on each side of wall alternatively horizontal dowels should be provided at wall to column interface.





DETAIL OF TOOTHED EDGES

- Concrete in the tie columns should be poured upon completion of masonry to desirable wall height.
- Bricks should be moistened before concrete is poured.
- Form work be supported properly and concrete should be vibrated thoroughly.





PLACEMENT OF REINFORCEMENT IN CONFINED MASONRY

Tie-Beams:

- Tie beams are constructed a top the wall at each floor level.
- The tie beam reinforcement bars shall consists of four 10 mm diameter deformed bars for longitudinal reinforcement, and 6 mm stirrups at 200 mm spacing.
- Tie-beam reinforcement needs to be continuous with the longitudinal reinforcement bars overlapped by at least 500 mm.
- Proper detailing of tie-beam to tie-column is must for satisfactory performance during earthquake.
- Minimum tie-beam cross section are 100mmx100mm
- Special lintel beams need to be provided across larger openings.



EXECUTION OF CONFINED MASONRY

Comparison for Construction Cost:

The construction of campus of IIT Gandhinagar at the Sabarmati was completed in April-2015. The construction of campus was executed by Project Team of Central Public Works Department. As per the paper published by IIT Gandhinagar regarding campus on the Sabarmati. The construction cost analysis of confined masonry and RC framed with masonry infill is tabulated below.

Building Type	Structural System	Built-up area (sqm)	Structural Cost (Rs in Crore)	Cost of Structure (Rs in Crore)	Total Cost (Rs in Crore)	Unit Cost (Rs per Sqm)
Faculty and Staff Housing (G+2)	Confined Masonry	49270	42.5	8626	127	25776*
Hostels (G+3)	Confined Masonry	35943	32.0	8903	79	21979*
Academic Building (G+2)	RC Frame with Masonry infill	45200	71.0	15708	192	42478*

(Source: Document published by IIT Gandhinagar regarding Confined Masonry for Residential Building for campus at IITGN)

* The cost shown in the table above is all inclusive i.e., building+MEP services including HVAC & passive cooling system and ELV system in the building and development of its appurtenant land. However, it doesn't include campus level development works like main roads ,trunk sewer ,water and drainage lines, water and sewerage treatment plants, electric substation and cost of electric , water and PNG supply lines to the campus.

Conclusion:

Confined masonry buildings have performed well in several earthquakes worldwide. This construction practice is widely used in many countries and regions for the following reasons:

- It is based on traditional masonry construction practice.

- It does not require highly qualified labor (as is the case with RC frame construction).
- Confined masonry technology falls in between that of unreinforced masonry and RC frame construction; however, due to its smaller member sizes and the lesser amount of reinforcement it is more cost-effective than RC frame construction.
- It has a broad range of applications, that is, it can be used for single-family houses as well as for medium-rise apartment buildings.
- Confined masonry construction is more expensive than unreinforced masonry construction and requires somewhat higher level of labor skills, however its earthquake performance is significantly better than unreinforced masonry construction;
- Confined masonry construction has a great potential for saving lives and property in areas of high seismic risk around the world
- Confined Masonry reduces brittleness of masonry during EQ loads.
- There is need for publishing separate IS Code for confined Masonry.
- Form work for pouring concrete in tie beam and columns in confined masonry is a big challenge to get bulging free concrete.

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  IS: 1905 (2002) Indian Standard - Code of Practice for Structural Use of Unreinforced Masonry. Bureau of Indian Standards, New Delhi, India.

CONFINED MASONRY

Manu Mittal, Project Manager, IIT Gandhinagar Project
Ajay Kumar Agrawal, Chief Engineer, WZ-IV, Gandhinagar

Abstract:

Load bearing masonry construction was most widely used form of construction for large number of buildings during 17th Century to the mid19th century. However, somehow this traditional technology lost its relevance against the other technologies, particularly RCC frame construction. This technology is still being used in construction of small residential buildings. The load bearing masonry, if confined with tie beam and tie columns, may greatly enhance the earthquake resistance capacity of the structures. Construction of buildings with confined masonry load bearing walls has been in practice in many parts of the world in high earthquake risk zones also.

Confined masonry offers an alternative to both unreinforced masonry and RC frame construction for applications in earthquake prone areas of the country. A transition from RC framed construction to confined masonry construction in most cases leads to savings in concrete and steel and with less intricate reinforcement detailing. Improved seismic performance will be achieved by use of reduced amount of materials and labour, typically associated with RC framed construction.

Introduction

Confined masonry construction is emerging as a building construction technology that has features of both,unreinforced masonry and RC frame construction and offers an alternative to these technologies. Confined masonry construction consists of masonry walls (made either of clay brick or concrete block units) and confined with horizontal and vertical RC confining members built on all four sides of wall panel. Vertical members, called tie-columns, resemble columns in RC frame construction except that they tend to be of considerably smaller cross-section. Horizontal elements, called tie-beams, resemble beams in RC frame construction. In order to clearly distinguish that confining elements are not beams and columns, alternative terms i.e. horizontal ties and vertical ties could be used instead of tie-beams and tie-columns.

The confining members are effective in

- Enhancing the stability and integrity of masonry walls for in-plane and out-of-plane earthquake loads (confining members can effectively contain damaged masonry walls),

- Enhancing the strength (resistance) of masonry walls under lateral earthquake loads, and
- Reducing the brittleness of masonry walls under earthquake loads and hence improving their earthquake performance.

The structural components of a confined masonry building are (see Figure 1):

- **Masonry walls –** transmit the gravity load from the slab(s) above down to the foundation. Walls act as bracing panels, which resist horizontal earthquake forces. Walls must be confined by concrete tie-beams and tie-columns to ensure satisfactory earthquake performance.
- **Confining elements (tie-columns and tie-beams) –** provide restraint to masonry walls and protect them from complete disintegration even in major earthquakes. These elements resist gravity loads and have important role in ensuring vertical stability of a building in an earthquake.
- **Floor and roof slabs –** transmit both gravity and lateral loads to the walls. In an earthquake situation, slabs behave like horizontal beams and are called diaphragms.
- **Plinth band –** transmits the load from walls down to the foundation. It also protects the ground floor walls from excessive settlement in soft soil conditions.
- **Foundation –** transmits the loads from the structure to the ground.

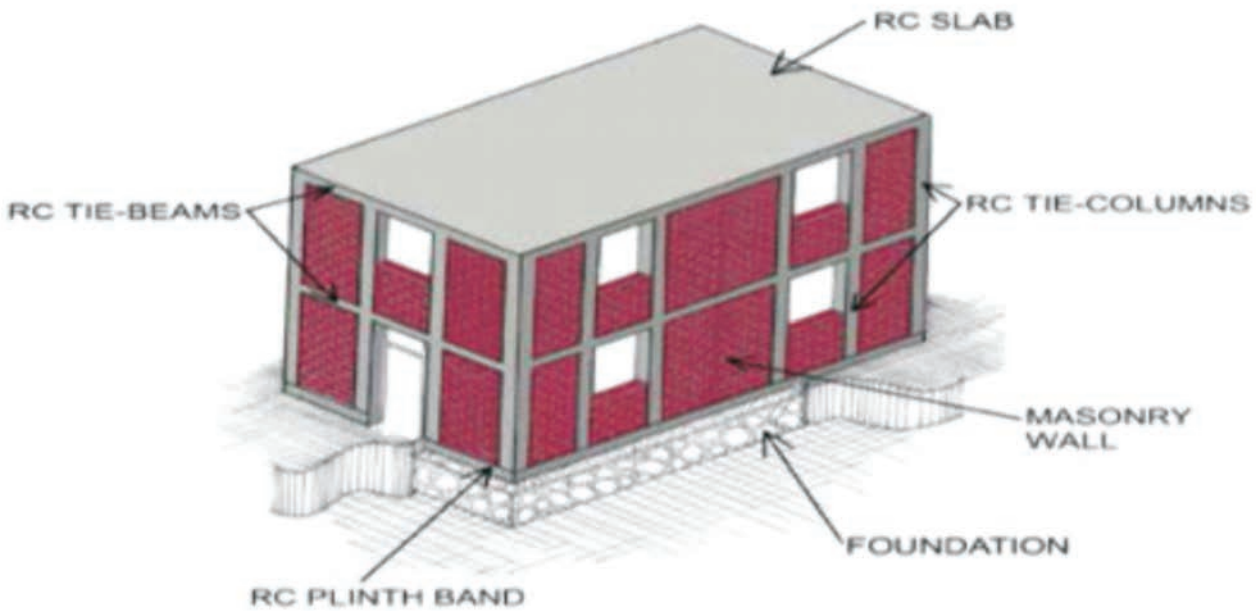


Figure-1: A typical confined masonry building

Comparison between Confined Masonry and RC Frame Construction

The appearance of a finished confined masonry construction and a RC frame construction with masonry infills may look alike, however these two construction systems are substantially different. The main differences are related to the construction sequence, as well as to the manner in which these structures resist gravity and lateral loads. These differences are summarized in Table 1 and are illustrated by diagrams in Figure 2.

Table 1. A comparison between the confined masonry and RC frame construction

	Confined masonry construction	RC frame construction
Gravity and lateral load resisting system	Masonry walls are the main load bearing elements and are expected to resist both gravity and lateral loads. Confining elements (horizontal and vertical ties) are significantly smaller in size than RC beams and columns	RC frames resist both gravity and lateral loads through their relatively large beams, columns and their connections. Masonry infills are not load bearing element.
Foundation Construction	Strip footing beneath wall and RC plinth band.	Isolated footing beneath each column.
Superstructure construction sequence	1. Masonry walls are constructed first. 2. Vertical ties are cast in place. 3. Finally, the horizontal ties are constructed on top of the walls, simultaneously with the floor/roof slab.	1. The frame is constructed first. 2.Masonry walls are constructed at a later stage and are not bonded to the frame members. These walls are non-structural, i.e. non-load bearing walls.

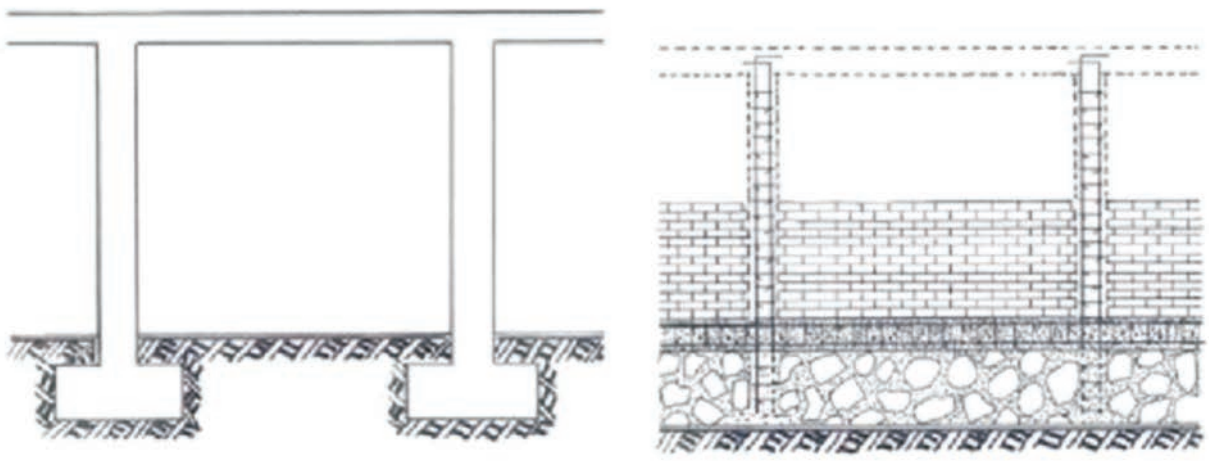


Figure 2. RC frame construction (left) and confined masonry construction (Right)

In confined masonry construction, confining elements are not designed to act as a moment-resisting frame; as a result, detailing of reinforcement is simple. In general, confining elements have smaller cross-sectional dimensions than the corresponding beams and columns in a RC frame building. It should be noted that the most important difference between the confined masonry walls and infill walls is that infill walls are not load-bearing walls, while the walls in a confined masonry building are.

Worldwide Applications

Confined masonry construction has evolved though an informal process based on its satisfactory performance in past earthquakes. The first reported use of confined masonry construction was in the reconstruction of buildings destroyed by the 1908 Messina, Italy earthquake (Magnitude 7.2). The practice of confined masonry construction started in Chile in 1930's after the 1928 Talca earthquake (Magnitude 8.0) that affected a significant number of unreinforced masonry buildings. Subsequently, the 1939 earthquake (Magnitude 7.8) that struck the mid-southern region of the country, revealed very good performance of confined masonry buildings (Moroni et al., 2004). Confined masonry construction was introduced in Mexico City, Mexico in 1940's to control wall cracking caused by large differential settlements under the soft soil conditions. Several years later, this system became popular in other areas of highest seismic hazard in Mexico due to its excellent earthquake performance (Meli and Alcocer, 2004). The use of confined masonry in Colombia dates from the 1930's and it is currently widely used for housing construction, from single-storey dwellings to fivestorey apartment buildings (Garcia and Yamin, 1994).

In one of a major shift in the building construction practices in India, hostel buildings for the students and residential apartments for the faculty and staff of IIT Gandhinagar, have been constructed in first phase with confined masonry with FALG brick units. Six blocks of hostel building in four storey vertical configuration (Plinth area 36000 Sqm) and three storied 30 blocks ofresidential apartment (270 Nos Plinth area 49000 sqm) have been constructed with confined masonry. Further, new buildings ofhostels and residential apartments in the second phase are also under construction with confined masonry.

Three storied residential buildings and four storied hostel buildings at IIT Gandhinagar have been designed based on the EERI literature and Mexican codes as no Indian Standard is available on confined masonry constructions. All the masonry below plinth level is with burnt clay bricks with minimum strength of 5 MPa and maximum water absorption of 15%. All the masonry above plinth level is with fly ash (FALG) bricks with minimum strength of 9 MPa and maximum water absorption of 20%. Typical details of vertical and horizontal tie in confined masonryare shown in Figure-3. Typical cross sections of the wall foundations adopted are

shown in Figure-4.

Building Height Limitation

1. Confined masonry is suitable for low- to medium-rise building construction. Eurocode 8 (1996) prescribes the following building height restrictions for simple confined masonry buildings:

a. Up to 4-storey high for a site with design ground acceleration up to 0.2 g (corresponding to seismic zone III of India)

b. Up to 3-storey high for a site with design ground acceleration up to 0.3 g (corresponding to seismic zone IV of India)

c. Up to 2-storey high for a site with design ground acceleration up to 0.4 g (corresponding to seismic zone V of India)

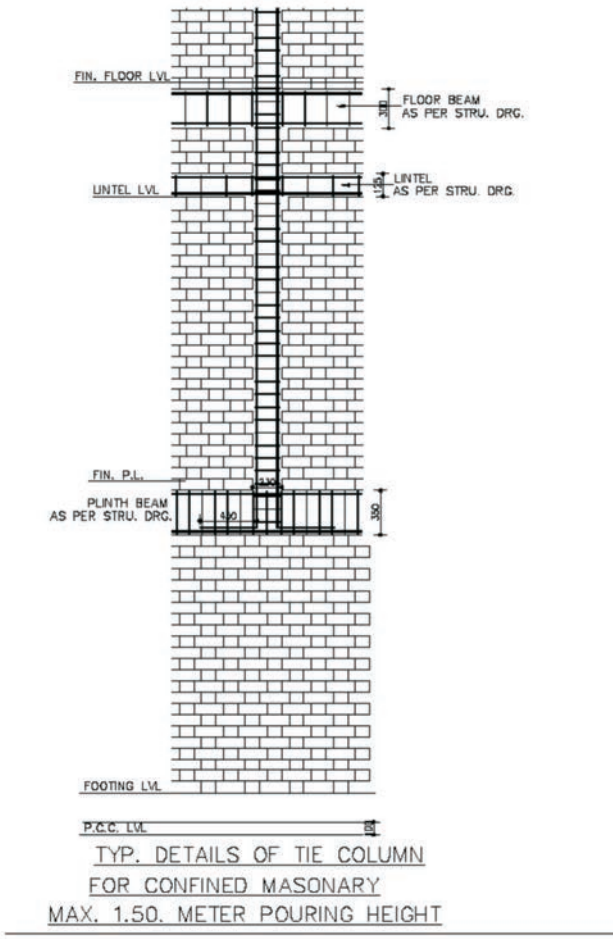


Figure-3: Typical details of tie columns for confined masonryfor three storey residential

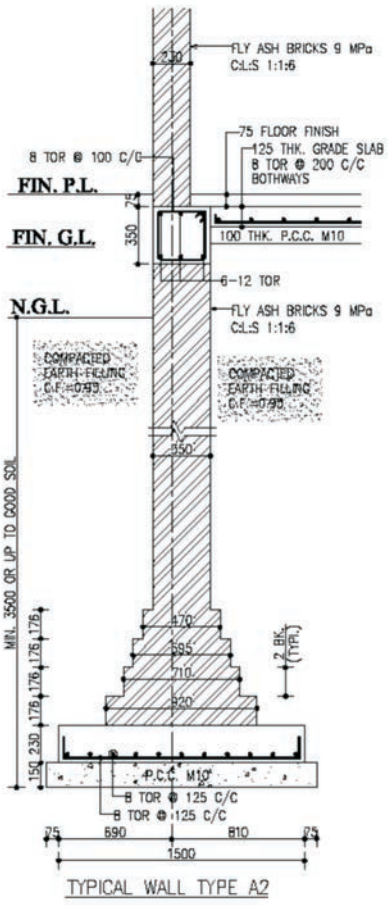


Figure -4: Typical wall foundations adopted for three storey residential buildingbuilding

How Confined Masonry Buildings Resist Earthquake Effects

1. A confined masonry building subjected to earthquake ground shaking can be modelled as a vertical truss as shown in Figure-5 (left). Masonry walls act as diagonal struts subjected to compression, while reinforced concrete confining members act in tension and/or in compression, depending on the direction of the lateral forces. This model is appropriate before the cracking in the walls take place. Subsequently, the cracking is concentrated at the ground floor level and significant lateral deformation take place. Under severe earthquake ground shaking, collapse of confined masonry building maytakeplacedue tosoftstoreyeffectsimilartotheoneobservedinRCframeswithmasonryinfills,asshowninFigure -5(right).

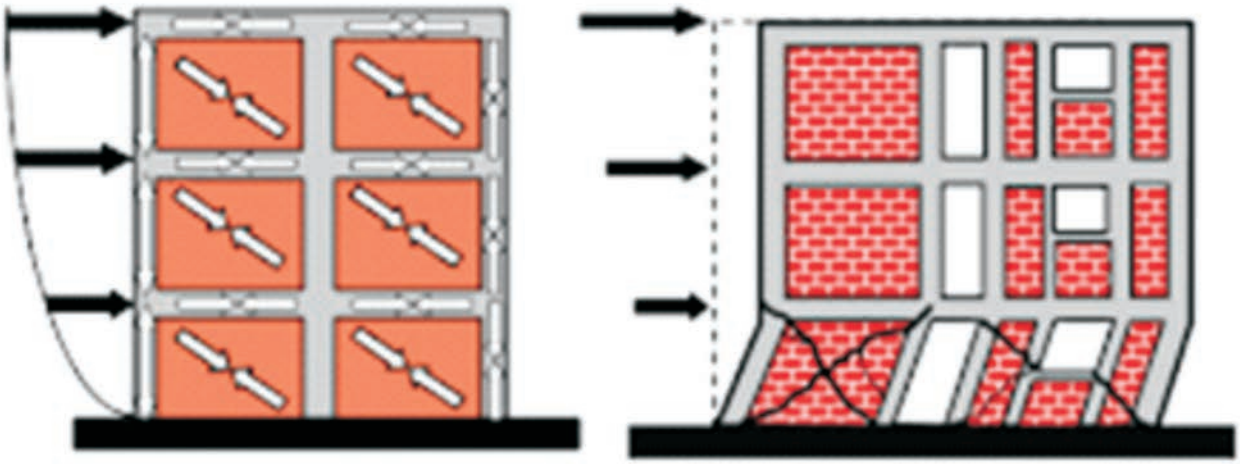


Figure-5: Confinedmasonrybuilding:verticaltrussmodel (left)andcollapseatthegroundfloorlevel(right)

Research studies that focused on later alload resistance of confined masonry walls identified the following failure modes characteristic of confined masonry walls:

- Shear failure mode, and
- Flex ural failure mode,

In confined masonry structures, shear failure mode develops due to in-planese is micloads (acting along in the plane of the wall), where as flexural failure mode may develop either due to in-plane or out-of-planeloads(acting perpendicular to the wall plane),

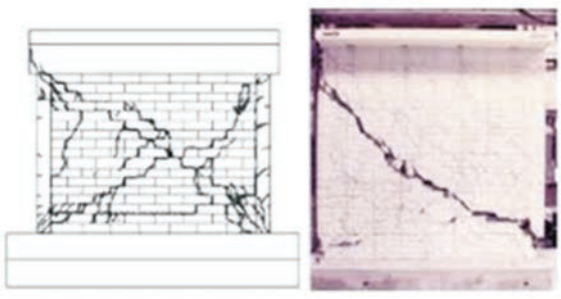




Figure-5 (Contd): Shear failure of confined masonry walls

2. Shear failure mode is characterized by distributed diagonal cracking in the wall. The sec racks propagate into the tie-columns at higher load levels, as shown in Figure 5. Initially, a masonry wall panel resists the effect so flateral earthquake loads by itself while the confining elements (tie-columns) do not play a significant role. However, once the cracking takes place, the wall pushes the tie-columns sideways. At that stage, vertical reinforcement in tie-columns become sengaged in resisting tension and compression stresses. Damage in the tie-column sat the ultimate load level is concentrated at the top and the bottom of the panel. These locations, characterized by extensive crushing of concrete and yielding of steel

reinforcement, are called plastic hinges (see Figure-6). Note that the term plastic hinge has a different meaning in the context of confined masonry components than that referred to in relation to RC beams and columns, where the sehinges form due to flexure and axial loads. In confined masonry construction ,tie-beams and tie-columns resist axial loads. Shear failure can lead to severe damage in the masonry wall and the to pand bottom of the tie-columns.

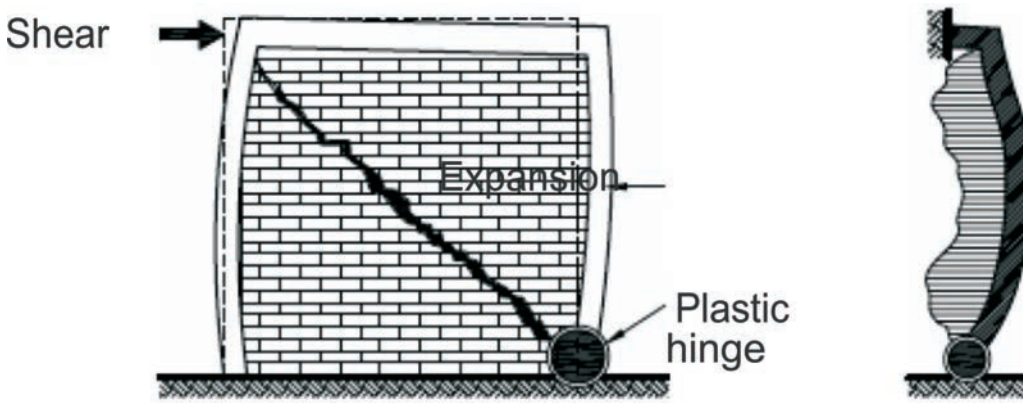


Figure-6: Plastic hinge developed in a confined masonry wall

3. Flexural failure caused by in-planel ateral loads is characterized by horizontal cracking in the mortar bed joints on the tension side of the wall, as shown in Figure-7.Separationoftie-columns from the wall was observed in some cases(when toothed wall-to-column connection was absent).Extensive horizontal cracking, which usually takes place in tie columns, as well as shear cracking can be observed

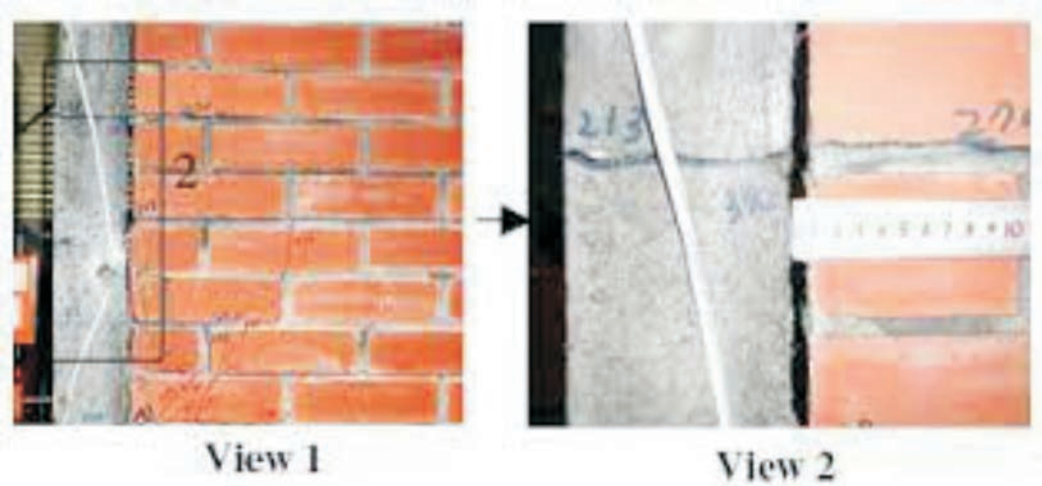


Figure-7:Flexural failure of confined masonry walls

Experimental studies have shown that, irrespective of the failure mechanism, tie-columns resist them a jorportion of gravity load when masonry walls suffers evere damage (this is due to their high axial stiffness and load resistance).The failure of atie column usually takes place when cracks pro pagate from the masonry wall into the tie-column and shear it off .Subsequently, the vertical stability of the entire wall is compromised. Experimental studies have shown that vertical strains in the confined masonry walls decrease at an increased damage level, there by indicating that a major portion of the gravity load is resisted by tie-columns. This finding confirms the notion that tie columns have critical role in resisting the gravity load in damaged confined masonry buildings and ensuring their vertical stability.

Key Factors Influencing Seismic Resistance of Confined Masonry Structures

Wall Density

Wall density is believed to be one of the key parameters influencing the seismic performance of confined masonry buildings. It can be determined as the transverse area of walls in each principal direction divided by the total floor area of the building.

Masonry Units and Mortar

Tests have shown that the lateral load resistance of confined masonry walls strongly depends on the strength of the masonry units and the mortar used. The walls built using low-strength bricks or un-grouted hollow block units had the lowest strength while the ones built

using grouted or solid units had the largest strength. However, use of grouted and solid units results in an increase both in wall mass and seismic loads. Also, the weaker the mortar, lower the masonry strength (due to the unit-mortar interaction, masonry strength is always lower than the unit strength).

Tie-Columns

Tie-columns significantly influence the ductility and stability of cracked confined masonry walls. Note that the effect of tie-columns on increasing lateral resistance of confined masonry structures has only recently been recognized. The provision of closely spaced transverse reinforcement (ties) at the top and bottom ends of tie-columns results in improved wall stability and ductility in the post-cracking stage.

Horizontal Wall Reinforcement

In many countries where confined masonry construction is practiced, reinforcement is usually not provided in masonry walls. However, in four-to-five storey construction in Peru there is a tendency to provide horizontal joint reinforcement in the form of one or two wires laid in the mortar bed joints, as shown in Figure 8. The Mexican Code NTC-M 2004 prescribes that the horizontal reinforcement, when provided, be placed continuously along the wall length. Horizontal rebars should be anchored into the tie-columns. The hooks should be embedded in the concrete within the tie-column (note that the tie-column reinforcement was omitted from the figure).

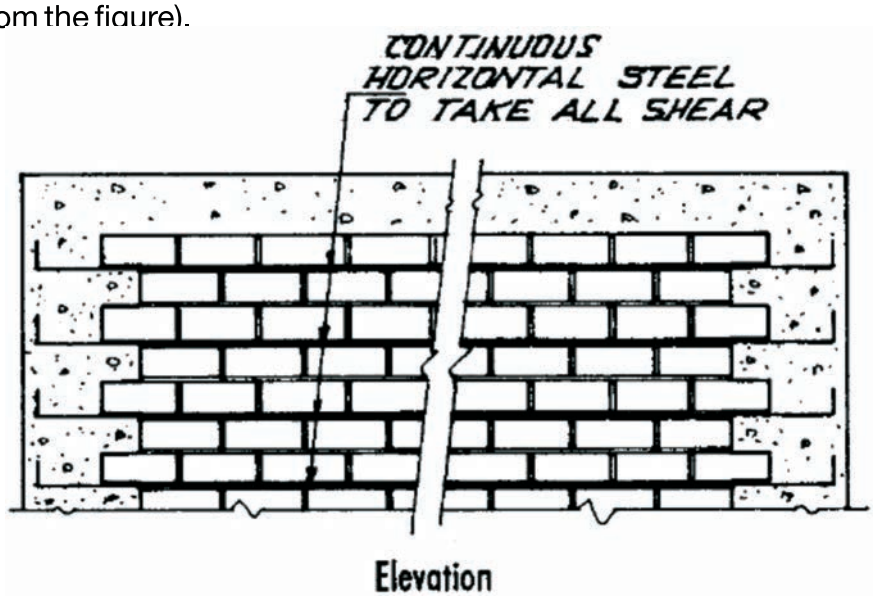


Figure-8: Horizontal reinforcement in confined masonry wall;

Openings

An experimental research study showed that, when the opening area is less than

approximately 10% of the total wall area, lateral load resistance of the wall is not significantly reduced as compared to a solid wall (i.e. wall without openings) (Yanez et al. 2004). The walls with larger openings develop diagonal cracks (same as solid walls), except that the cracks are formed in the piers between the openings; thus, diagonal struts form in the piers, as shown in Figure 9.

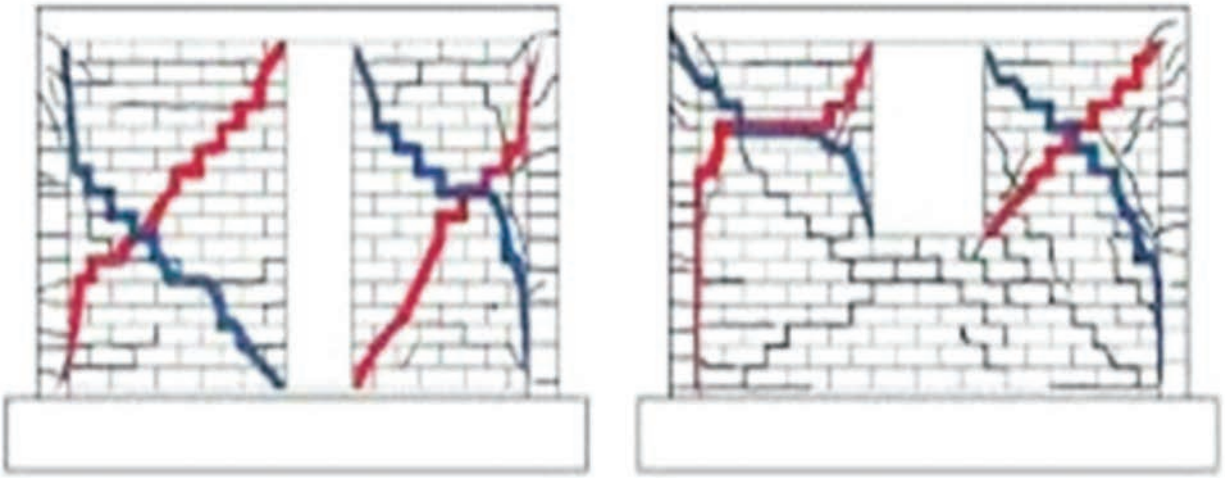


Figure-9. Failure mode in the confined masonry walls with openings



Unconfined Opening Confined Opening

Figure-9(contd). Failure mode in the confined masonry walls with openings

On successful completion of buildings of Faculty residential units and Hostels with confined masonry at IIT Gandhinagar, new three storied buildings of residential units and four storied hostel buildings under the present phase of works at IIT Gandhinagar, are under construction

with confined masonry.



Figure-10: Residential and hostel buildings under construction at IIT Gandhinagar, Palaj

A comparative study for consumption of cement concrete and steelmade for a three storied residential block constructed in confined masonry viz-a-viz in R C frame structure is shown in Table 2.

Table-2 A comparison of concrete and steel consumption for a three storied Building:

	Description of Item	**RC Frame Construction**	**Confined Masonry Construction**	**% Reduction**
	Concrete (In Cum)			
1	(a) Below Plinth	*416*	*207*	
	(b) Above Plinth	*776*	*603*	
	Total	**1192**	**810**	**32 %**
2	**Reinforcement Steel (In Kg)**			
	(a) Below Plinth	*20950*	*11845*	
	(b) Above Plinth	*117900*	*79290*	
	Total	**138850**	**91135**	**34.36 %**
3	Brick Work	610	681	

Considering 35% Component of RCC & TMT in the overall building cost (based on frame structure) the approximate saving in structure based on confined masonry, works out to 35@0.33= 11.55%(say 10 to 12%)



Figure-11:Completed student hostel Buildings of Hostels and faculty residential apartments constructed with confined masonryin first phase at IIT Gandhinagar

Conclusion

Confined masonry buildings have performed well in several earthquakes worldwide. This construction practice is widely used in many countries and regions. This technology falls in between that of unreinforced masonry and RC frame construction, however due to its smaller member sizes and the larger amount of reinforcement it is more cost-effective than concrete construction. There are several advantages are associated with confined masonry construction e.g. saving in consumption of Cement and reinforcement steel, smaller number of skilled manpower required in comparison to RC frame construction, it is based on traditional construction practices are few to quote. However, there are challenges also associated with confined masonry construction e.g. suitability up to G+3 structures, slow speed of construction, not suitable for areas surrounding staircases, lower strength and ductility compared to properly built ductile RC frame construction, may require larger wall area in comparison to RC frame construction with masonry infills.Confined masonry construction has a great potential for saving lives and property in areas of high seismic risk in India. However, like any other construction practice, good earthquake performance is based on use of good quality materials, good quality concrete and masonry constructionand simple architectural design.

Confined masonry has been adopted as new and emerging technologies in CPWD and approved to be adopted for all projects of CPWD across the country irrespective of location and project cost, vide O.M no 133/SE(TAS)/DSR/2018-19/519 Dated 16/11/18 the

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PRECAST CONCRETE PAVEMENTS – A SMART SOLUTION FOR INDIAN ROADS

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Abstract:

The main obstruction in construction and rehabilitation of rigid pavements is the prolonged lane closure which causes serious hindrance to the moving traffic. Prefabrication of concrete slabs off-site and assembling at project site offers major time and user cost savings in comparison with the conventional cast-in-place concrete pavements. Precast concrete pavement technology is a ground-breaking process that can meet the existing demand for short working windows at high-density urban areas and a sustainable pavement solution for adverse climatic conditions and urgent military operations. Precast concrete pavements, with a high-quality control, are tailor-made at the industry, transported and safely installed at project site over a prepared base. It has an extended service life and requires minimal maintenance. This paper reviews the applications and developments of precast concrete pavements in the recent past and summarizes the potential information to boost the successful employment of prestressed precast pavements in India.

Keywords: Precast Pavements; short working windows;intermittent repairs; high durable; prestressed precast pavements;

Inroduction

Rehabilitation and reconstruction of pavements are major activities for government and private highway agencies. These activities have significant impact on government resources and are a source of traffic disruptions caused by extensive and extended lane closures. In recent years, many countries have started investigating strategies for pavement rehabilitation and reconstruction that are faster and to produce durable pavements. Conventional rehabilitation techniques that results in a shorter pavement lifespan is no longer considered acceptable by most highway agencies. A promising alternative rehabilitation technique is the effective use of precast concrete panels, principally precast concrete pavement (PCP) systems, which provide for rapid repair and rehabilitation of pavements and also result in durable, longer-lasting pavements. The fast construction techniques can considerably minimize the impact on the driving public, as lane closures and traffic congestion are kept to a minimum. Road users and worker safety is also improved by reducing road users and workers exposure to construction traffic.

Precast concrete is an alternative solution to cast- in-place concrete. Precast concrete technique is a well-established, widely practised and economical solution which proved its efficiency as a structural member. It is successfully used in beams, columns, piles, box culverts and many other structural systems like buildings and bridges. The merits of precasting includes high degree of quality control, economical mass production and faster rate of construction. Precast concrete panels are advantageous repair method for extending the service life of distressed concrete pavement. Precast prestressed concrete pavements offer dramatic increase in durability, while it also significantly decreases the construction time and the user costs.

Background

A generic definition of a precast concrete pavement system is given as, "Precast pavement systems are fabricated or assembled off-site, transported to the project site and installed on a prepared foundation (existing pavement or regraded foundation). The system components require minimal field curing or time to achieve strength before opening to traffic.

Better quality concrete, better concrete curing conditions, minimal weather restrictions on placement, reduced delay before opening to traffic and elimination of construction related early age failures are the specific advantages of using precast concrete pavements versus cast-in-place concrete pavements.

Over the last 10 years, several countries have begun to implement the precast concrete pavement technology, and a few others have constructed demonstration projects. The implemented precast concrete pavement systems include proprietary as well as non-proprietary systems. The precast concrete pavements systems are used in highway corridors with high traffic volume and where lane closures are a challenge. For production use, the precast concrete pavements work is performed during the night and with short closures, typically from about 8 p.m. to about 6 a.m. The production rate per lane closure is about 15 to 20 repair locations and about 122 to 183 m lengthwise for continuous rehabilitation. The key issues of concern for precast concrete pavements are constructability, concrete durability, and pavement performance as primarily affected by joint load transfer and panel support condition.

Precast Pavement Applications

PCP technology can be used for projects of different sizes, as given below.

1. Localized repair of distressed areas of existing jointed concrete pavements (JCPs).

2. Rehabilitation of short lengths of distressed concrete pavements.

3. Rehabilitation of longer lengths of existing distressed concrete or asphalt pavements.

4. Because of this versatility, precast concrete pavements systems are often used in the rehabilitation of special pavement facilities, such as toll plazas, intersections, freeway ramps, bridge approach slabs, and tunnels. In addition, precast concrete pavements systems can be used for new construction where new roadways cross the paths of existing high-volume roadways.

The application of precast concrete pavement technology can be classified as intermittent repairs and continuous applications

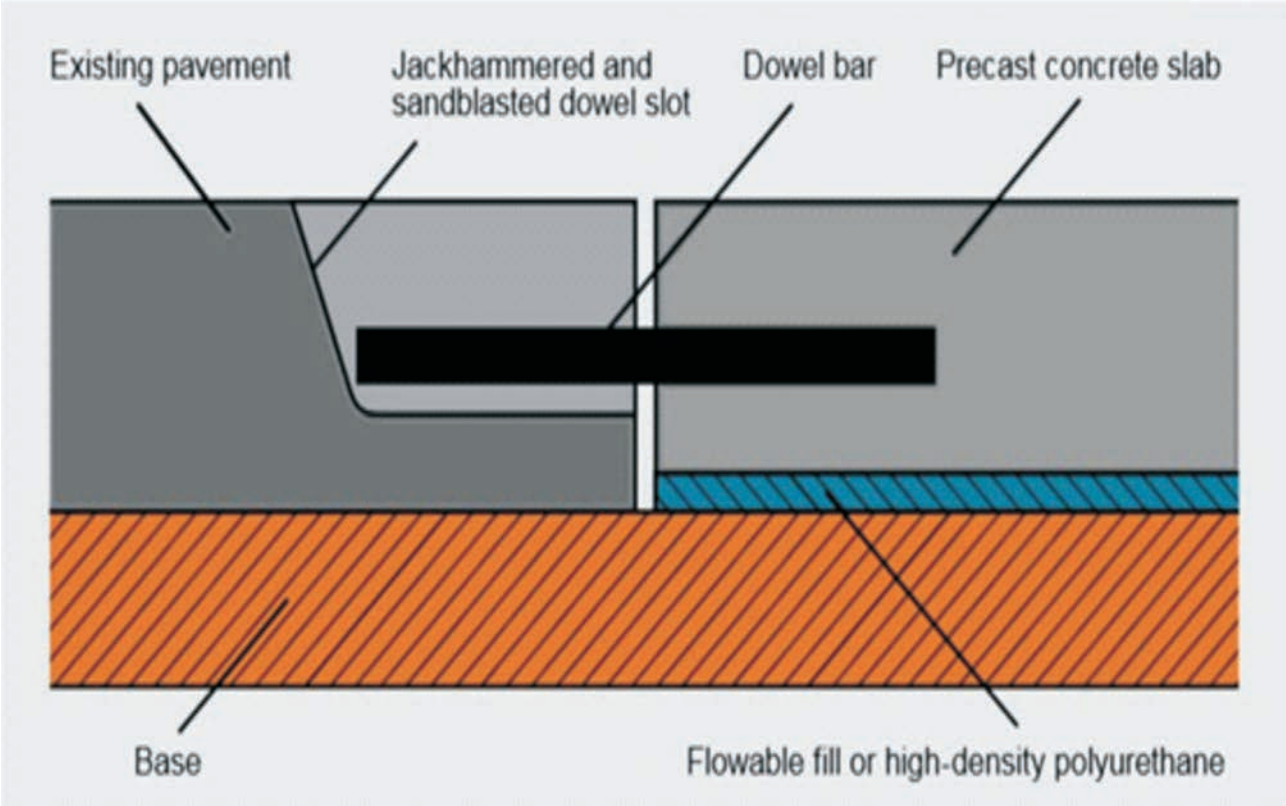


Figure 1. Intermittent repairs(Note: Dowel bar caps should be used)

From Figure 1, usage of precast panels in intermittent repairs can be clearly seen. (Image Source: Shriaz et all, 2013). The dowel bars are embedded in the precast panel, and slots for dowel bars are cut in the existing concrete pavement, similar to the dowel bar retrofit (DBR) method, as illustrated in Figure 2. The dowel slots are then filled with fast-setting patching material. In a variation of this method, no dowel bars are embedded in the precast panel and dowel bars are installed after panel installation using the DBR technique, as shown in Figure 3.

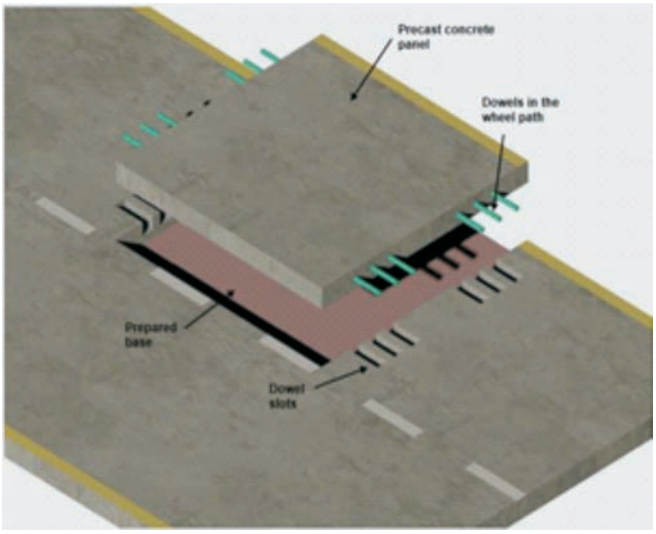


Figure 2. Precast panel with embedded dowel



Figure 3. Precast panel without dowel

In another scheme for intermittent repairs, the dowel bars are positioned in the existing concrete pavement by drilling and epoxy grouting, similar to cast-in-place concrete full-depth repairs or full-slab repairs, and the slots for the dowel bars are fabricated in the repair panels along the bottom of the transverse sides (Figure. 4). The slots and the joint perimeter gap are then filled with fast-setting grout.

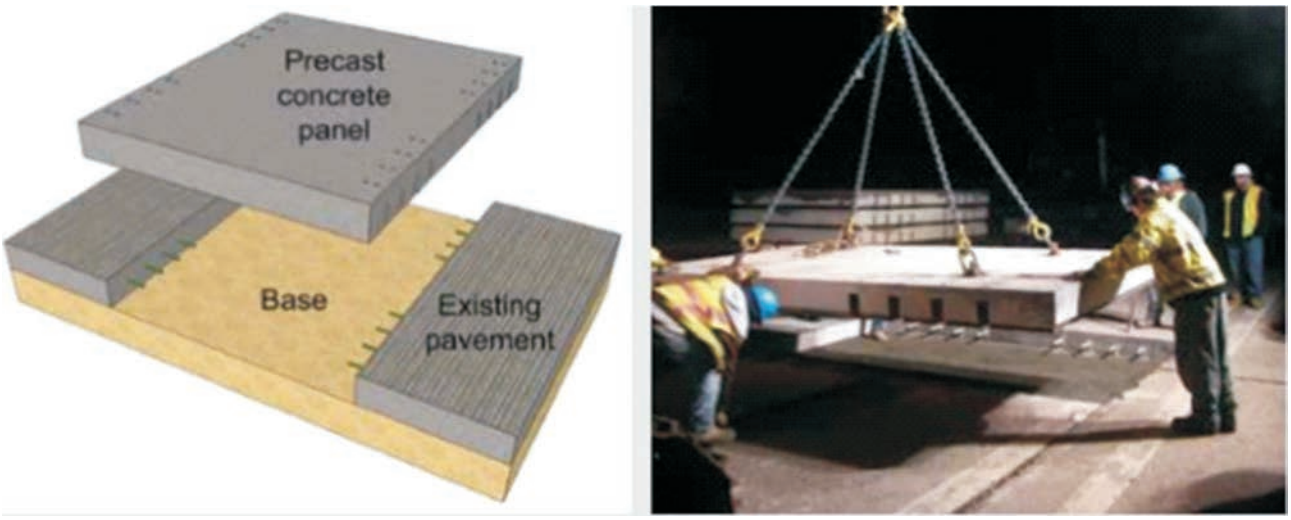


Figure 4. Intermittent repair- Precast panel with slots for dowels at bottom

* Under continuous application approach, full-scale project-level rehabilitation (reconstruction or overlay application) of bituminous and concrete pavements is performed using precast concrete panels. Three categories of continuous application are described below,

- Jointed precast concrete pavements: Jointed precast concrete pavements are similar to cast-in-place jointed concrete pavements. Once installed, jointed precast concrete pavements behave similarly to cast-in-place jointed concrete pavements. Jointed precast concrete pavements incorporatesteel reinforcement for load transfer at transverse joints. Jointed precast concrete pavements use round dowel bars, typically steel bars, for load transfer. Figure 5 shows one scheme thatis used to affect the load transfer, similar in concept to the system in Figure. 4 for intermittent repairs. Under this scheme, one side of the panel has slots along the bottom to accommodate the dowel bars, and the other side has embedded dowel bars at locations that match the slot locations. After installation, the slots and the joint perimeter gap are filled with fast-setting grout. A simpler scheme using a dowel bar retrofit can also be used for jointed precast concrete.



Figure 5. Jointed precast concrete pavements with dowel slots at bottom

- Precast, prestressed concrete pavements: Precast, prestressed concrete pavements simulate cast-in-place posttensioned concrete pavements. These systems incorporate longer posttensioned sections and expansion joints between sections. The posttensioned sections are formed by posttensioning together a series of panels. The individual panel width may be single-lane or multiple lane, and panel length can vary from 2.4 to 3 m for multilane panels to 9 m or more for single lane panels.

Case study example: Three types of precast, prestressed concrete pavement systems have been developed in US.

In the original version, used in the first precast concrete pavement project in Texas, base, central stressing, and expansion joint panels were used:

- Base panels: the majority of the connected (posttensioned) panels.

- Central stressing panels: to apply posttensioning from the midportion of the connected panels using slots prefabricated in the panels.
- Expansion joint panels: one at each end of the posttensioned sections. These panels include dowel bars for load transfer and provisions for joint sealing.

In the second version of the precast, prestressed concrete pavement system, used on the Delaware, Missouri, and Virginia projects, only base and expansion joint panels were used:

- Base panels: the majority of the connected (posttensioned) panels.
- Expansion joint panels: one at each end of the posttensioned sections. These panels include dowel bars for load transfer, provisions for joint sealing, and provisions for applying posttensioning using slots prefabricated in the panels.

In a third version of the precast, prestressed concrete pavement system, which was used on Interstate 680 in California, base, end joint, and expansion joint gap panels were used:

- Base panels: the majority of the connected (posttensioned) panels.
- End joint panels: one at each end of the posttensioned sections. These panels include dowel bars for load transfer, provisions for joint sealing, and provisions for applying posttensioning from the face of the panel using anchorage system pockets prefabricated in the end panels.
- Expansion joint gap panels: one expansion joint gap panel, about 4 ft (1.2 m) long, to fill the gap between adjacent panels to accommodate the posttensioning. For new construction where lane closure is not a concern, the gap panel may be cast in place. The gap panel includes provisions for dowel bars for load transfer and for joint sealing.

- **Incrementally connected precast concrete pavements:** Incrementally connected precast concrete pavements simulate jointed reinforced concrete pavement with hinged joints and incorporate panels of varying lengths, typically 15 to 30 ft (4.5 to 9 m), which are connected to achieve a continuous section length of 60 to 100 ft. (18 to 30 m). The panels are connected using deformed dowel bars that lock the joint and also provide the required load transfer. A narrow expansion joint is provided between connected panels.

The advantages of incrementally connected precast concrete pavement are fewer active joints and narrower expansion joints. Both nominally reinforced and prestressed concrete panels can be considered for use. The prestressed concrete panels allow use of thinner

panels but require good support similar to that needed for precast, prestressed concrete pavements.

4. Performance Evaluation Of Precast Concrete Pavement Systems

Only a limited amount of field monitoring has been conducted by highway agencies. The actual field testing indicated that once installed, precast concrete pavements behave similarly to cast-in-place concrete pavements. In terms of the structural behaviour and the performance of the listed PCP systems, load transfer between adjacent panels represents a crucial aspect. Concrete spalling and cracking were observed at systems using precast concrete panels with slots at the top surface. Moreover, systems with locked joints inserts enable only a limited in-plane movement of a slab and as a consequence stress concentrated at interlocking system result in crushing of the concrete in the joint area under significant temperature changes. Their wider utilization is limited by production costs which areestimated 1.6 to 4 times higher than the cast-in-place repair methods. On the contrary, cost savings associated with shorter time required for repairs and traffic restrictions increase significantly when PCP systems used and consequently slightly compensate the high production costs.

5. Conclusion

This paper presents an overview of precast concrete pavement technology as it is practiced across the globe. The paper also addresses some technical considerations related to the design of precast concrete pavements. The load transfer provision at transverse joints and the support condition under the precast concrete panels are two critical design features and must be properly addressed for any precast concrete pavement. Precast concrete pavement technology is maturing and continues to evolve. It is expected that innovations in this technology will ensure a permanent place for the application of the precast concrete pavement technology for durable, rapid repair and rehabilitation of existing pavements and will help reduce the cost of panel fabrication and installation. Hence developing nations should start implementing the technology supported with fundamental research.

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A SUSTAINABLE APPROACH TO FLOOD DAMAGE REPAIR OF HILL ROADS IN TRIPURA USING SOIL FILLED GABIONS – A CASE STUDY

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Abstract:

Use of rock fill wire mesh gabion retaining and breast walls are gaining popularity due to their ease of construction, better structural performance, better dissipation of pore water build up and quality control of components. In this study, rock fill is substituted in some part of the wall with soil fill from landslide debris. It obviates the need for rock mining, brick, cement, sand and other construction materials and also reclaims the landslide debris. It is a sustainable innovation which can be of immense use, especially in the north eastern parts of the country which encounters large number of small landslides which jeopardize connectivity in these strategically important parts of the country.

Keywords : Gabion, geotextile, landslide, flood damage, sustainable, soft rock

Introduction

The Indo-Bangladesh Border states of West Bengal, Assam, Meghalaya, Mizoram and Tripura have high rainfall and silty soil of the Indo Gangetic and Brahmaputra plains. This leads to considerable flood damage to the road embankments in this region during the monsoon season. It is therefore a challenge to maintain connectivity of the roads, especially those along the international borders which are strategically important and have been built over the years with considerable investment. Some of the states among these also have the additional drawback that there is a dearth of stones/rocks which makes use of rubble masonry and gabion structures expensive. Therefore, it is desirable to look for technological innovation to improvise the situation by adopting usage of locally available marginal fills.

Flood damage repairs in the North-Eastern states mainly require construction of breast walls / retaining walls where there are small landslides, reconstruction of washed away road embankments, culverts and construction / renovation of roadside drains. Out of these, the construction of retaining walls is the most time consuming and costly affair. In the far flung areas of the North-Eastern states, retaining walls are usually constructed with random rubble masonry, except in the state of Tripura, where stones are not naturally available and conventional retaining walls are made of bricks. This case study deals with the construction of soil filled gabions in the state of Tripura. However, similar situations are encountered in many other locations of the N-E states.

Tripura - Climate And Topography

Tripura has a tropical climate with hot and humid summers. It is surrounded on the north, west, and south by Bangladesh. The average annual rainfall of the state is 2100 mm. The maximum summer temperature is around 35°C and minimum winter temperature is around 10°C. The terrain is plain in the northern parts and hilly in the central and southern parts. The dominant soil types available in Tripura are the red loamy soil, reddish yellow sandy soil and silty alluvial soil. Soil structure is granular and susceptible to erosion. There is heavy soil erosion due to high rainfall as well as reducing forest cover. Tripura has about 839 kms. of international border with Bangladesh (Ref. 6). The Indo Bangladesh Border roads pass through the districts of North Tripura, Dhalai, West Tripura and South Tripura.



Plate 1 : Extensive damage to IBB road in Tripura – The soil has been totally eroded and rain water has made deep channels on the road side



Plate 2 : Extensive damage to IBB road in Tripura – The surface runoff on the road has washed away the berm – requires retaining wall to prevent further damage

Mitigation And Repair Of Flood Damage - Existing Practices

The hills of Tripura are largely devoid of rocks and consist of soil with forest cover. They are prone to rain cuts and often lead to road sub grade damage. It seriously affects the connectivity of border roads and also causes silting and blockage of rivers /streams. The following practices are normally adopted for mitigating such flood damage during the rainy season.

a) Brick masonry gravity retaining walls

The usual practice in the states with low supply of rocks is to go for burnt clay brick masonry gravity retaining walls and breast walls. Drainage of water is achieved by providing sufficient

number of weep holes in the wall. The base width is kept as 0.6 to 0.7 times the height and the structure checked for sliding and overturning. The locally available soil itself is used as backfill. A layer of 150-200 mm thick lean concrete is provided below the retaining wall. The wall is generally constructed in cement mortar 1:6 (1 Cement: 6 coarse sand).

b) Bamboo Piling with bamboo mat backing :

The use of closely driven bamboo piles with split bamboo mats has been a traditional practice in the North Eastern states in India for retaining earth for making bunds, diverting river water, etc. The bamboo piles of 65 to 80 mm diameter and 3 to 4 m. in length are driven into the ground at close spacing up to around half their length to make a wall. These are then tied together by horizontal half split bamboo runners, 65 to 75 mm diameter inside and outside, to maintain alignment. Inclined stays are provided at 1 m. intervals with bamboo of same size as used for piling. A mat made of 50 mm wide bamboo strips is placed behind the bamboo piles and tied to the walling with binding wire to keep in place and earth filled and compacted behind the mat (see sketch below).

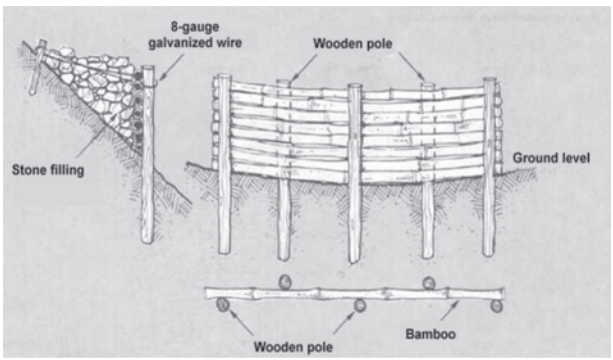






Plate 3 : Damaged old retaining wall – There are many such locations where walls constructed in RR masonry have started failing. These need to be rebuilt / extended



Plate 4 : Damage to embankment due to absence of wing walls – temporary bamboo piling to prevent washing away of road.

While this traditional bio-engineering method works well for erosion control in sloped channels (Ref. 8), especially when installed in a series by acting as minor check dams, it suffers through some major drawbacks as a permanent solution to embankment failure repairs owing to disparity in durability of bamboo, especially in hot and humid climate and suffer due to non-engineered approach and non-conforming construction methods. They are destroyed by vermin attack over 2 to 5 years. Also the bamboo piles are often not taken to their full depth as these are hand driven. In addition, the soil behind the piling is lost through the pores in the mat during the rainy season. As a result, the earth filing shows subsidence and requires continual refilling and periodic maintenance. To prevent such loss of soil, it would be appropriate to provide a geotextile as a filtration layer between the bamboo piles and the mat. However, the costing of the textile should be such that it remains economical for a temporary construction designed for a life of five years..

At some locations use of empty bitumen drums and bamboo mat walls for low height retaining walls are also seen, these are very few and cannot be treated as a standard solution to the problem of flood damage repairs to road formations.

Problems with Conventional Brick Masonry Retaining Walls

The following problems are usually encountered while constructing brick masonry gravity structures in remote locations:

The masonry gravity retaining structures are rigid structures that cannot take ground movement.

- These require deeper foundations and base width at bottom is accordingly high.
- Drainage provision in these structures is built in through weep holes which choke up over time and lead to build up of pore water pressure behind the walls.
- The quality of construction materials like bricks, sand and water is inconsistent in far flung areas where day to day supervision is extremely difficult.
- Process Quality control measures like soaking of bricks, removal of broken brick bats, quantity of cement in mortar for brick work and plaster, curing of brick work and plaster, etc. through local labour require continuous supervision.

Use of Gabion Structures With Rock Fill

Retaining wall structures erected by filling stone boulders in wire mesh gabions are a good substitute for masonry or concrete retaining walls. The gabion walls being flexible, are more suited to seismicity and weak foundation soil conditions, etc. and are suitable for heights of

4-6 m. (Ref. 3,4). These are designed as gravity retaining walls. The gabion walls generally have a backing of non-woven geotextile filter that allows water to pass through but retains the soil. The drainage properties of boulder filled gabions with geotextile backing is much superior compared to conventional weep holes with HDPE pipes in masonry retaining walls. Most importantly, it allows in plane drainage within the geotextile and effectively dissipates water pressure buildup in case of local clogging.

The gabions are factory manufactured in accordance with ASTM-A-975-1997 (Re-approved 2016). (Ref. 1) and IS and MoRTH Specifications (Ref. 5,7). These are made of galvanized wire mesh with or without PVC coating. The geotextile is provided as per the requirements of filtration use in accordance with AASHTO-288-05 (Revised 2017).(Ref. 2) and MoRTH Specifications (Ref. 7). The grain size distribution of back fill soil is important for determining the engineering properties of the geotextile.

At locations where the toe of the gabion wall is in wet soil, the toe is stabilized using bamboo or wooden piles (saal balli), which increase the sliding and overturning resistance of the wall.

The design of the gabion walls is done as per standard practice for gravity retaining walls – for sliding and overturning modes of failure. The safe bearing capacity of the soil at the base of the wall is also a consideration. The factor of safety against sliding is kept as 1.5 and that against overturning is kept as 2.0. The minimum base pressure should not be less than 0 and maximum should not be more than allowable bearing pressure. (Ref. 4).

Another important aspect here is the ease of quality control in gabion retaining walls given the fact that all the components i.e. gabions, boulders and geotextile are easily accessible for QC check at anytime. It is easy to install and does not require highly skilled labour. On the contrary, in case of brick/concrete walls, issues like cement content, quality of bricks/sand/water, water cement ratio, curing, workmanship, quality of shuttering, etc are critical and need to be supervised.

Non-availability of boulders locally and cost of transportation are two important factors that go against the use of this technology in the state of Tripura.

In this case, two walls were constructed – one at a lower level above the river stream and the other above the first at road level – both are 4m high with 0.5m embedment for foundation.



Plate 5 : A rock fill gabion wall with geotextile backing under construction. The inset picture shows gabion boxes being prepared for placement.



Plate 6 : Gabion wall provided with bamboo piles at the toe to prevent structural distress during rainy season when the water level in the stream rises.

Use of Geo Textile Bags in Gabions for construction of Retaining Walls in Tripura – A Case Study

The state of Tripura in the North east of India is characterized by absence of rocks in its geological formations. As a result, the requirement of stone aggregates for roads, buildings and other infrastructure works, which is normally manufactured by crushing rocks, has to be imported from nearby states of Assam, Mizoram, etc. The practices therefore have adapted to this shortage and road construction is often done with broken over-burnt brick aggregates (jhama bricks), except the weathering course (top layer), for which stone aggregates are brought in from neighboring states.

Rock filled Wire mesh Gabion retaining walls have not been a viable solution except in areas adjoining Assam, Mizoram, etc.

Using Geobags (Soft Rock) instead of Rock in Gabion retaining walls :

In this type of system, the 1mx1mx1m gabion boxes are filled with stitched Non woven geotextile bags which are filled by granular sand which is locally available. The weight of a sand filled gabion compares well with that of a rock filled gabion and hence can be used as a retaining structure (Ref. 9)..

The gabions are filled with rock/stones of 200 mm average size whereas the soil from the slide debris is filled in geotextile bags and tamped with wooden mallet.

The density of fill material, and hence the earth pressure, are calculated as :

$\gamma = [(G_s + S_r.e).\gamma_w] / (1+e)$, and **$e = n/(1-n)$**

where γ = Density of fill material (t/m^3), G_s = Specific gravity of fill material

γ_w = Density of water (=1 t/m^3) e = void ratio of fill material (V_v/V_s)

S_r= Degree of Saturation (%) n = porosity of fill material (V_v/V)

V_v = Volume of voids V_s = Volume of solids V = Total Volume

Rock filled Gabion	**Soil filled Gabion**
Here Gs = 2.7 γ_w = 1 t/m^3 S_r = 0% (free draining) n = 0.2 as per CPWD Specs Vol I para 1.27 Therefore e = 0.25 Hence Density of fill material (γ) = 2.16 t/m^3	Here Gs = 2.6 γ_w = 1 t/m^3 S_r = 100% (saturated soil) n = 0.08 as per CPWD Specs Vol I para 1.27 Therefore e = 0.09 Hence Density of fill material (γ) = 2.47 t/m^3 Under dry conditions (S_r=0), γ = 2.39 t/m^3

It can be seen that the bulk weight of the soil filled gabion is more than the bulk weight of the rock filled gabion. As such its performance with regard to sliding as well as overturning will be superior. However, the foundation level stresses as well as the bursting stresses on the geotextile need to be checked. For low height walls around 4m to 6m height, foundation level stresses are within usual limits. If the subgrade is weak, additional corrective measures will be required.

The geotextile used here is of the type Terram 1000 which is a non-woven (70% Polypropylene and 30% Polyester) textile. The function of the geotextile is separation and filtration. The key engineering properties (as provided by the manufacturer) being - :

Strip Tensile Strength - 8 KN/m at 28% peak Elongation; Mass per Unit area – 125 gsm

CBR Puncture Resistance – 1500 N; Apparent Opening Size (AOS / O90) :150 µ

Permeability (VIH50, 50mm Head) : 100 l/m2.s

The fill soil was non plastic and %tage passing 0.075mm sieve was in the range 15 to 50. As such all parameters required by Section 700 of the MoRTH Specs for Road and Bridge Works (Ref. 7) are met.

It provides excellent engineering performance, but is suspect for its longevity; especially given the fact that Geotextile undergoes UV degradation when exposed over extended periods, unless they are specifically manufactured for extended life under exposed

conditions.

In the instant case, bamboo mats are used to protect the geotextile, to prevent exposure to UV radiations. Bamboo mats (chhecha beda) are a local product and gives employment to the people in the vicinity of the project.

A trial panel was executed with Non-woven geotextile bags, alongside rock filled gabions. The bags were locally stitched by hand, and placed inside 2m x 1m x 1m machine made gabions of 2.7mm zinc coated wire (without PVC coating) and 10x12 mesh opening size. This work was carried out in December, 2011 and monitored till February 2015.



Plate 7 : One panel of soil fill gabion wall with 1m x 1m x 1m gabion boxes constructed alongside rock fill gabion to compare their behavior over time.



Plate 8 : Soil filled Gabion wall provided with HDPE drainage pipe as an additional drainage measure. Inset picture shows use of bamboo mat for UV protection



Plate 9: Gabion wall in May 2012 – Some green cover is seen over the walls



Plate 10: Gabion wall in March 2013 – Green cover has increased



Plate 11: Gabion wall in March 2013 – Soil fill gabion panels are holding fine



Plate 12: Gabion wall in March 2013 – No subsidence is seen behind the wall



Plate 13: Gabion wall in Feb 2015 – Sufficient vegetation over wall, note the wet toe of lower wall



Plate 14: Gabion wall in Feb 2015 – No subsidence is seen at road level over the wall. Vegetation growth is abundant

Limitations of the use of soil filled gabions :

Soil filled gabions suffer from the following problems in execution:

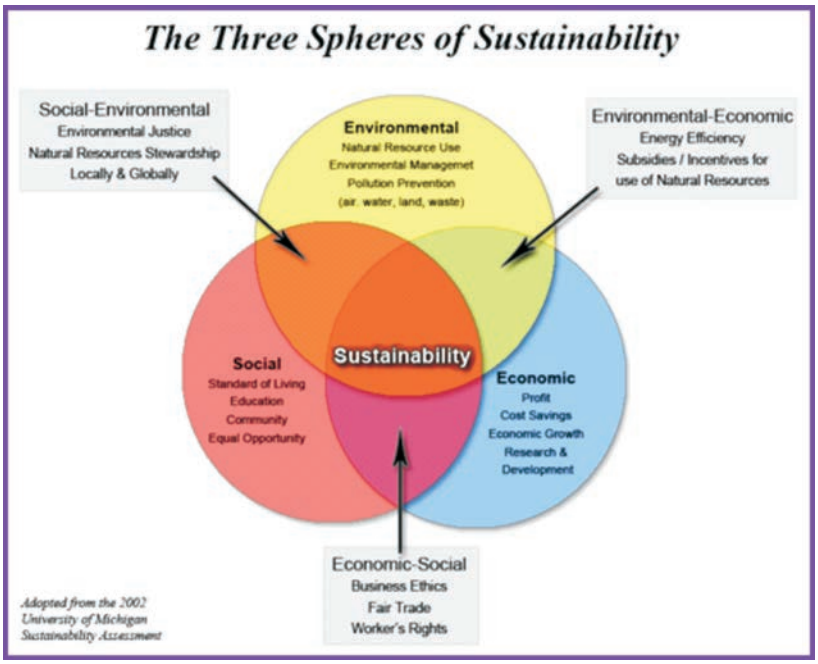
- The geotextile tends to bulge out of the gabion openings if the mesh opening is too large. The burst strength of the textile needs to be higher in such cases, especially for larger wall heights. The choice of smaller mesh size and special geotextile is a matter of cost economics and availability.
- Fixing of bracing wire, especially when bamboo mats are placed between the geotextile and gabion wall, is cumbersome. It also damages the geotextile. At such locations, a piece of brown tape is put on both sides of the geotextile to prevent progressive tearing of the material.
- The soil tends to settle down after some time, especially as upper layers put load on the bottom layers. Hence the filling is required to be slightly on the higher side, with proper tamping and compacting.
- The lead time for transportation of gabions and geotextiles is high for remote locations. However, with increasing use of these materials, the lead time is decreasing.
- More field trials are required to gain confidence in this application, as soil filled gabions in retaining applications are few and far between and remain mostly un-instrumented or performance recorded.

The Sustain Ability Paradigm

Sustainability has been defined by many authors, with a common thread running through them, that of development which is as equitable over generations as it is within the current generation.

“Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.” – Brundtland Commission, “Our Common Future”, 1987 (Ref. 10).

Sustainable development is a balance between environmental, economic and social factors – it therefore becomes a multidisciplinary optimization problem with soft constraints and objectives. In addition, the time scale on which the performance is to be evaluated extends over decades instead of months and years (Ref. 11). It is also pertinent to mention that since environmental and social factors come into play, the sustain ability parameters have local dimensions and there is no “one size fits all” formulation of the problem.



A key step in the move towards sustainability is the freezing of the indicators for measuring sustainability, which may often be a qualitative measure. Separate indicators define economic, social and environmental states (Ref. 13) and often a trade-off is necessary amongst them.

For example, energy use, land use, noise pollution, water pollution, air pollution etc. are common environmental indicators for infrastructure projects. Similarly, local employment generation, protection to cultural heritage, service benefits to the project vicinity, change in land value, etc. are some valid social indicators of infrastructure projects. Economic indicators are technical superiority, project cost, financial risk, maintenance and operation costs and paybacks over the life cycle, etc. (Ref. 12).

Soil filled Gabions – Sustainable Indicators :

The relative indicators for sustainability relevant to this type of work, for the conventional brick work type construction and for the soil filled gabion retaining walls. The indicators chosen here are qualitative. The following table is self explanatory :

S.No.	Indicator	Qualitative Assessment		Remarks
		Conventional System (Brick masonry R/Wall)	New System (Soil filled Gabion R/Wall)	
A..	***Economic Indicators***			
1.	Capital Cost per cu.m. of retaining wall	Moderate	Excellent	Cost per cu.m. for brickwork in the instant location works out to approx. Rs. 6000/- per cu.m. whereas for new system it is Rs. 4000/- (At 2011 prices)
2.	Maintenance cost	Moderate	Good	Low maintenance cost of gabions compared to brick work requiring plaster, whitewash, etc.
3.	Engineering performance	Moderate	Excellent	Brick structure - rigid structure, poor long term drainage, Quality Assurance problematic. Gabion structure - Flexible with superior drainage properties, factory made components ensure better Quality Control.

B.	***Social Indicators***			
1.	Local employment generation	Moderate	Moderate	The labourers in both cases are locals and there is not much difference in the quantity of labour. However, in the conventional system, local contractors benefit from supply of materials much more than in the new system
2.	Lesser road blocks / landslides	Good	Very Good	Better performance of the new system leads to better safety & accessibility in hilly areas.
3.	Conservation of agricultural land	Low	Very Good	The large scale demand for bricks lead to mushrooming of kilns and consequent loss of agricultural land, thus lowering local food grain availability.
C.	***Environmental Indicators***			
1.	Energy Usage	Poor	Excellent	The gabions and geotextile come in better packaging, i.e. each truck load brings material for large volume of work, with little wastage at site. For bricks, truckability is moderate. Also wastage in bricks is much higher at around 5%. The embodied energy of brickwork is very high, especially due to kiln burning.
2.	Land usage	Good	Moderate	Brick retaining walls take up lesser space than gabions in plan area, for usual heights of 4 to 6m.
3.	Construction material usage	Moderate	Moderate	The volume of construction materials is almost same, however brickwork inputs are costlier than gabion filled with sand / soil.
4.	Conservation of top soil	Moderate	Moderate	The top soil loss at the site of work is almost similar, as in case of gabions, the plan area is higher, however, the top soil is partly put back over the gabions for greening.
5.	Green Surfacing of Structure	Poor	Very Good	The soil filled gabions grow local vegetations, especially in hot and humid conditions, which binds the silty / sandy soil.

(Note: Grading has been given as Poor, Moderate, Good, Very Good and Excellent. The qualitative gradings have been selected by the author from his own experience. More sophisticated qualitative assessment methods are available)

Relative performance of the New System vis-à-vis the Conventional System :

The new system is found to be superior on most sustainability indicators, whereas on some other aspects it is neutral with respect to the conventional brick masonry system.

Inhibitors for Adoption of Sustainable Measures:

The following factors can be considered as the major inhibitors in the present context:

1. The status quo is beneficial to the contractors who also own brick kilns. They tend to lose their established profitable activities. Hence there is local resistance.

2. Triple bottom line is not an established norm in decision making, which remains anchored

to cost economics alone.

3. Policy level decisions towards sustainable development are not translated to operational methodologies due to subjectivity and complexity of the processes involved.

Conclusion And Road Ahead

It is seen that the use of soil filled gabions with geotextile bags and bamboo mat UV protection is a practicable and eco-friendly solution for small height retaining walls and breast walls, for slope repairs and retrofitting of small landslide locations. It uses locally available landslide debris and does not entail stone/sand mining. It is also quite fast and does not require much specialized labour.

As brought out above, it is a sustainable technology for areas having dearth of rock formations or where the environmental responsibilities dictate a non invasive methodology for flood damage mitigation and repair.

Considering these few panels of soil filled gabions as a technology demonstration, there is a need to take up larger walls with this method.

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MONOLITHIC ALUMINUM FORMWORK CONSTRUCTION FOR SPEEDY CONSTRUCTION

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Abstract:

Due to requirement of mass housing, the conventional construction systems cannot meet the present requirement of fast track construction and at the same time meeting functional and structural requirements. The rapid monolithic disaster proof construction with aluminum formwork is an emerging construction systemwhich leads to fast track, cost effective sustainable development in construction, ensuring quality, time, cost, and durability due to its homogeneity. This paper discusses about practical approach of this technology with advantage of speed, quality, construction method and financial aspects, stages of construction and comparison with conventional system.

Introduction

Adoption of Monolithic Concrete Construction leads to quick, efficient, and cost effective construction simultaneously leading to aesthetics and seamless constructiondelivering greater site productivity. Evolution of such technique had been on track sifting back and forth driven by the demands of particular times in which all the components like walls, slabs, staircases, sunshades etc are cast monolithically at one time using one homogeneous material that is concrete. Therefore the basic essential input forsuch construction is with highly workable concrete mix, pre-engineered formwork system and reinforcement. Thus, monolithic construction technology is a means to achieve quality, speed and productivity for turning out unprecedented volumes in terms of built form.

Such scenarios of delivering complex functional and aesthetic built forms to be made possible, the need is of an integrated and technologically advanced construction practices, augmented by 'as required skill' workforce. And the need has to be imperative to all stakeholders that are government organizations, consultants, builders and owners to be diligent in adopting them and other innovative ideas to increase construction productivity.

Recent time high focus on adoption of monolithic concrete construction technology by government and private sector can contribute to the increasing demand of rapid urbanization, speed and adoption of limited energy resources and the concerns for basic essentials such as “Safety, Health, & Environment(SHE) due to less pollution created by advanced construction technologies. Even Hon'ble Supreme Court favoured imposing a fine of Rs. 50,000 on a daily basis on construction sites for generating high levels of dust in Delhi

and the national capital region while hearing a PIL seeking directives to curb rising pollution in Delhi and the NCR, a bench headed by Chief Justice of India T S Thakur. Thus, less polluting construction technologies like monolithic concrete construction is going to take front seat in future.

Amid rising concerns for quality, speed and pollution, Central Public Works Department (CPWD) has approved monolithic construction technology for adoption in major projects.

Monolithic Concrete Construction

In the last 50 years, a tremendous amount of knowledge has been accumulated from research, design and construction of concrete structures as over the years these structures have performed very well and have shown excellent durability even when subjected to severe earthquakes. Such construction has been marketed on the basis of savings in materials and labour, economy, quality and workmanship with high speed in construction. High degree of success for such construction is also dependent on economic criteria for contractors considering equivalent desired quality the technology offered. In fact, it has become a high-quality low-cost deliverable!

In today's context, a great amount of rebuilding the urban infrastructure is involved in already existing dense urban areas in India. Hence, major construction can be techno commercially and environmentally feasible only by such technologies.

Monolithic construction uses less materials. Thus, savings in construction materials directly mean lesser depletion of all natural resources that get consumed to produce the construction materials. Also, resources utilized during construction process like minerals(limestone, gypsum etc), fossil fuels (coal, oil ,gas etc) and timber largely consumed in the conventional construction process for temporary bracing, shuttering, forming, dunnage etc too will be largely reduced leading forest conservation. Reduction in traffic impact on the highways during the construction phase of the building project is alsoachieved which means reduction in highway maintenance costs and the associated materials and energy required for repairs. Less of road repairs is great relief to commuters in terms of nuisance and fuel wastage by traffic congestion coupled with engine idling as well as air pollution.

Lower Carbon Footprint, Safe and Quality Work

Construction sector is a major contributor of Greenhouse Gases (GHGs) and ethically has the responsibility to control them by less polluting technology as well as best practices wherever possible to curtail its carbon footprint needing to utilize already available existing engineering knowledge and construction technology as well as the experience to develop more greener

and safe construction practices that consume less natural resources, energy and labour.

The skillful and efficient use of construction materials results in lighter, stronger, earthquake resistant structures. It is bad enough that catastrophic earthquakes cause building collapses, heavy loss of life and multiple injuries. However, it also puts an added burden on our ecosystem in terms of further depletion of natural resources as well as the addition of greenhouse gases generated in rescue operations, and demolition,

Monolithic construction provides higher earthquake resistance through the monolithic casting of the walls with the floor slab.

Adoption of Monolithic Concrete Construction System Using Aluminum Formwork by CPWD for various Projects

CPWD in general is executing construction works by adopting load bearing and RCC in situ framed constructions. In both the systems, the basic materials like sand, cement, aggregates, and steel shuttering materials are to be brought at site. Further, the different types of labours like mason, carpenter, beldar, plumber, welder etc with different degrees of skills are employed for execution of works. In such type of constructions, the following is noticed;

- It increases environmental pollutions of air, water and noise etc.
- It may lead to inconsistent quality.
- The working condition of site is hazardous to health.
- The progress of work is frequently affected due to environmental factors such as vagaries of the weather, festivals etc.
- The progress of work cannot be increased beyond a certain limit due to on-site execution of various items.
- Availability of skilled manpower is limited which affects the quality & speed of work.

In order to overcome this situation, technologies using ready mixed higher performance concrete have been found to be most suitable because of their versatility, fewer limitations, design flexibility, good quality and robust construction, established codal provisions and adoption for large scale work etc.

Internationally also, precast and monolithic construction technologies are largely adopted in projects of housing and office buildings, concrete being most versatile construction material though for very tall and special structures, composite steel construction is adopted.

Countries where precast and monolithic construction is predominantly in vogue are USA, UK, Russia, Europe (Germany, Netherland, Finland), China, Singapore and Malaysia.

Choice of technology to be used is dependent upon the type and nature of building, volume of work and cost specific to a location.

Central Public Works Department has adopted monolithic construction technology as one of the technologies for quick, quality, dust free construction. By using advanced form work system,this system, replaces traditional column and beam construction by walls, floors, slabs, columns, beams, stairs together with door and window openings being cast in situ in one operation at site using specially designed, and easy to handle (with minimum labour and without use of any equipment) through a pre-engineered modular form work made of steel, Aluminium or plastic along with the electrical, plumbing, sanitation, and other servicesso that entire unit acts as a single body. The formwork offers proper alignment and smooth surfaceswhich eliminates the need of bricks, plastering, and other building materials. All of these factors and repeatability mean construction can save time and money with accuracy.

Some of the projects taken by CPWD in Monolithic Concrete Construction using aluminium formwork are;

1. 700 Multi storied Residential Quarters (Type II) for CRPF personnel at Khadarpur, Gurugram

This was first work in CPWD that was taken up in Dec'2016with monolithic construction technology using Aluminum form work at a cost of Rs 155 Cr.



2. Residential quarters (Type II) for CRPF at Pappankalan, New Delhi

This was second work in CPWD that was taken up in Jan'2017 with monolithic construction technology using Aluminum form work at a cost of Rs 52Cr.



3. 938 Residential Quarters for CRPF personals at Amethi, UP



This was third work in CPWD that was taken up in July'2017 with monolithic construction technology using Aluminum form work at a cost of Rs 112 Cr.

Redevelopment of GPRA colonies of Mohammadpur and ThyagrajNagar have also been taken up with such monolithic construction apart from Type VII Quarters at Minto Road, New Delhi, MS Flats for MPs, New Delhi and redevelopment of GPRA colonies at various other

locations in Delhi are also going to be taken up with this technology.

Construction Process

Trial erection of the formwork is carried out in factory conditions which ensures that all components are correctly manufactured withall pin and wedge system, wall ties, props and other components to enable easy site erection and dismantling.After receipt of form work at site, a level survey and corrections if any needs to be carried out to maintain horizontal level for setting out formwork. Formwork is then erected at site alongwith kickers over beam. Usually a 4- day cycle is followed as under:

- Day 1 - Erection of vertical reinforcement bars and one side of the vertical formwork for the entire floor or a part of one floor.
- Day 2 - Erection of the second side of the vertical formwork and formwork for the floor.
- Day 3 - Fixing reinforcement bars for floor slabs and casting of walls and slabs
- Day 4 - Removal of vertical form work panels after 24 hours, leaving the props in place for 7 days and floor slab formwork in place for 2.5 days.

Major advantages of Aluminum Form work System:

- The formwork is light, does not depend upon heavy lifting equipment, has convenient support system, and can be handled by unskilled labours with high speed.
- Exceptionally good quality accurate construction for all openings to receive windows and doors etc, with smooth finishing of wall and slab concrete surface to receive painting directly without plaster.
- Durable and reusable several times with high salvage value.
- No construction garbage on Site.

Major advantages of Monolithic Construction:

- Much lesser air & noise pollution and construction waste, Optimum use of water
- No use of timber/ plywood for shuttering
- Increased labour productivity due to working in controlled environment, all weather site execution
- Cost saving due to compressed completion time and rental cost reduction.

- Better site organization, utilization of resources
- Higher useful carpet area as 5-8% of plinth area due to thinner shear wall construction.
- Maintenance cost is negligiblesince the walls and ceiling being smooth and high quality concrete repairs for plastering and leakage's are not at all required frequently.
- Provides more seismic resistance to structure and highly durable than that of conventional column and beam slabs construction combined with brick or block work subsequently covered by plaster.
- Speedy construction – 5 to7 days cycle of casting a floor together with all slabs, as against 40-50 days cycle in the conventional method, completed reinforced concrete structure is available for subsequent finishing.

Conclusions

Monolithic concrete construction technology using aluminum formwork has great potential due to good quality, speed, higher seismic resistanceand economic construction and will never deter the project speed nor will it be uneconomical. Being modular predesigned formwork system, it acts as an assembly line production and enables rapid construction of multiple/mass scale of units of repetitive type. As India needs a lot of rapid dwelling units to provide affordable housing to its rising population, this technology is one of the solutions to the overgrowing problem.

This technology can also be suitable to set the new standard in providing both low environmental impact, and energy saving green buildings that are economic to build and maintain and can save money over the life-cycle of the structure.

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3S PREFAB BUILDING TECHNOLOGY

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Abstract

For mitigating the housing shortage through affordable as well as sustainable built environment, adoption of prefab mass housing movement is the only viable solution. The ambitious 'Housing for All' mission can be realised through capacity building for precast mass housing constructors by ensuring continuity of work besides proactive changes in the tendering system which exists today. The construction of mass housing through precast technology has been successfully implemented by BG Shirke Construction Technology Pvt. Ltd. The timely execution of large scale mass housing projects using 3S System on Design-Build turnkey basis has aptly justified it to be a time-tested and proven technology.

The benefits of 3-S prefab system; which is practiced for the past over 4.5 decades by the company makes it one of the versatile options for mass housing constructions with best quality in India. With the motto as 'Industrialization of civil engineering' this system, which uses total prefab elements, limited cast-in-situ concrete work for wet jointing and not requiring formwork, has been evolved and perfected to cater to the varying geophysical, climatic and seismic conditions prevailing in India. Being an open componentalised system, it enables flexibility for accommodating every possible architectural planning and aesthetic application for all types of dwellings, layouts and storey configurations.

Preamble:

Our Honourable Prime Minister has already declared that by 2022, about 2 crore affordable houses for the needy will be constructed all over India.

PM's Mission - Housing for all:

The basic need of human being is **“Roti, Kapada and Makan”**. By and large, the Government has been successful in solving the basic issues, like **Roti & Kapada,** to some extent. However, as far as the **“Makan”** is concerned, there has been extremely slow progress in providing affordable housing mainly for Economically Weaker Section (EWS) and Low Income Group (LIG) categories. Our Hon. Prime Minister, a visionary, has appreciated the importance of providing the basic necessity to the common man, i.e. shelter in the form of affordable house and accordingly has prepared an ambitious programme in his own wisdom for providing affordable housing for the weaker sections of the society.

As per the Government's ambitious Housing for All Mission to be accomplishedby year 2022, when independent India will be celebrating its 75th Independence Day, every Indian family should have a house of its own.

For fulfilling this ambitious program of ourGovernment,such massive requirement of housing, particularly for EWS & LIG categories, cannot be met with byconventional outdated methods and materials. This is so because, apart from being costly and scarce, these materials and methods to a larger extent have outlived their technical and commercial usefulness, inasmuch as they have no capacity to touch even the fringe of the massive demand and supply situation prevailing in India, today. In order to meet this mammoth task of housing, we would require over 200 constructors, having capability to deliver at least 20000 houses yearly.

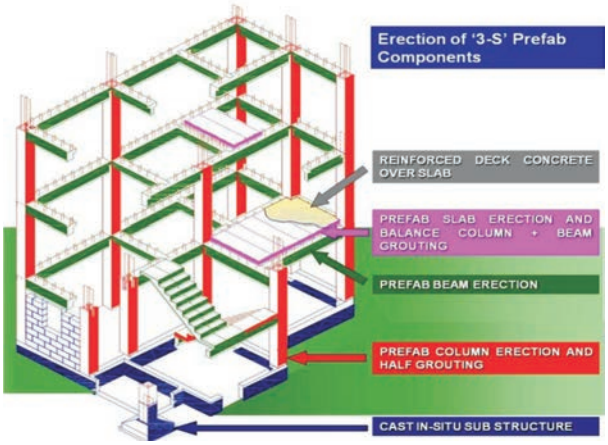
Tried, Tested And Proven 3-s Prefab Technology:

The Founder Chairman, Padma Shri B.G. Shirke, a visionary and reformist, had visualized the burning problem of housing shortage in India about 45 years ago and decided to completely transform civil engineering into its total industrialization by innovating, developing and introducing new products, having scientific & objective quality controls and capable of being modularly planned for economy and standardization, which can cope up with future challenges for effectively solving India's acute and nagging problem of housing shortage and slum proliferation.



(a) Technology:

SHIRKE Group, the pioneer of Prefab Building System, using factory produced precast structural components for building construction since 1972. '3-S' (S-Strength, S-Safety, S-Speed) is the brand name of prefab building construction system, which is developed and perfected by SHIRKES after years of strenuous Research and Development supplemented by extensive field trials. SHIRKES have developed total technology for effective implementation of this '3-S' system of building construction for Mass Housing Projects. The '3-S' system is successfully used for the last about45 years in India & abroad and have constructed over2 lac houses in all types of climatic conditions, heavy rainfall areas and seismic zones.





The technology consists of foundation with conventional methods and superstructure frame with dense concrete hollow cored columns, dense concrete partially precast beams, lintels, staircases, chajjas etc. and autoclaved aerated cellular reinforced (AAC)Siporex slabs/RCC precast slabs and Siporex blocks for masonry, precast walls.Reinforcedscreedis provided on slab to have monolithic construction. The Siporex Blocks & Slabs are manufactured in permanent factory and other structural components, like columns, beams;precast wall panels, precast slabs, staircases, lintels, chajjasetc, are manufactured at precast factories established at site under stringent quality control. The prefab components are erected, aligned and connected, using self-compacting concrete of appropriate grade andsecured with embedded reinforcement.

(b) Successful implementation of technology for Mass Housing at Delhi:

Considering the volume of work, such as construction of about 55,000 houses at Delhi for Delhi Development Authority in a short period of 3 years, the state of the art plant & machinery has been establishedwhich is biggest such facility in Asia. The factory is laid out over 25,200 sq.m area with Storage/ Stacking area of 46,000sq.m for the precast components. The most modern sophisticated machineries being utilized for Prefab Housing Projects are as under:

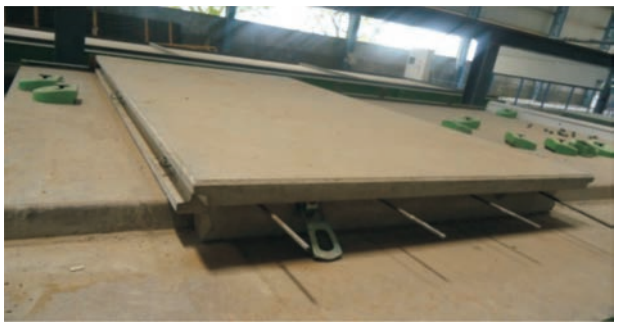
- Computerized weigh batching & mixing plant for concrete.
- High capacity tower cranes for erection of structural components.
- High quality moulds for precasting of slabs, walls, columns & beams. The carousel system adopted for casting the walls comprises of 68 pallets. This reduces the cycle time, thereby increasing the rate of casting the walls.
- Automated system for moulding and demoulding of mould sides.
- Specialized vibration system for proper compaction of concrete.
- Automated overhead concrete transport & pouring system.
- Specialized magnetic shuttering.
- Specialized equipment for concrete surface finishing.
- Arrangements for modern ways of curing by hot water circulation, curing chambers with hot air circulation, vapour curing system for precast beams, sprinklersetc., which not only conserves water but also provides efficient curing.
- Specialized tilting, lifting and transportation equipment for early age concrete components.
- Most modern reinforcement steel cutting and bending machines.
- Reinforcement bar decoiler and straightening machine.
- Automatic slab and wall cage welding machine.
- Slab and wall cage bending machine.
- Automatic column cage welding machine (Capacity – 250 sq.m/Hr).
- Automatic stirrup making machine.

- Automatic raft steel binding machine.
- Automatic lattice girder fabrication machine





LATTICE GIRDER MANUFACTURING FACILITY FOR PRECAST SLABS (7500 m/day)





PRECAST WALL PANELS (1400 Sqm/day)



CURING CHAMBERS - FOR ACCELERATED CURING





PRECAST COLUMN CASTING





PRECAST BEAM CASTING(1800 m /day)

© Evaluation of Technology by reputed Institutions:

The Precast Technology (3S system) has been developed and perfected since 1972 by carrying out field and laboratory tests by many reputed organizations, which are as under:

- City Industrial Development Corporation (CIDCO) has carried out actual performance load test to check the safety and stability of the structure by loading the structure to destruction and found that the structural behaviour was most satisfactory.
- Tests were carried out by Indian Institute of Technology, Mumbai, and they have certified that the joints fully established the behavior in the elastic range with adequate safety margins; absence of any separation cracks or any structural distress in the joints; adequacy of the bare portal to offer resistance to horizontal forces; ultimate load is on the higher side and ductility ratio is more than what is specified and required; joints of the

beam column connections have behaved as monolithic, as designed.

- TOR Steel Research Foundation of India has carried out the tests and concludedthat there is no distress feature in any of the joints&assembly of precast units is safe for resisting the loads for which they are designed for.
- Tests were carried out by Prof. Haresh C. Shah, Head of Civil Engineering Department, Stanford University, and he certified that the design calculations & detailing of the structure are such that for vertical loads, seismic loads & the wind loads, the buildings should provide safe and desired performance.
- Central Building Research Institute (CBRI), Roorkee, has also carried out tests and experimental results on Full Scale Building Structure and established the desired performance and behaviour of '3-S prefab building system under all design load conditions, including seismic (Zone-IV) for high rise buildings. CBRI has also certified that protective treatment given to steel reinforcement in Siporex is quite effective compared to corrosion of steel in normal conventional concrete.

(d) Technological and Financial Benefits:

Technological advantages:

- Reduction in dead weight due to light weight prefab components is beneficial from seismic considerations.
- Use of fire resistant Siporex products enhances the safety of the buildings
- Thermal insulation properties of Siporex products leads to increased comfort levels inside the buildings.
- Due to use of precast structural members, cycle time required for each floor is reduced substantially.
- Elimination of plaster to precast units, such as slab, wall panel etc., since these components are form finished, which is similar or better than that of a plastered surface.
- Quality is ensured automatically as structural units have BIS(ISI) norm and markings and are manufactured in permanent / site factories with objective quality control.
- Considerable reduction in quantities of natural resources, such as sand, metal, water, wood etc, by optimum utilization of construction materials.

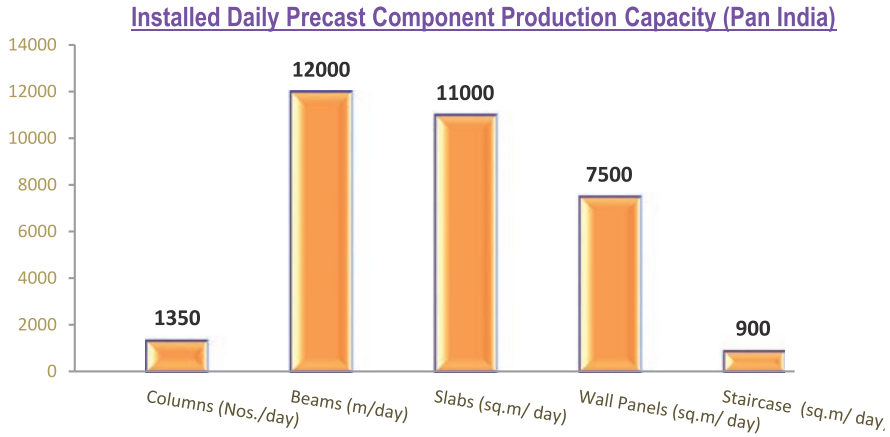
Financial Benefits:

- Due to turnkey, saving in planning & design fee.
- Reduction in dead weight results in saving in foundation and frame work cost.'
- Saving in cost due to elimination of slab, wall panel plaster.
- Due to early completion, financial benefits are as under:
  a. Saving in interest on investment.
  b. Saving in escalation cost
  c. Saving in establishment cost
  d. Early return on investments
- Cost saving in maintenance due to quality construction.
- Rapid Speed of erection & fast construction, resulting in earlier occupancy & reduced financing cost.

In case tangible and intangible financial benefits are quantifieddue to technological advantages, there is time saving of 15 to 20% and cost saving of about 30 to 40%.

(e) Environment Friendly Technology:

'3-S' Prefab Technology is eco-friendly due to judicious use of construction materials, reduction in wastage of materials, using more durable materials, use of energy efficient building materials, use of products that contribute to a safe, healthy built environment, use of construction system minimizing air, water and noise pollution during construction, use of fly-ash, very minimal requirement of water for construction, non-generation of construction debris, elimination of use of timber / wooden scaffolding, judicious use of scarce natural resources, use of eco-friendly products for walling, flooring and roofing.





Prefab mass housing project at Delhi for DDA



India's 1st High rise 25 Storeyed Prefab Residential Towers at Mumbai



Conference Hall at Hon. Vice President Residence, New Delhi
(Constructed in 82 days)



Prefab mass housing project at Delhi for DDA



MIG & HIG Housing Project at Kharghar,
Navi Mumbai for CIDCO



18 Storeyed Mass Housing Project for BDA at Doddabanahalli, Bangaluru

ADOPTING NEW TECHNOLOGIES FOR FASTER CONSTRUCTION

Sh. Harnam Singh, Chief Engineer, CPWD, New Delhi

Abstract:

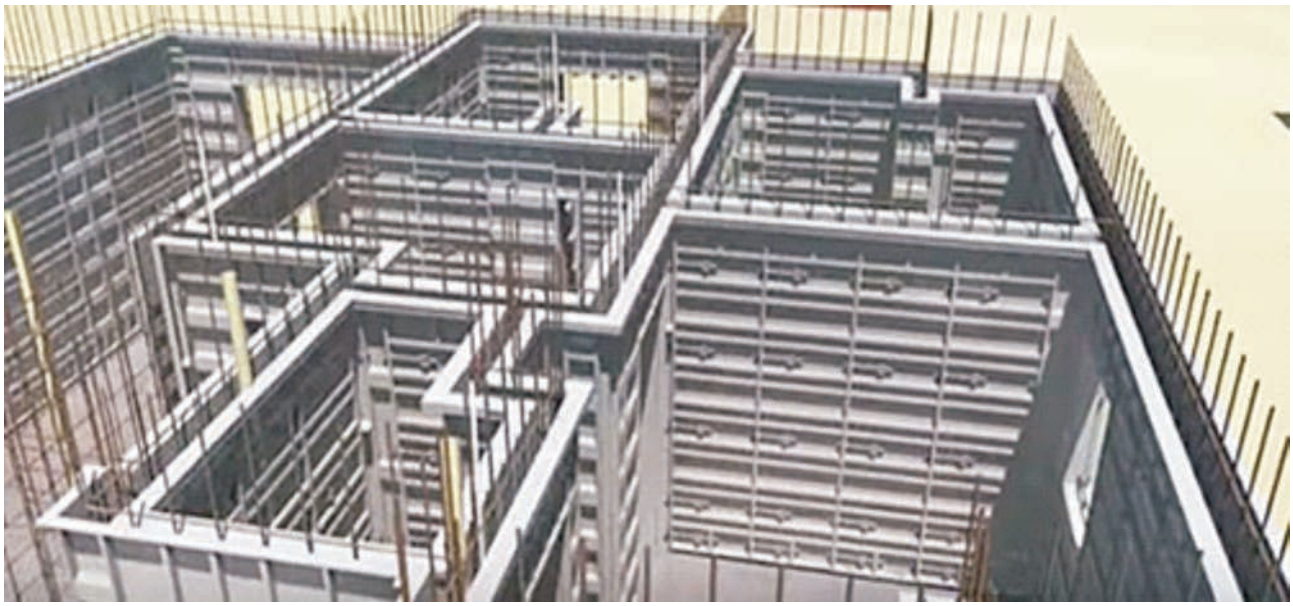
Urban housing shortage was 18.78 million in 2012 and now it is around 10 million. Urban population in India has increased from 285 million to 377 million from 2001 to 2011 at 32 % : (A study by KPMG). Due to rising trend in Urban population, shortage in housing may further increase to 30 million by 2030. Lack of skilled manpower is one of the identified constraints for speedy construction in housing as listed out by many studies. Monolithic Construction technology is a means to quality and productivity for turning out unprecedented volumes in terms of built form i.e to achieve the target of Housing for all.

With a growing focus on affordable homes and Housing for all, there is increasinglyemphasis on the use of new and innovative construction techniques. One such technology is Aluminium form work which is being promoted for its ability to aid mass construction activity.Its use is being promoted in India to realize the most ambitious government scheme – Housing for All by 2022.

Construction technique



Setting up the wall Reinforcement steel – The wall reinforcing with steel is used to give a structure to the building and support the concrete until they gain half of the required strength. The aluminum formworks are cast around the steel mesh, which is factory made and directly erected on the construction site.



Different type of structural system are categorized by method of construction

Conventional Method & Monolithic Method

Conventional method is a traditional method in which the construction method used i.e. simple R.C.C. framed construction. For lateral supports against loading and forces, beam and column are provided.In this method commonly RCC frames./pre-stressed work at site is done and the materials used are concrete, masonry steel and wood.

In Monolithic system, all walls , slabs, stairs, together with door and window opening are cast in place in one operation at site by use of specially designed, easy to handle with less labor and equipment efforts, modular formwork made of aluminum.

In this system the lateral and gravity load resisting system consists of reinforced concrete wall and reinforced concrete slabs. Reinforced concrete structural walls are the main vertical structural element with a dual role of resisting both the gravity and lateral loads.

Sequence of Construction

Slno.	Activity	Time taken
1	Marking of surface for Form Panels placing and Reinforcement works.	01st day
2	Vertical reinforcement works.	02nd day

3	Vertical and Horizontal Form works Placing and Fixing in position with all accessories.	03rd Day
4	Concreting works for the complete units including Walls, Chajja , Lofts and Top Slabs including the sunken portions.	04th day
5	Wall Panel de-shuttering works after minimum 16 hours of continuous curing and check on cube strength.	05th day
6	Slab Panels de-shuttering works after a period of 36 hours/ 3 days of concrete time of completion with immediate re-propping the slabs with continuous curing methods/ Curing compounds on surface application.	06th day
	Continuous curing will be carried out as per standards, As these above days are for 1 Pouring unit of a house complete, same system will be continued in vertical and horizontal directions depending on the speed of works systems.	

Erection of Shuttering System:

Wall forms are placed after the wall (rebars)reinforcement is placed in position., electrical conduiting are laid in place, while for PHE lines a groove is created through shuttering itself. Wall forms are connected through wedge and pins the wall ties are used for lateral stability of wall shuttering. After erection of wall forms, slab forms are erected. Required reinforcement is placed in position and electrical conduits fixed in slab. Now, the unit is ready for concreting in one pour.

Concreting

Self compacting concrete (SCC) of suitable grade as per mix design and structural requirements is used for concreting. The inherent property of SCC is self compaction without segregation. Hence, SCC is more suitable for this technology. Free flow of concrete is maintained to be 600mm minimumindaimeter,during the pour, to ensure the proper flow and

compaction.

Deshuttering (Stripping of formwork)

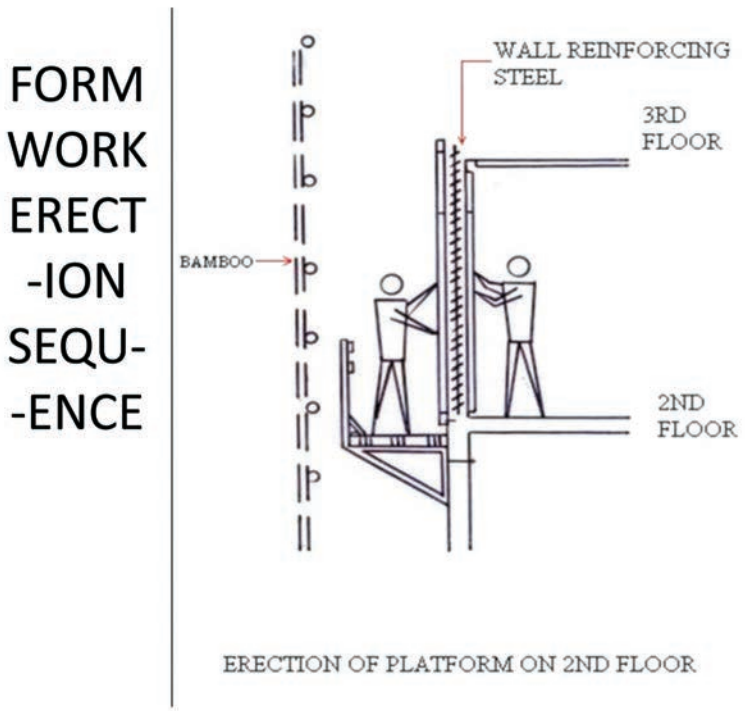
Deshuttering of wall forms will be carried out after 16-24 hours of concreting as per structural requirements. Slab forms will be removed after 3 days and props will be refixed at appropriate locations immediately after removal of slab forms

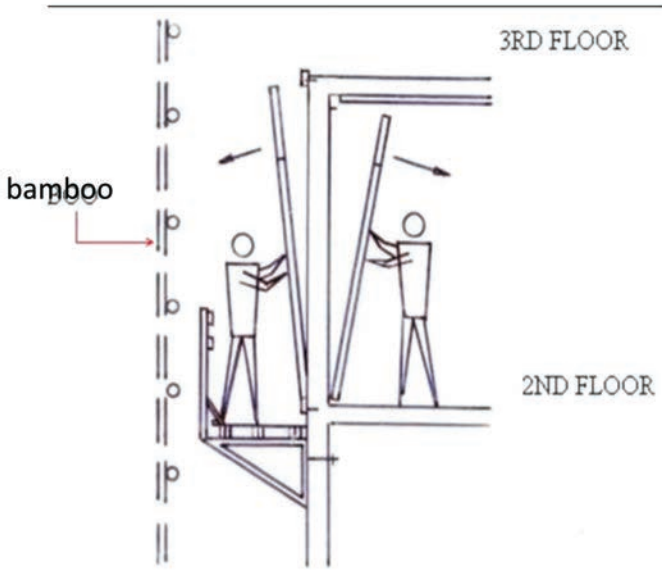
Curing

Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration. Curing is designed primarily to keep the concrete moist, by preventing the loss of moisture from the concrete during the period in which it is gaining strength. Curing has a major influence on the properties of hardened concrete such as durability, strength, water-tightness, wear resistance, volume stability, and resistance tofreezing and thawing.

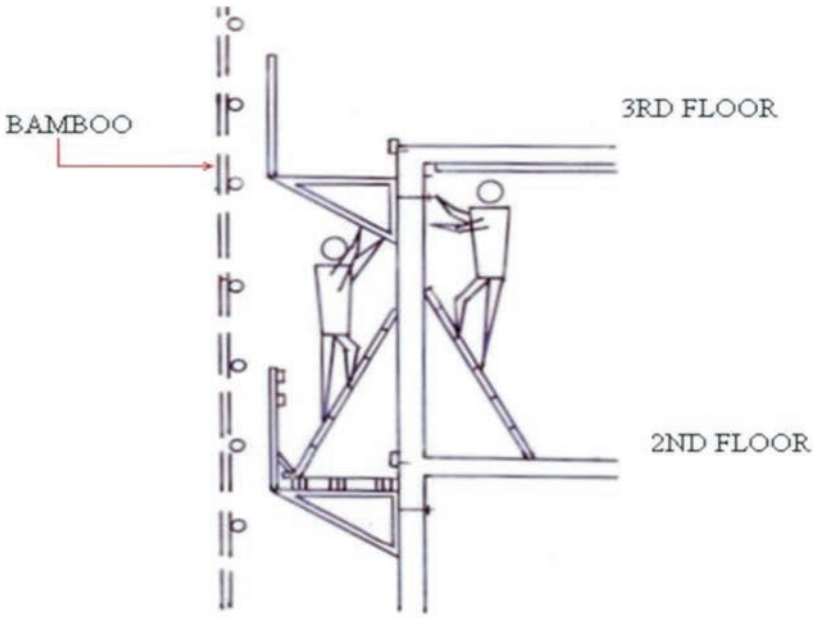
Membranes forming curing compounds (BASF Mastercure-107) are the liquids which are applied directly onto the concrete surfaces and which then dry to form a relatively impermeable membrane that retards the loss of moisture from the concrete immediately after removal of wall shuttering. This compound is wax based.Slabs are cured by ponding method for a minimum of 7 days

Sequence of form work

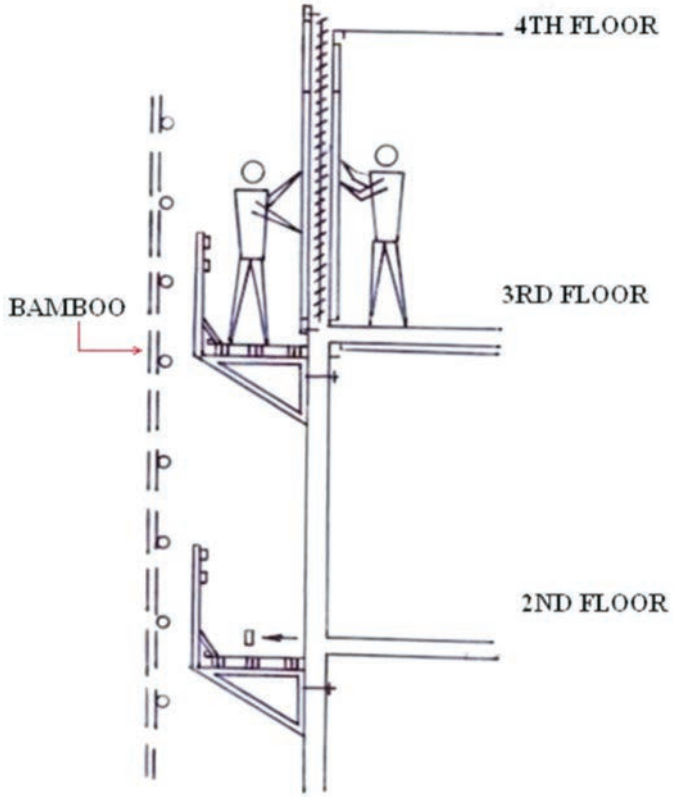




STRIKING OF ALL FORMS CAN BE DONE WITHIN 10-15 HOURS. THE ONLY TOOL REQUIRED FOR DISMANTLING IS HAMMER.



POSITONING OF WORKING PLATFORM BRACKET ON 3RD FLOOR LEVEL AND SECURING NUTS ON TIE ROD ON INSIDE THE BUILDING.



REMOVING KICKER FROM 2ND FLOOR LEVEL & ERECTING ALL FORMWORK ON 3RD FLOOR

General Advantages of Monolithic construction over Conventional technology

Slno.	Activity	Normal RCC Construction	Monolithic construction
1	Time of construction	Conventional RCC frame construction takes more time than RCC Monolithic construction.	Monolithic construction is faster than ConventionalRCC
2	Sequence of construction activities	Whole storey can not be cast cast in one go, a sequence is to be followed., First cast column, beam and slab, deshutter thenerect walls.	Whole storey can be cast in one go
3	Wall	Brick Wall require more time for erection and weathering time before plastering.	RCC Walls are cast along with slab and requires minimal curing by use of curing compound.

4	External finish	Plastering is required on both faces internal and external requires lot of labour, curing and water requirement	Plastering is not required as the smooth finish is obtained from the aluminium shuttering.
5	Shuttering	Initial Cost is less (Rs 4200/sqm) but finish is not good and life cycle cost is high due to less repetitions 70-80. Cost of shuttering is Rs 400-500 per sqm	Initial Cost is high (Rs7500/sqm) but finish is very smooth and life cycle cost is low due to Large no of repetitions 175-200. Cost of shuttering is Rs175-200 per sqm

Better seismic resistance

One to ten storey conventional and monolithic system were analysed and designed as per the codal provisions and the results are compared in various aspects. It is found that storey displacement in monolithic structural System decreases as compared to conventional structural system in both the directions. Drift is also decreases in both the directions for monolithic structural system as compared to conventional structural system. As modal time period is less in monolithic structural system. Also advantages like, rapid construction work and all over project cost will be reducing.

(Ref: Study by Prof. AsishP.Wagmare and Renuka S. Hangarge published in IRJET July 2017)

Distinct advantages of Aluminium formwork.

Aluminium formwork requires lesser labour in handling and fixing being light weight.

More seismic resistance provided by shear wall structure.

Increased durability.

Lesser number of joints (wall beam joints omitted on external walls which are susceptible to leakage) and hencereduced leakages.

Higher Carpet Area due to lesser thickness of shear walls.

Smooth finishing of walls and slabs.

Uniform quality of construction.

Negligible maintenance.

Faster completion.

Negligible construction wasteas compared to conventional technology.

More than 200 to 250 repetitions (reuse) as claimed by manufacturers but 175 -200 seems realistic figure. Aluminium will fetch higher scrap vale which is 40 % as compared to steel which is 25%

Fast track construction technology

Total units is made up of concrete which is stronger, durable and Solar Heat Resistant

Forms can be custom made to the requirements.

Designed for supporting loads and for lateral restraint.(no side supports required due to use of wall ties.)

Reduced cycle time 6-8 days per floor

Faster completion.

Reduced effective cost.

Lesser manual labour.

Better sound reduction coefficient.

Integral and smooth finishing of wall and slab.

Environmental Impact is lesser due to reduced construction and no duct pollution at site.

Disadvantges

Thermal Behavior of Structure

100 mm RCC Walls and Roof has thermal transmittance value as3.59 W/m2k) (as per IS 3792:1978). Since it is more than brick wall, (that means clay brick has better insulation property) proper planning for air ventilation provisions in housing units is required to be done.

Acoustic: Average Sound reduction for 100 mm concrete is 45db (as per IS1950:1962). For external walls or common walls of living units require 55 db sound reduction which can be achieved by providing 180 mm thick wall whereas same sound reduction can be achieved by 230 brick walls

Ease of fixing services:All electric and plumbing fixtures, lines has to be preplanned an placed before concreting is done. Post construction alternation is not durable.

Initial investment is more in shuttering and lead time is more as shuttering is to be designed and fabricated for the requirement of particular project.

Adoption in CPWD:

CPWD has started using monolithic technology recently. In redevelopment Project Zone till today three works have been awarded in EPC mode for construction of following projects. Cost per square metre as per tendered cost is as below.

SlNO	Name of Work	Total Cost in Lakhs of Rupees.	Total Plinth area in sqm	Cost per sqm with services (Rupees)	Cost per sqm without external Services (Rupees)
1	C/o 740 Houses (TypeII-400 No, Type III- 345 No at Mohamadpur (G+11storey) DOS SEP 2017	24909.25 Lakhs	1.04000.00	23951	21770
2	C/o 740 Houses (TypeII-380 No ,Type III- 310 No and Type IV -50 No at Thyagraj Nagar (G+9 storey) DOS DEC. 2017	25085.57 Lakhs	1.02100.00	24560	21720
3.	C/o 2408 Houses (Type-II-560 No ,Type III -1260 No and Type IV -588 No at Sriniwaspuri (G+29 storey) DOS MARCH 2019	108644.91 Lakhs	418020	25990	24200

Services included in development works are like water supply, sewerage, STP, internal roads, storm Water drainage, Rainwater Harvesting and podium and basement parking. Since monolithic construction has been taken up recently, details and data of costing is not available in the CPWD. However cost comparison of two structures G+15 storeys having built-up area of 10923 sqm was done and it is found that monolithic structure was costing only 2 % more than conventional structure but there will be substantial saving in completion time in monolithic construction.

Conclusion:

It can be concluded that Monolithic construction with Aluminium form work is better option for faster construction. It is suitable for the construction where repetitive shuttering is required i.e where more number of repetitions are required. It gives better and uniform finish. In addition to saving in time requirement of water is reduced due to omission of erection of walls at site and rendering on it. These activities are not only time consuming but also require lot of water during construction for preparation of mortars and curing. By adopting monolithic construction there is minimal generation of construction and demolition waste, which is generated due to chipping of buldged concrete and chase cutting for housing electric and water pipes in walls. This system also requires advance planning for all the services i.e plumbing electrical and firefighting. In this method the impact on environment is much less than the conventional technology as construction time is reduced by 40% as casting is done in one go and dust from brickwork work, due to chase cutting in masonry is eliminated. Hence the rising demand of housing in the country can be met in shorter time by adopting this kind of technologies.

POST TENSIONED CONSTRUCTION TECHNOLOGY FOR MULTI-STOREYED BUILDINGS

K M Soni, ADG (T), CPWD
Bharat Kataria, EE, CPWD

Abstract:

New and innovative materials are to be adopted for functional requirements, aesthetics, durability, economy or speedy construction. Therefore, new and innovative materials and technologies will be adopted in the construction sector on large scale.

Multi-storeyed construction has also become essential due to scarcity and high cost of land. Large module and span are now preferred particularly in office and commercial buildings due to economy in construction. It is also desired that more units are accommodated in same height of the building to minimise the cost per unit area of constructed space or for air-conditioning ducts. New techniques will be required to be adopted for accommodating more number of units within same height of buildings or getting higher headroom. Post tensioned construction technology offers the advantage of elimination or reduction in sizes of beams and slabs hence, in future such technology is going to replace traditional RCC construction in India.

Post Tensioned Construction Technology

Pre-stressing of concrete can be done through pre tensioning or post tensioning. Pre-tensioning is the method of pre-stressing in which tendons are tensioned before the concrete is placed. The tendons are temporarily anchored when tensioned and the pre-stress transferred to the concrete after it has set. Post tensioning is a method in which the tendons are tensioned after the concrete is hardened. Thus, pre-stressing is almost always performed against the hardened concrete and the tendons are anchored against it immediately after pre-stressing. When post tensioned, the tendons are anchored at their ends by means of mechanical devices to transmit the pre-stress to the concrete. Such a member is called end anchored. In pre-tensioning, the tendons generally have their pre-stress transmitted to the concrete simply by their bond action near the ends.

Bonded tendons mean that they are bonded throughout their length to the surrounded concrete while non bonded tendons are to be protected by galvanizing, greasing, or some other means from corrosion. Non end anchored tendons are necessarily bonded ones while end anchored may be bonded or unbounded.

Where the cables are contained within the ducts inside a concrete section, cement grouts are

pumped for protection from corrosion. But a fundamental requirement for pre-stressing tendons is that they must be protected against corrosion in order to maintain integrity of the structure.

In pre-stressed concrete entire section of the concrete becomes effective where in reinforced cement concrete (RCC), only the portion above neutral axis is supposed to act. High strength concrete which cannot be economically utilized in RCC is desirable and essentially required in pre-stressed concrete. In pre-stressed concrete, high strength concrete is required to match with high strength steel and to resist high stresses at the anchorages.

In pre-tensioning, the transfer of pre-stress is accomplished in one operation and within a short period. For post tensioned members, the transfer is often gradual, the pre-stress in the tendons being transferred to the concrete one by one. In both the cases, there is no external load on the member except its own weight. If a member is cast and pre-stressed as per the requirements, it becomes self supporting during and after pre-stressing. Thus centring/form work can be removed after pre-stressing.

Post-tensioning helps to meet the design objectives, both architectural as well as functional. Some of the benefits of such technology are;

I. Post-tensioning allows the floor framing to be more slender.

ii. With post tensioning, small structural depth is feasible for long spans.

iii. It leads to thinner sections thereby reducing the quantities of concrete and steel.

iv. It imparts high early strength in concrete.

v. It helps in reduction of dead load of the building.

vi. It provides considerable column free space thus larger useable space.

vii. It provides larger floor to floor space i.e. higher headroom for the services like air-conditioning ducts else more floors can be accommodated in same height.

viii. It allows earlier stripping of formwork.

ix. As significant part of the load is resisted by post tensioning, handling of non pre-stressed reinforcement is simple.

x. It helps in speedy and quality construction.

xi. It reduces the chances of corrosion.

xii. Post tensioning enhances durability.

Post tensioning being a specialized work also ensures proper quality control in field. Thus, post tensioning helps in durability of concrete (Soni & Kataria, 2014).

Post Tensioned Construction Technology Adopted by CPWD in Mumbai

Post tensioned (PT) construction technology has been adopted in most of its major multi-storeyed buildings in Mumbai. Some of such buildings recently completed are Central Bureau of Investigation (CBI) office building at BKC, Mumbai, Income Tax building at BKC, Mumbai, IDBI building at Belapur, Navi Mumbai and Academic Blocks of National Institute of Securities Markets (NISM), Mumbai.

Details of Post Tensioning in CBI Building

CBI office building is 2B+G+13 storeyed RCC framed construction in which all the floors are constructed with PT construction technology. The pre-stressing strands having seven wires were used in pre-stressing tendons conforming to ASTM 416/90 specifications. 7 wires (super type of strands) had 15.24 mm nominal diameter and 140 sq mm steel area with ultimate tensile strength of 260.7 kN and modulus of elasticity as 195 kN/sq mm. Strand diameter at anchorage relaxation was 6 mm.

Sheathing used was suitable for the pre-stressing system and strong enough to withstand the placement and compaction of the concrete without suffering damages or deformation. The sheathing and all splices were mortar-tight having friction factor as 0.21 and Wobble factor as 0.001 rod/m. Anchorage device was capable of transmitting a force not less than the ultimate tensile strength of the tendon without overstressing the concrete.

Cubes of nominal size 150 mm were cast for the purpose of determining the concrete strength at transfer. These Cubes were stored under the similar conditions as the concrete they represented. Post-tensioning was carried out after concrete attained a strength of 25 N/mm2.

Grout for filling pre-stressing ducts composed of cement, water and additive to reduce shrinkage and bleeding was used. The grout was injected into each duct. Continuous steady flow of grout was maintained until the duct got completely filled by pouring from all vents and from the far end until all entrapped water and air got expelled. The vents were thereafter closed as required to ensure complete filling of the duct.

Casting procedure

Before casting, the contractor was asked to submit the design and shop drawings for the

pre-stressing system. The design was based on Presscrete Post-Tensioning System (PPS). Concrete in one member panel was placed in one operation. Bottom reinforcement was laid as per the design/drawing after the formwork was ready. The cover was maintained as per specifications. Bursting steel for slab casting was laid before the ducts were joined for the casting. Galvanised flat duct was laid and strands inserted into the flat ducts according to the drawings. Bar chairs were placed and profile adjusted as per design. Grout vent with hose was fixed at both ends of the tendons and at the mid spans of the tendons for tendons exceeding 25 m length.



Duct laying in progress



Concreting

Care was taken that the pre-stressing tendons do not get displaced or damaged prior to casting and during casting. It was also ensured that discharge of concrete was not directed onto the pre-stressing tendons. Vibrating was avoided from coming into contact with the pre-stressing tendons. Proper compaction of the concrete in anchorage areas was ensured due to high local stresses in these areas and care taken that all the grout hoses remain exposed and protruding from the concrete surface.



Concreting in progress

Stressing

After concreting, the carpenter removed the vertical sides of end form work. All the stressing recesses were cleared and pre-stressing barrels and wedges fixed to all pre-stressing casting. When concrete reached the transfer strength as per the shop drawings and confirmed from the results of cube tests, stressing of cables was carried out. All cables were tensioned to the required jacking force and monitored through the pressure gauges.





Stressing of slab tendons

Grouting

Excess cable length was cut after the stressing and pre-stressing tendons flushed with clean water. Grout was mixed according to the design mix for at least two minutes until a colloidal consistency produced. The water was put into the container first and then cement slowly added. When the cement and water got thoroughly mixed, the non-shrink additives were added to the mix. The grout then was injected into the pre-stressing tendons. Grouting was carried out at one end of the duct until clear grout flowed out from the other end. The grout hose at the both end was then sealed. Grouting works were commenced when all scaffolds at a particular storey where grouting works were to be carried out, were removed.





Post tensioning

Bonded post tensioning system was used in the present case. The tendons were laid in sheathing. Casting was done by keeping one end fixed called dead end. After casting when concrete attained desired strength, stressing was done. The tendons were laid in the slab according to the profiles before pouring the concrete. After the strands got locked within the anchorage by the wedge, they were individually stressed with hydraulic jacks. The ducts were then filled with cement based grout for bonding the strands to the concrete through the duct all along the length of the tendon.

Since the cables/tendons in the slab are stretched to high tensile strength, it is extremely important that the slab is not drilled, cut, chiselled or disturb in a way so as to expose the tendons.

Advantages and Disadvantages of Pre-stressed Concrete over RCC

The advantages and disadvantages of pre-stressed concrete over reinforced cement concrete are given in the following;

Material saving

I. Reduction in concrete due to thinner concrete members.

ii. Reduction in rebar in floor elements.

iii. Reduction in dead load resulting into saving in concrete and reinforcement of structural members including foundation.

iv. Saving in building cladding, vertical mechanical/service elements, rebar and concrete in shear walls and other materials due to lesser sizes.

Faster construction

i. Potential pour cycle of 3-4 days.

ii. Reduced re-shoring.

iii. Better coordination with embeds and MEP openings.

Increased performance

i. Improved seismic behavior.

ii. Reduced deflection and vibration.

iii. Improved crack control and water proofing properties, especially beneficial for parking garages and balconies.

iv. Longer spans and fewer columns giving greater flexibility in floor layouts in office/residential buildings and better lighting in parking garages which enhances personal safety.

Reduced lifetime cost

i. Lower maintenance and lifecycle cost.

ii. Reduced building height resulting to higher headroom and energy savings.

iii. Potential to conform to green building norms.

Pre-stressed concrete design is more suitable for long span structures and those carrying heavy loads. Pre-stressed structures are slender and thus yield to more clearance. They do not crack under working loads and dead loads, and the deflection is reduced due to cambering effect of pre-stress.

Though both reinforced concrete and pre-stressed concrete will be safe when designed for the conditions but in pre-stressed concrete, there is partial testing of both of steel and concrete during pre-stressing operations and when materials can stand pre-stressing, they

are likely to possess sufficient strength for the designed service loads. The resistance to corrosion is better in pre-stressed concrete than that in reinforced concrete due to denser concrete and non existence of cracks. Pre-stressed concrete members require higher order of care in design, construction and erection than reinforced concrete.

Pre-stressed concrete is economical in certain cases when same unit is repeated many times, under heavy loading of structures, and long spans.

Pre-stressed members are likely to be less prone to corrosion and as such better suited in coastal areas and in the places where atmospheric conditions are adverse.

Pre-stressed members cannot be drilled during their service life else are likely to get damaged which may cause failure of the structure.

In India, the post-tensioning is a specialised job and is done by few agencies expert in post-tensioning system. Due to involvement of specialised agencies, the specifications are followed as per the design standards and quality maintained during all the operations. Due to better quality control, members with very low porosity are produced thereby having longer service life than conventional RCC members.

Conclusions

Pre-stressed construction technology has been widely used in the bridges but is gaining popularity in multi-storeyed buildings particularly having large spans and to gain more headroom. Also, pre-stressed construction technology helps in preventing corrosion and produce faster and quality construction. Due to adoption of such construction technology, more units can be planned within same height for reduction in cost per unit of floor area.

In Mumbai, pre-stressed construction technology is being adopted widely by the builders and government organisations. CPWD is also taking up such construction in Mumbai; details of such a building constructed for CBI have been presented.

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V-INFILL WALL (LIGHT WEIGHT EPS WALL)

Narashima Rao, Assistant Vise President (Technical)

1.2.2 Brief Description

V-Infill Wallis an innovative emerging building and construction technology using factory made 8/10mm fibre cement boards (V-Premium board- IS 14862:2000 Type "A" category 3) on either side of GI studs and erected to produce straight to finish walls which are filled with light weight EPCconcrete made of EPS (Expanded Polystyrene), cement, sand and additive. The system may be integrated with conventional column and beam of RCC OR Steel columns and beams of pre-engineered buildings. The walls may be used asNon-loadbearing partition walls for external and internal applications.

The GI studs are"C" cross-section with knurled flanges and built in service holes in the web fixed between floor and ceiling channels using anchor fasteners at spacing of 400mm to 600c/c. Provisions for doors, windows, ventilators and other cutouts as required shall be incorporated. Electrical and plumbing pipes/conduits shall be provided in the service holes of studs before concreting is done.

The firm is also the manufacturer of fibre cement board branded as V board, G I studs & channels branded as Vnextframes, Visaka additive and Visaka bond liquid which are used in producing the V-Infill Wall.

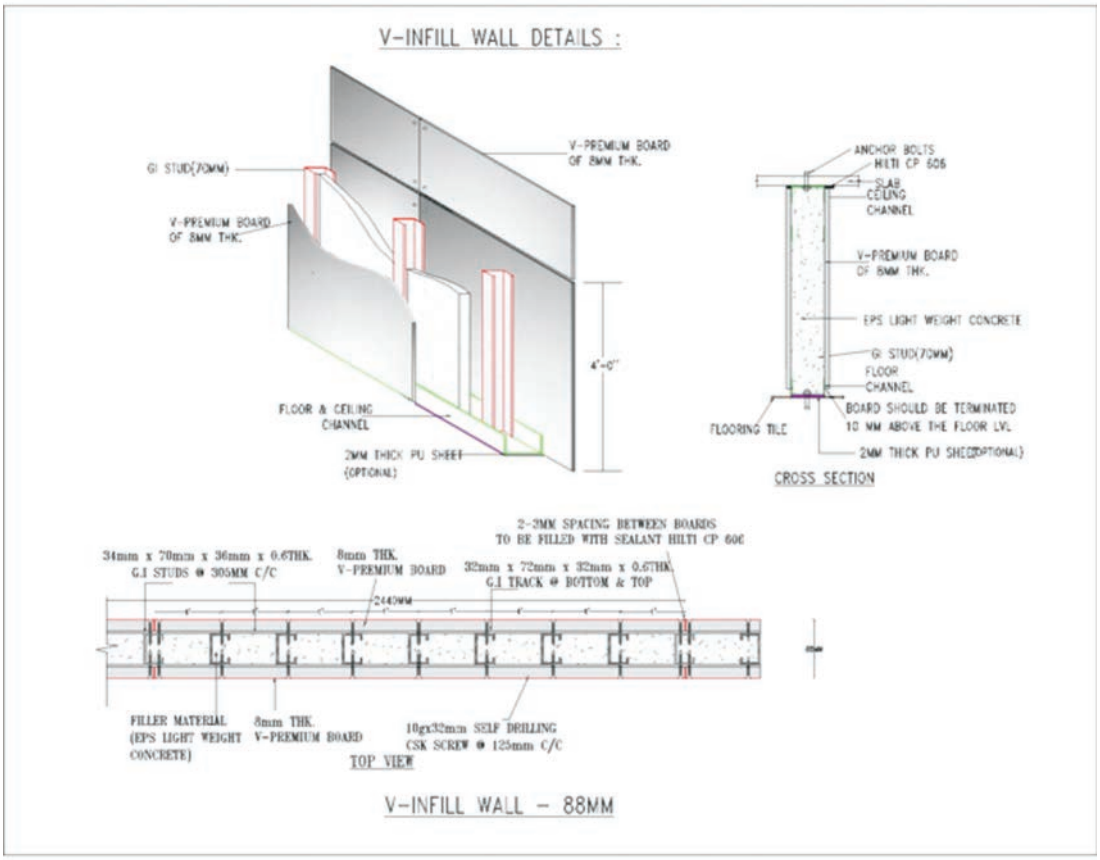
1.2.3 Types of Walls

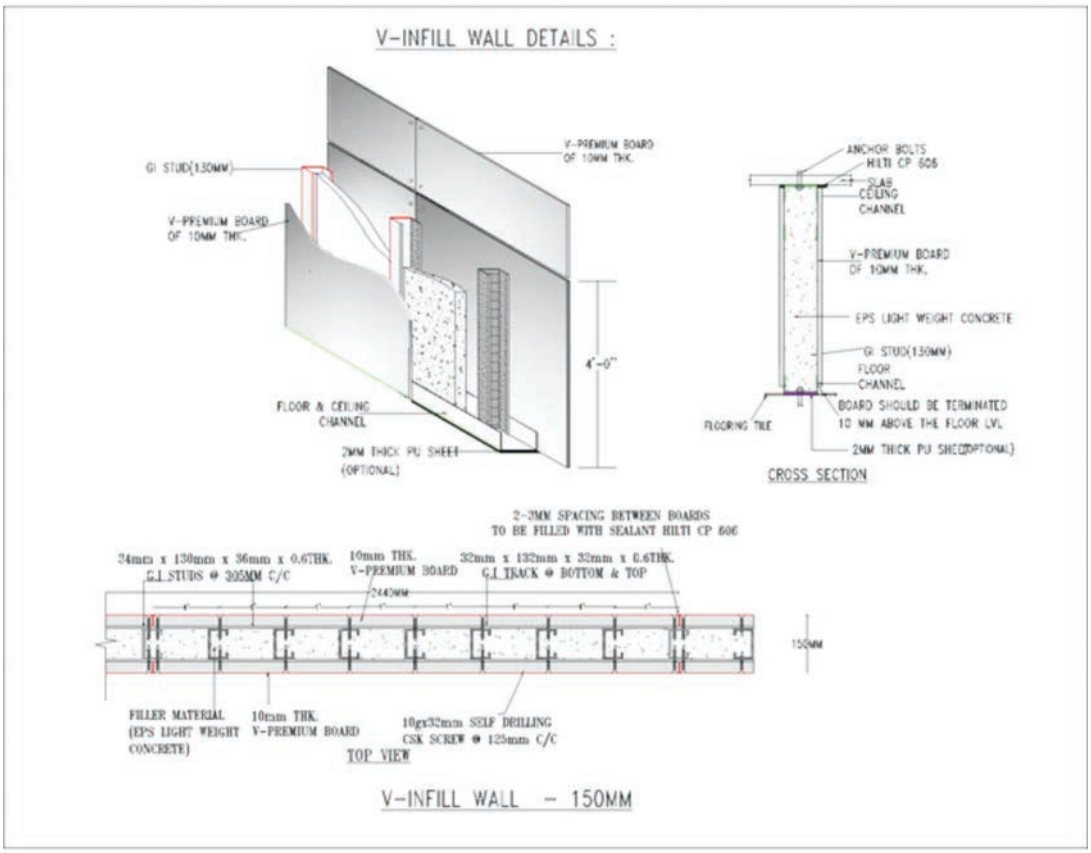
1.2.3.1 There are two types of V-Infill Walls as per details given below

1. 88 mm thick wall consists of 8mm thick V premium board of size 1.22m x 2.44m on either side of 70mm G.I studs and CSK self-drilling screw of 8g x 25mm length.
2. 150mm thick wall consists of 10mm thick V premium board of size 1.22m x 2.44m on either side of 130mm G.I studs and CSK self-drilling screw of 10g x 32mm length.

Size of Walls:

Walls are made in-situ so there is no standard size of walls. However, height and length of wall shall not be more than 3m and 5m respectively. Details of V-Infill Wall is shown in fig. 2


V-INFILL WALL DETAILS :
GI STUD(70MM)
V-PREMIUM BOARD OF 8MM THK.
V-PREMIUM BOARD OF 8MM THK.
4'-0"
FLOOR & CEILING CHANNEL
2MM THICK PU SHEET (OPTIONAL)
ANCHOR BOLTS HILTI CP 606
SLAB CEILING CHANNEL
V-PREMIUM BOARD OF 8MM THK.
EPS LIGHT WEIGHT CONCRETE
GI STUD(70MM) FLOOR CHANNEL
BOARD SHOULD BE TERMINATED 10 MM ABOVE THE FLOOR LVL
FLOORING TILE
2MM THICK PU SHEET(OPTIONAL)
CROSS SECTION
2-3MM SPACING BETWEEN BOARDS TO BE FILLED WITH SEALANT HILTI CP 606
34mm x 70mm x 36mm x 0.6THK. G.I STUDS @ 305MM C/C
8mm THK. V-PREMIUM BOARD
32mm x 72mm x 32mm x 0.6THK. G.I TRACK @ BOTTOM & TOP
240MM
FILLER MATERIAL (EPS LIGHT WEIGHT CONCRETE)
8mm THK. V-PREMIUM BOARD
10gx32mm SELF DRILLING CSK SCREW @ 125mm C/C
TOP VIEW
V-INFILL WALL - 88MM


V-INFILL WALL DETAILS :
GI STUD(130MM)
V-PREMIUM BOARD OF 10MM THK.
V-PREMIUM BOARD OF 10MM THK.
4'-0"
FLOOR & CEILING CHANNEL
2MM THICK PU SHEET (OPTIONAL)
ANCHOR BOLTS HILTI CP 606
SLAB CEILING CHANNEL
V-PREMIUM BOARD OF 10MM THK.
EPS LIGHT WEIGHT CONCRETE
GI STUD(130MM) FLOOR CHANNEL
BOARD SHOULD BE TERMINATED 10 MM ABOVE THE FLOOR LVL
FLOORING TILE
2MM THICK PU SHEET(OPTIONAL)
CROSS SECTION
2-3MM SPACING BETWEEN BOARDS TO BE FILLED WITH SEALANT HILTI CP 606
34mm x 130mm x 36mm x 0.6THK. G.I STUDS @ 305MM C/C
10mm THK. V-PREMIUM BOARD
32mm x 132mm x 32mm x 0.6THK. G.I TRACK @ BOTTOM & TOP
240MM
150MM
FILLER MATERIAL (EPS LIGHT WEIGHT CONCRETE)
10mm THK. V-PREMIUM BOARD
10gx32mm SELF DRILLING CSK SCREW @ 125mm C/C
TOP VIEW
V-INFILL WALL - 150MM

1.3 Uses, Limitations/Precautions for Walls

1.3.1 Uses:

V-Infill Walls may be used as Non-loadbearing partition walls for external and internal applications for residential and commercial buildings, schools, hospitals, factories and malls etc.

1.3.2 Limitations/precautions to be taken for using V-Infill Wallson the basis of performance, safety, geo-climatic Conditions:

- Height of 88mm wall thickness should be limited to 3m only.
- Height of 150mm wall thickness should be limited to 5m with intermediate nogging and 12mm diameter TMT bars @1' intervalsand cross members through service holes to form a mesh in the frame work.
- If wall tiles are to be used, cementious tile adhesive shall be used which will act as bonding agent between the wall and tile instead of mortar

1.4 Basis of Assessment

1.4.1 Scope of Assessment

1.4.1.1 Scope of assessment included conformance of manufactured non-load bearing walls to the specified requirements for external and internal applications for commercial buildings, schools, hospitals, factories and malls etc.

1.4.2 Basis of Assessment

Assessment of the suitability of the Lost-in-Place Formwork System

- V-Infill Wall is based on:

(I) Tests conducted for performance characteristics of the Wall by Bureau Veritas(I) Pvt.Ltd, Hyderabad.

(ii) Test performance for heavy weight anchorage byJ.N.T.U.H. College of Engineering, Hyderabad.

(iii) Quality Assurance of Fibre Cement Board, G.I studs, Channel,Screws & anchors used in V-Infill walls shall be as per the relevant IS/specifications of themanufacturers.

(iv) Performance Evaluation of two bed room house by Bureau Veritas (I) Pvt.Ltd,

Hyderabad.

1.5 Machinery & Equipment

The following equipment's are required for erection of V-Infill Wall as reported:

Sl.No.	Name of the Machine	Make
1	2	3
1.	Screw driving drill Machine	Bosch or equivalent
2.	Anchoring/Grouting Machine	Bosch or equivalent
3.	Fibre Cement Board cutting Machine	Bosch or equivalent
4.	Concrete Miller	Indian
5.	Manual Pouring Tools	--
6.	Digital Weighing Machine	Avery

1.6 Typical Activity

Typical Activity for construction using V-Infill Wall is given below:

Activity

Pre-construction

Excavation, foundation and PCC

Construction Activities

1) Erection of frame work withGI studs and channel
2) Fixing of fibre cement board (V-premium board) on one side fully and other side upto 4ft of G.I. frame work.
3) Providing electrical and plumbing conduits
4) V-Infill Concrete mixing and pumping / pouring manually between the boards upto 4ft then upto 8ft and balance area.
5) Finishing of joints with jointing powder mixed with fevicol OR acrylic putty and recommended jointing compound.

1.6.1 Framing

The framing section shall be cold form “C' type of 0.55 mm to 0.60 mm thickness in required length as per structural design requirements, duly punched with service holes at required locations as per approved drawings. The slots shall be along center

line of the web and shall be placed at 250 mm min. away from both edges of the member. The studs shall be of specified dimensions and fastened with GI channel to both top and bottom slab. Frames shall be assembled together to fabricate structures using anchor fastener The V-Infill Wall frames shall be connected by using special screws which shall conform to ASTM C 1513.

1.6.2 Fibre Cement Board (V-premium boards) shall be non-Asbestos autoclaved product. It shall be composed of a composite matrix containing special grade cellulose fibres, ordinary Portland cement, fine silica, quartz and mineral additives. It shall be manufactured as per IS 14862:2000 Type “A” Category 3having good acoustic and thermal insulations.

1.6.3 Light Weight EPS Concreteshall be prepared by mixing the raw materials in proportion as below.

1	Cement -Kg	50	per batch
2	Water -Ltrs	22.5 to 25	per batch
3	Visaka Additive- gms	100	per batch
4	EPS- 3 to 5 mm Dia beads- Kg	1	per batch
5	Sand - coarse- Kg	25	per batch

The concrete used shall be light weight and free flow. The light weightEPS concrete shall be mixed and used at site. The light weight EPSconcrete shall be pumped into the gap between the boards.

1.7 Conditions of System

1.7.1 Technical Conditions

1. Raw materials shall conform to the requirements of the prescribed specifications.

2. M/S Visaka Industries Limited shall provide full details of manufacture and erection of the V-infill wall to the agency who may be engaged for production and construction.

1.7.2 Quality Assurance

The system shall implement & maintain a quality assurance system in accordance with Quality Assurance Plan (QAP).

1.7.3 Handling of User Complaints

1.7.3.1The System holder shall provide quick redressal to Consumer/user complaints proved reasonable & genuine and within the Conditions of warranty provided by it to

customer/purchaser.

1.7.3.2 The system holder shall implement the procedure included in the Scheme of Quality Assurance (SQA).

2. Technical Specification

2.1 General

2.1.1 The SYSTEM holder shall provide servicesin accordance with the requirements specified in the relevant Standards. In addition it shall follow the Company standards specifying requirements of various materials used in the manufacture of the panels(see Part 5)

2.2 Specifications

2.2.1 Raw Materials

(i) OPC shall conform to relevant grade of Indian Standard.

(ii) Fly ash shall conform to IS 3812 (Part 2):2003.- OPTIONAL

(iii) Coarse sand shall conform to IS 383:2016

(iv) Fibre cement board (Vpremium board) shall be 100% asbestos free and of Type A, Category 3 min. as stipulated in IS 14862:2000.

(v) EPS beads shall conform to IS 4671:1984

(vi) GI stud and channel shall conform to IS 277:2003.

(vii) Adhesive shall conform to the specifications of the manufacturer.

(viii) Liquid bond shall conform to the specifications of the manufacturer.

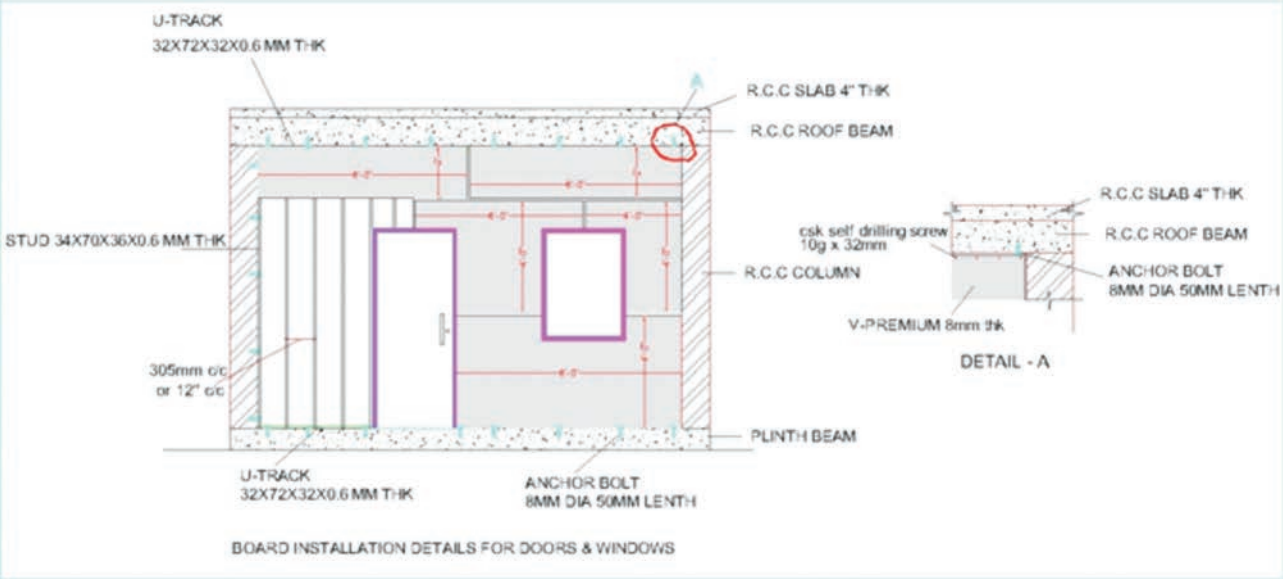
(ix) Screws and anchors shall conform to IS 277:2018.

2.3 Design Parameters

- V-infill Wallsshall be erected using fibre cement board, G.I studs and channels, anchor bolts, cement, fly ash along with EPS beads and bonding agent to form walling material.

- All concreting work shall be done in accordance with light weight concrete mix design or as per the requirement of the manufacturer with regard to workmanship and materials.

- M/s Visaka Industries Limited shall provide design data for good practices and as ready reckoner for users.

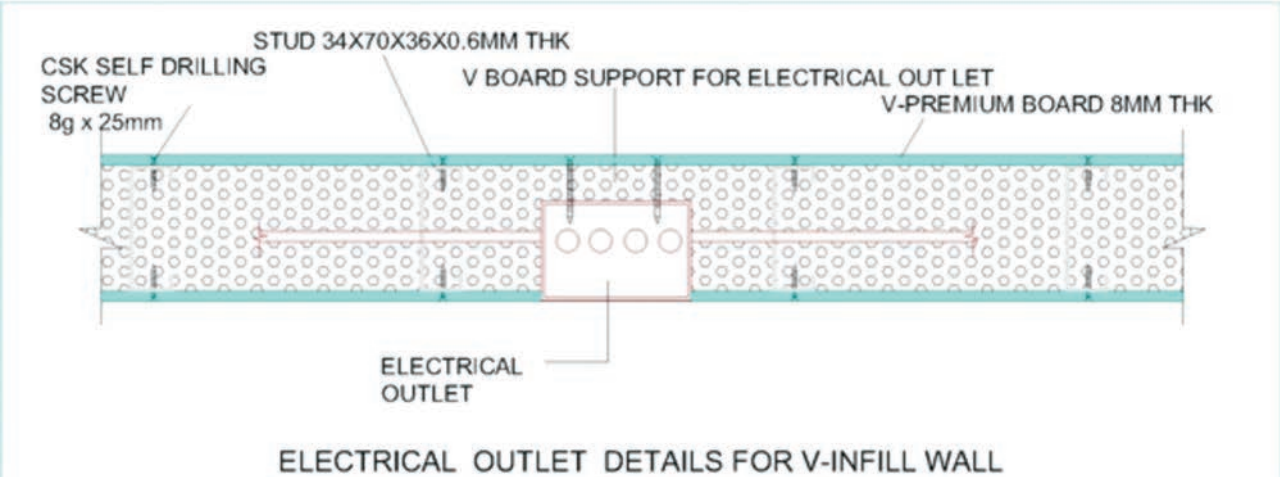


2.4 Erection of V-Infill Wall:

- Line marking shall be as per wall layout with chalk or pencil.
- The frame structure shall comprise of “C “cross section studs (vertical members) and tracks (horizontal members) frames assembled together by means of mechanical screws. GI Channel tracks (72mm) shall be placed on the foundation or on the floor and ceiling in alignment. They shall be fixedusing anchor fasteners of 6mm dia. at spacing of 400mm-600mm c/c.
- After fixing of floor and ceiling channels, GI “C” studs (70mm) shall be placed vertically with a minimum gap of 12mm to 20mm from top and bottom of floor channel webs. They shall be fixed together with self-driven metal screws at spacing of 300mm c/c. For provision of doors, windows and other openings, additional studs shall be provided.See in Fig. 4



- Electrical conduits and plumbing pipes shall be placed through the slots/holes provided in the web of the studs. Electrical boxes and boards should be fixed and embedded in EPS concrete properly. See in Fig. 5



ELECTRICAL OUTLET DETAILS FOR V-INFILL WALL





- Before fixing of cement fibre board, adhesive (liquid PU) shall be applied on flanges of GI studs. After that Vpremium board of thickness 8/10 mm shall be fixed horizontally on both sides of the frame work up to 1220mm (4ft) height using self-driven CSK screws of 8g x 32mm at 150 to 200mm spacing. See in Fig.6



2.5 Concrete mix

Light weight and free flowEPS concrete shall be used for this purpose. Concrete shall be prepared by mixing cement, coarse sand, EPS beads, water and additives in specified ratio.

2.6 Pouring of Concrete:

Prior to start concrete pour, it must be re-checked to ensure that all members are properly aligned and plumbed. The concrete specified shall be highly workable, free flowing mix poured from the top into the cavities using a small hose for pumping. The boards should be made wet by spaying water to maintain the moisture balance in the EPS concrete so that the water in the concrete will remain in it and attains its' strength. For small building construction, concrete can be poured manually using a funnel. Filling the cavities with concrete shall be done in two layers of 600mm height with an interval of 2 to 3 hours between each layer. Needle vibrator or rubber mallet or TMT bar may be used for equal distribution and compaction of concrete inside the cavities. Pouring shall be continued in the upper portion in a similar manner. Top portion shall

be filled after cutting 150mm x 150mm U shape slot in the board.





2.7. Joint Treatment:

- After walls are completely filled and mix dried, joint treatment shall be done using fibre mesh / non-oven tape and putty mixed withbinder(fevicol SH) in specified ratio on interior joints OR Cynosure N-fill or equivalent. For exterior joints, Cynosure X-fill or equivalent, an exterior jointing compound as recommended by manufacturer.

- One coat of putty shall be applied to close the joint, thensecond coat shall be applied in order to flush recessed part.
- Mesh tape shall be sandwiched between first & secondcoats to have a hold over the wall.
- All the corner joints / joints between the beam and wall / joints between columns and wall should be treated with acrylic sealant or Cynosure X-fill OR Cynosure N-fill. See in Fig.7



Wall is now ready to accept primer & paint after applying skim coat of putty as per site condition.



2.8 Typical Connection Details

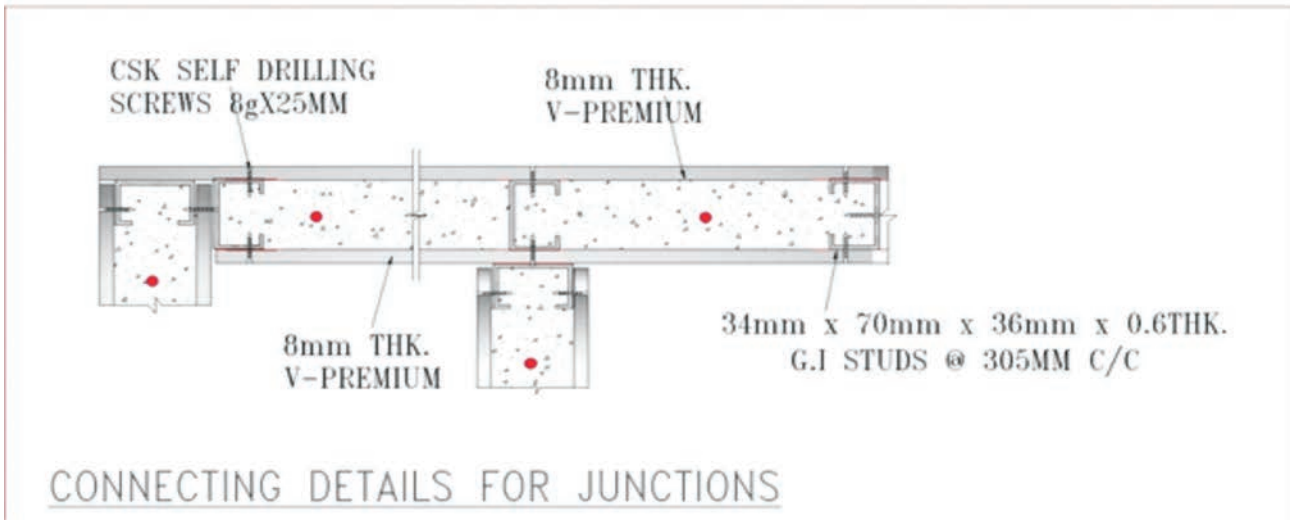


Fig.8

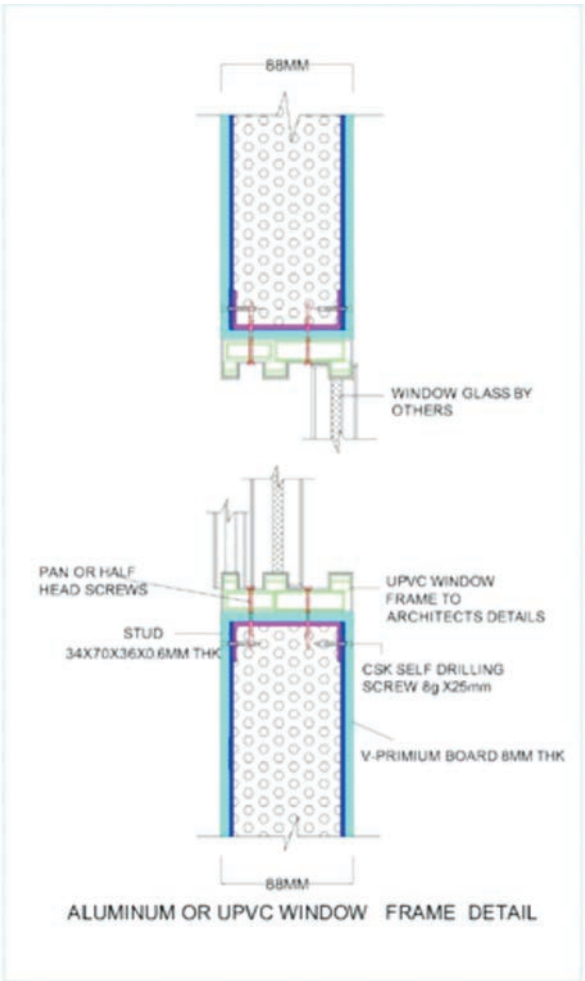


Fig.9

2.9 Manuals

VISAKA shall provide Construction, Installation and Quality Manuals and necessary diagrams, drawings, detailing to the customers and/or their structural designer.

2.10 Skilled/Training Needed for Installation

Skilled labourers like carpenter, masons shall be trained on the system and other unskilled labourers shall be trained in max. 7 days' time. Training shall be conducted on or off site depending upon the numbers.

2.11 Guarantees/Warranties

Visaka Industries Limited warrants to the Client and the Architect/client that all materials and equipment furnished under this Contract shall be fit for their intended purpose, unless otherwise specified. All work shall be of good quality, free from faults and defects and in conformance with the Contract Documents. All work not conforming to these requirements, including substitutions not properly approved and authorized, may be considered defective. If required by the Architect/Client, Visaka Industries Limited shall furnish satisfactory evidence as to the kind and quality of materials and equipment.

Warranties shall be in accordance with the Contract Documents.

2.12 Responsibility

- Specific design using V-Infill Wall is the responsibilityof the designer with the instructions, supervision and approval of Visaka Industries Limited.
- Quality of maintenance of the building is the responsibility of the building owner.
- Providing necessary facilities and space for movement of machines and vehicles is the responsibility of the building developer.

3.2 Tests Performed on V-Infill Wall

3.2.1 Tests performed on Fibre cement board (Vpremium board) by manufacturer.

S.No.	Test conducted	Test Method	Test Result
1.	Dry Density	ASTM C1185 ---	1298 kg/m^3
2.	Flexural Strength-wet	ASTM C 1185	8.8 N/mm^2
3.	Water Absorption	ASTM C1185	30.64 %
4.	Heat-Rain resistance (25 cycle)	ASTM C 1165	Pass
5.	Thermal Conductivity-W/m deg.K	ASTM C 518	0.0748
6.	Sound Insulation (8mm thick)	dB	29

3.2.3 Tests performed on samples of V-Infill Wall of thickness150 mm collected by the IOs for carrying out the following tests by Bureau Veritas, Hyderabad.

S.No.	Tests	Test Method	Result Obtained
1.	Dry Density	IS 15622:2006	1250 kg/m^3
2.	Compressive Strength	IS 15622:2006	1.56 MPa
3.	Water Absorption	IS 15622:2006	17.15%
4.	Screw Pull Out test	IS 15622:2006	913 N
5.	Flexural Strength	IS 15622:2006	2.81MPa
6.	Nail Holding capacity	IS 15622:2006	813 N

3.2.4 Tests performed on samples of V-Infill Wall of thicknessof 88 mm collected by the IOs for carrying out the following tests by Bureau Veritas, Hyderabad.

S.No.	Tests	Test Method	Result Obtained
1.	Dry Density	IS 15622:2006	1250 kg/m^3
2.	Compressive Strength	IS 15622:2006	3.21 MPa
3.	Water Absorption	IS 15622:2006	17.15%
4.	Screw Pull Out test	IS 15622:2006	1373 N
5.	Flexural Strength	IS 15622:2006	6.01MPa
6.	Nail Holding capacity	IS 15622:2006	627 N

3.3 Execution of Projects

Totally about 1, 05,000 Sq.ft of V-Infill walls have been constructed till date using our V-Infill technology.

3.4 V-Infill Completed Projects



Mr. Narender Rao Residence at Warangal, Hyderabad.



Mr. Pradeep at Salem





Hero Honda Show Room at Bangalore



Mr. Sridhar Goud at Hyderabad.

ANNEX I

(Clause 1.4.2)

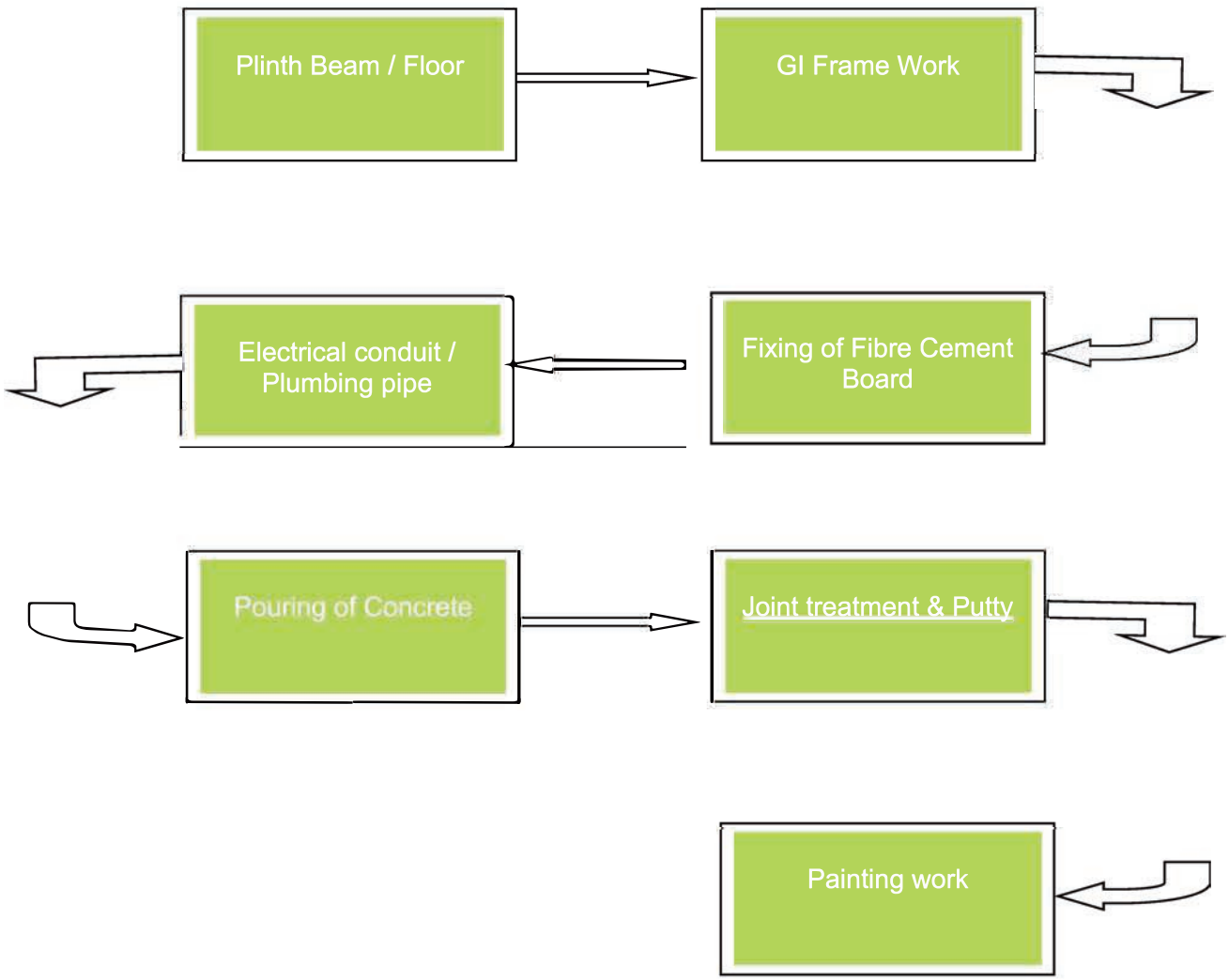
Quality Assurance Plan For V-Infill Wall System

S. No.	Parameters to be inspected	Requirement Specified	Test Method	Frequency of Testing
Raw Materials				
1.	O P Cement 43 Grade	As per IS 8112: 2013	Manufacturer's test report	Every batch/lot
2.	Fly ash Grade 1	As per IS 3812(Part 1):2003	As per IS 1727: 1967	Every batch/lot
3.	Fibre cement board	IS 14862:2000, Type A,cat-3	Manufacturer's test report	Every batch/lot
4.	GI Section	Manufacturer's test report	Manufacturer's test report	Every batch/lot
5.	EPS Beads	Manufacturer's test report	Manufacturer's test report	Every batch/lot
6.	Screws/Anchor bolt	Manufacturer's test report	Manufacturer's test report	Every batch/lot
7.	Putty	As per IS 419:1967	Manufacturer's test report	Every batch/lot
8.	Nail Holding capacity	4.6 kg/cm^2 (single nail)	IS 2380 (Part 14):1977	One time or as per requirement
9.	Fire Resistance	4 hours	ASTM E 119	One time or as per requirement

ANNEX II

(Clause 1.6.3)

PROCESS FLOW CHART OF V-Infill Wall



POLYISOCYANURATE (PIR) DRYWALL PRE-FAB PANEL SYSTEM TECHNOLOGY FOR HOUSING AND CONSTRUCTION

Saumya Anand, Covestro (India) Private Limited

Abstract

Urbanization in India has become an important and irreversible process, and it is animportant determinant of national economic growth and poverty reduction. The process ofurbanization has been characterized by a dramatic increase in the number of large cities, althoughIndia may be said to be in the midst of transition from a predominantly rural to a quasi-urbansociety. Atcurrent rate of growth, urban population in India is estimated to reach a staggering 575 millionby 2030 and 875 million by 2050[1]. However, the supply of land and housing has not kept pace with the increase in urban population; which also indicates towards enormous increase in energy consumption.

However, there is a huge gap to be bridged in order to provide housing needs to these many people which has to be energy efficient, comfortable and safe; and can be delivered in minimum time. Achieving this target with existing conventional technology/methods seems challenging, given the time constraint and rapid rate of urbanization.

While addressing aforementioned issues, Government of India has launched 'Housing for All by 2022' scheme; where alternative and new technologies for housing and construction are also being promoted, to meet demands of urbanization. This paper presents Polyisocyanurate (PIR) drywall pre-fab system technology as a non-conventional approach to housing and related construction activities. This technology addresses the concern(s) of energy efficiency, fire retardant, thermal/sound insulation, faster implementation, environment-friendliness in a housing/construction project. The PIR technology is being presented by Covestro (India) Private Limited.

Keywords:Urbanization; Housing for All; Alternative and New Technologies; Polyisocyanurate (PIR), Drywall, Pre-fab System

Introduction

India is currently in a state of transition, fueled with rapid urbanization and favorable high rate of economic growth. India's urban population is estimated to reach 575 million by 2030 and 875 million by 2050[1]. In order to provide good, comfortable and safe housing to these many people in a limited time period; alternative, new and non-conventional housing and construction technologies shall be promoted to address the gap. One of such technologies being presented in this paper is Polyisocyanurate (PIR) drywall pre-fab system technology, from Covestro (India) Private Limited.

Covestro has introduced this novel technology in affordable housing sector that can prudently meet the needs of the underserved community by providing them with people and process friendly solutions. These solutions possess characteristics that are in perfect alignment with the SDGs. This demand side intervention can be considered as a perfect example of reverse innovation – a solution whose early adopters are the underserved communities. These communities then help in propagating the usage of the solution to the top-of-pyramid segments of the society.

Polyisocyanurate (PIR) drywall pre-fab system technology is a BMTPC, MoHUA, GoI certified technology (under PAC No. 1039-S/2018, issue no. 1) [2] for housing and related construction. The technology has been well tested and tried in Indian climatic and cultural ecosystem. The technology is currently, in its commercialization phase,primarily focused on housing needs of underserved communities across India. So, far PIR drywall pre-fab system technology has been used for construction of native community housing, affordable residential housing, sanitation including school, public, community and individual household toilets, kinder-garden buildings. These projects have been delivered across Malaysia, Philippines, Nepal, Sri Lanka, India and Germany.

Polyisocyanurate (PIR) Drywall Pre-fab Panel System Technology

Polyisocyanurate (PIR) is a superior form of rigid polyurethane (PUR) technology, with better thermal insulation, sound insulation and fire retardant properties.PIR foams forms a ring structure to create a strong cross-linked 3-D

Molecule network.PIR drywall pre-fab panel systems are sandwiched panels having Polyisocyanurate (PIR) as foam/filling material with external/internal covering fiber cement board (for housing) and PPGI sheets (for sanitation). These are factory made panel systems, carried via injection molding on continuous/ discontinuous manufacturing lines. They are used for internal/external partitions and roofing panel requirement(s) in housing and related project activities, mounted over concrete/steel skeleton of building as per project design.

Raw Material and Sub-component of PIR Technology

- Fiber Cement Board: Shall be 100% asbestos free and of Type A, Category 3 min. as stipulated in IS 14862:2000.
- Poly Isocyanurate (PIR): Shall be as per specifications from Covestro. Chemical used to make PIR are basically Isocyanate and Polyol mixed in a specific ratio in presence of blowing agent.
- PPGI sheet: shall be 0.5mm thick and as conform to IS 14246:2013

- Square Hollow Section (SHS)/ C-Channel: Shall be manufactured from pre-galvanized high tensile steel conforming IS 277:2003.
- Fiber glass mesh, Acrylic based glue and Galvanized MS screws
- Anchor fasteners: Shall be in of 10mm to 12mm dia., 50mm to 75mm length as per manufacturer specification.
- Premix putty: Shall conform to IS 419:1967.

Manufacturing Process of PIR Panels

There are basically two panel manufacturing methods:

(a) Continuous Process – all materials used are processed together and completely formed panel is cut to desired length without stopping the line. Continuous Process (for both wall and slab panels) – consists of (i) External layers processing section (ii) Insulating material process section and (iii) Panels handling section.

(b) Discontinuous Process – materials are processed separately, this means that the facings are formed and cut to desired length and then assembled together in a press where foam is injected. Diverse technologies apply to discontinuous production process, namely:

- Manual mode injection technology at closed mould
- Automatic mode lance displacement at closed mould
- Automatic mode injection technology at closed mould.

Assembly/erection method – steps involved in installation of PIR panels

- RCC/Concrete Base: (1a) A concrete base shall be constructed as per design. (1b) Surface over which SHS/C-channel is to be placed shall be cleaned.
- SHS/C-channel: (2a) SHS/C-channel shall be placed over concrete surface. (2b) Top layer of SHS/C-channel shall be drilled. (2c) Bottom layer of SHS/C-channel that goes into concrete shall also be drilled. (2d) Fastener of 10mm to 12mm dia. And 50mm to 75mm length shall be inserted into drilled hole @600mm c/c and fixed tightly. These steps shall be repeated to fix entire SHS/C-channel.
- Panel installation over SHS/C-channel: (3a) Panel shall be identified with reference to respective points of installation as per drawings. (3b) 15mm groove shall be made at

panel edges, as required.

- Screwing of Panels with SHS/ C-channel: (4a) Screws shall be fixed on the points marked on the panels. (4b) Proper drilling procedure as specified by manufacturer shall be followed. (4c) SHS/ C-channel bottom runner G.I. section shall be fixed with RCC base with anchor fastener @600 c/c on which vertical G.I. support will be screwed. (4d) Panel shall be supported on vertical support and bottom runner by screwing.

- Finishing of Panel Joints: (5a) MS flat rod shall be used to rub the joint edges so that edges become blunt and shall appear as V-shaped groove. (5b) Joints shall be cleaned to remove dust etc. (5c) V-groove shall be provided at joints to be filled with elastomeric putty and fiber mesh shall be pasted. (5d) pre-mix acrylic glue shall be applied over joints, using a putty knife and let it dry. (5e)Surface shall be smoothened with sand paper. (5f) After that glass fiber mesh shall be pasted over first coat of pre-mix glue. One more coat of pre-mix glue shall be applied properly over glass fiber mesh and let it dry for 5-6 hours. (5g) For final finish, surface shall be painted.

Comparison of Polyisocyanurate (PIR) Drywall Pre-fab Panel System Technology with Conventional Technology

S. No.	Parameters	Polyisocyanurate (PIR) Drywall Pre-fab Panel System Technology	Conventional Technology
1	Skeleton and Foundation	Concrete / Steel frame (as per design)	Concrete
2	External/ Internal Partitions	PIR pre-fab panel systems	Brick and mortar
3	Plastering of Walls	Not required	Required
4	Thermal Insulation	Excellent (PIR has K-factor of 0.02 W/m-K.)	Poor
5	Sound Insulation	Good	Poor
6	Cement and Sand Requirement	Reduced	Not reduced
7	Carpet Area	Increased	No Change
8	Carbon Foot-print	Reduced	Increased
9	Fire Retardant	High	Low
10	Time of Construction	Fast	Slow
11	(Overall) Operational life-cycle cost of house	Reduced	No Change
12	Transportation	Easy and reduced number of vehicle rounds (comparatively)	-
13	Reusable	Can be dissembled and re-used	No

Select Project(s) Implemented Using PIR Drywall Pre-fab Panel System Technology

Project(s) - **India**		
	JAIPUR: G+3 House with Built-up Area: 510 sq. ft.	KANCHIPURAM: 7 no. of (G+0) Houses with Built-up Area: 350 sq. ft.

Project - Malaysia	
	Kg. Kudei: Kindergarden

About Covestro [3]

With 2018 sales of EUR 14.6 billion, Covestro is among the world's largest polymer companies. Business activities are focused on the manufacture of high-tech polymer materials and the development of innovative solutions for products used in many areas of daily life. The main segments served are the automotive, construction, wood processing and furniture, and electrical and electronics industries. Other sectors include sports and leisure, cosmetics, health and the chemical industry itself. Covestro has 30 production sites worldwide and employs approximately 16,800 people (calculated as full-time equivalents) at the end of 2018.

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PRECAST TECHNOLOGYIN CONSTRUCTION: ELEMATIC – FINLAND BASED TECHNOLOGY PARTNER

Shrikant Luktuke, Elematic India

As India ushers into the era of development, Industrialisation of construction activity is required to achieve speed – Quality – Cost equation.

Precast Technology offers all the above and accelerates the Critical path and increases throughput by eliminating bottlenecks.

Precast construction technology will gain prominence because of the following drivers that are driven by Government policy and market forces;

- Affordable housing-India has huge shortage of houses especially considering the population and migration into cities which makes living difficult and is an impending disaster if not addressed now.
- India has to meet its target of housing for its people within a short time frame.

  Case to study: Leading the way is Delhi Development Authority which has ventured into precast and at the moment is being delivered 40-45 apartments per day totalling to about 10,000 housing units per year with B G Shrike as the contractor.Such humungous volume of construction within a short time with assured quality is possible only in precast.
- New policy norms introduced by the government such as RERA, IBC&GST all propel the growth of organised construction hence support technology such as precast construction.
- The new acts are a response to the dire need of Indian consumers and in discharge of the sovereign functions towards public interest. RERA incorporates defect & liability clause.
- Precast construction ensures buildings are built to last and not for repair. That the lifecycle cost of building is almost nil.The precast buildings usually require minimal maintenance for many years

Precast technology, by virtue of the process of casting under controlled circumstances, adheres to the highest standards of quality control. Production in a precast plant ensures effective curing and monitoring, unlike onsite pouring, which is affected by factors outside the control of the contractor and hence affects , quality and workmanship.

Precast constructionhas some significant advantages over traditional cast in situ construction;

- Technology -Move towards organised construction
- Time savings- where up to 50%-time savings compared to traditional construction has been achieved
- Labour savings - Significantly brings down the labour requirement at site.
- Efficiency – Man – Material – Money-It gives a huge impetus to the productivity.
- Plaster Free -The top finish in a precast building is so good that we can save on the top finishes which amounts to time and cost saving.
- Predictable Time lines- The unpredictability and variation in construction costs and timeline significantly comes down allowing a professional approach to construction.

One of the biggest advantages of precast is unmatched capacity to handle scale and unmatched sustainability that it brings on the table.







Elematic is a 60-year-old Finland based company, providing precast construction technology solutions.A world leader in supply of pre-cast equipment., Elematic in India is operating since 2007 and has setup a manufacturing plant at Alwar, Rajasthan.

Elematic has installed more than 30plants across India. End to end handholding for the customer wanting to adopt Precast construction is available.

Elematic Provides complete support to the customer from Concept to Execution of a precast project and have a 100 member well qualified team offering;

- Concept design and Engineering services
- Plant selection and designing of plant
- Plant installation and training
- After sales service
- 3rd party services such as quality audit and project management

In today's situation, time is the essence of any project. That is why, precast is the only option to reduce the timeline in handing over the projects quickly.Precast Construction is a sine qua non to take India from a developing country to a developed country.

BUILDING INFORMATION MODELLING

Usha Batra, Special DG(WR), CPWD, Mumbai
Dr K M Soni, Additional DG (T), CPWD, New Delhi

Abstract

Construction industry is at the cusp of a new era, with technology creating new applications and tools that are changing the way we design, plan, and execute projects. By providing advanced software, construction-focused hardware, and analytical capabilities, the innovative technology is eliminating many of the problems that have dogged the construction sector in the past. Such improvements are unpreventable as construction projects are becoming increasingly complex and costly, putting project managers under greater pressure to manage time, quality and cost.

BIM (Building Information Modeling) technology helps to resolve these issues. BIM improves understanding and cross-comprehension between disparate parties who are working on the same construction project, allows problems to be detected, diagnosed, and fixed before construction starts saving considerable amount of time and money.

Introduction

Better designed buildings provide increased comfort, productivity and efficiency to its users due to adoption of efficient building design, materials, services and cost effectiveness. Construction projects have large number of stake holders involved during planning, design, construction and maintenance hence their coordinated efforts and concepts in terms of design before actual execution through virtual execution of works can provide the best of them.

BIM (Building Information Modeling) is a single piece of information source where all the ideas of the stakeholders, designs, functional characteristics, operational details etc. of a construction project are compiled, kept intact, without spilling out or even creating any redundant data or information as it is an intelligent 3D model based process that provides architecture, engineering, services, and construction professionals the insight and tools to plan, design, construct, and manage buildings and infrastructure more effectively. BIM creates a high-quality digital representation of the building which can be used to predict performance, estimate costs and plan construction through virtual construction and as such it has the ability to foresee problems in a project even before start of construction. It's a technique and series of software programs that is being used more often now because of all such benefits. It improves communication and operational efficiency and heavily cuts down

the cross referencing and approval time during the project's construction phase. Increased productivity in turn directly helps in reduction of the overall project construction time and cost overruns.

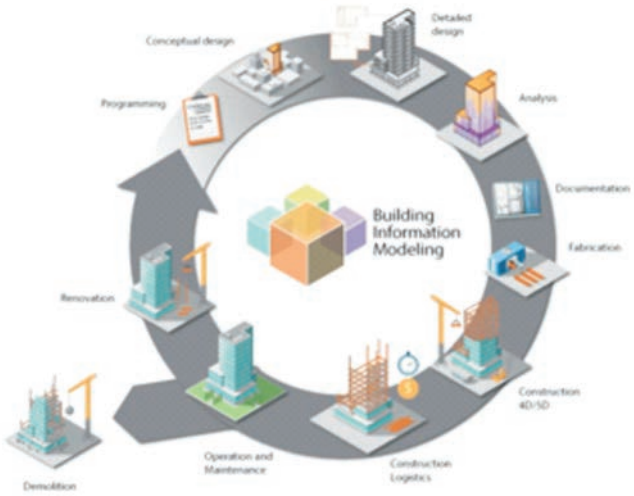
Time and Cost Overruns

Reasons for time and cost overruns as surveyed by NED university include long period between design and tendering, and excessive change orders. Main reasons for long gap between design and tendering include coordination issues between various drawings. Change orders are due to inability to visualize the final product at the design phase in 2D drawings causing delays and extra cost, less coordination and collaboration between various stake holders resulting in poor decision making and dissatisfaction of everyone affecting quality of work resulting in coordination errors.

Since construction projects involve huge number of stake holders, problems in construction industry include lack of proper planning and coordination among various stakeholders, poorly coordinated designs, change orders, delays and cost overrun leading to claims and litigations, difficulty in responsibility fixation, lack of project monitoring, lack of integrated project decisions and delay in payment to suppliers and sub contractors. BIM helps in resolving these issues.

BIM (Building Information Modelling)

BIM is parametric, 3D model that is used to generate coordinated plans, elevations, sections, perspectives details, services and schedules including all other necessary components to document the design of a building from the data or 2 D drawings available. BIM saves time and money during planning / design, construction and management and more so in case of conflicts in various drawings/designs.

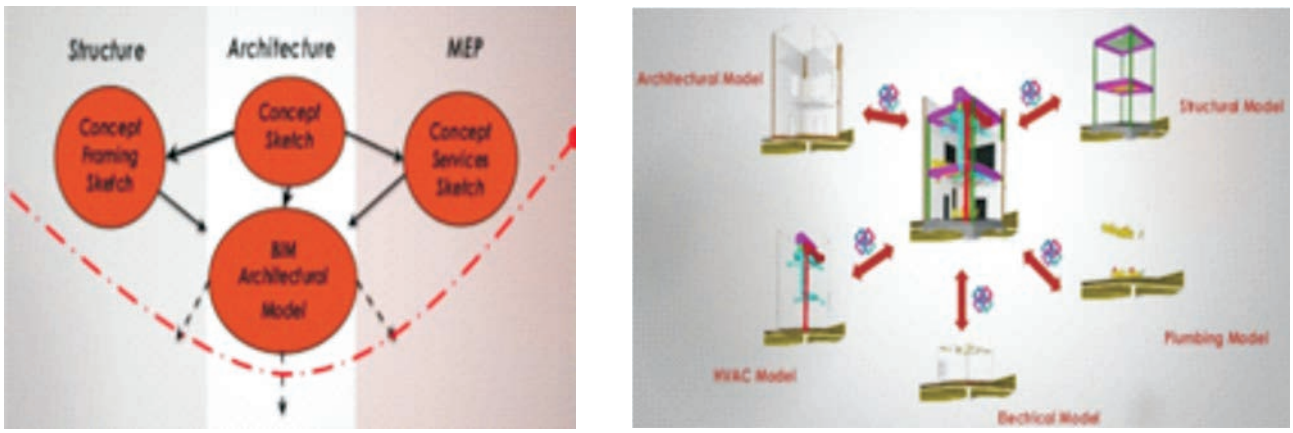


Life-cycle of the building information model

BIM, the creation and use of information about the construction can be used to form a solid basis for all decisions over the lifetime of the object – from concept to completion. The implementation of BIM is not a transition to a new program rather is the implementation of the new technologies to work with objects, including a new approach to design, a new level of organization of construction and completely different ways to manage it. The use of BIM may not stop after the building is designed and built but continue for the phase of operation and maintenance as well and can be used for renovation and demolition in future.

The 3D model is related to the information database, in which each element of the model can consist of additional attributes. The main idea is that a project is designed as a single unit, and a change in one of its parameters entails automatically a change in the other related parameters and objects, also the drawings, renderings, specifications and timetable, thus, less need for rework and duplication of drawings for the different requirements of building disciplines. The model contains more information than a drawing set, allowing each discipline to annotate and connect its intelligence to the project. Unlike the general practice where one division/unit isn't fully aware or informed about other division/unit in the overall project and provides stakeholders, engineers, designers, managers, etc. an overall view of the entire project. Thus, with BIM, various units can work coherently by indexing their work in centrally located BIM data leading to improved coordination, and providing a great work environment.

As BIM is centralized, any updates or changes made by an individual are instantly reflected in the centralized model leading to uniformity of information and work which leads to zero construction errors. Thus, BIM drawing tools have the advantage of being much faster than 2D drawing tools as each object is connected to a database.



Work done on individual models of Architectural, structural, plumbing, electrical and HVAC is reflected in central model

Sharing and collaborating in BIM is easier than with drawing sets, as there are a lot of functions that are possible only through a digital workflow.

BIM has the increasing number of simulation tools that allow designers to visualize such things as the sunlight during different seasons or to quantify the calculation of building energy performance. The BIM helps automate clash detection of elements such as electrical conduit or ductwork that run into a beam. By modeling all of these things first, clashes are discovered early, and costly on-site clashes reduced.



Clashes detected during planning can be corrected in planning itself before start of construction

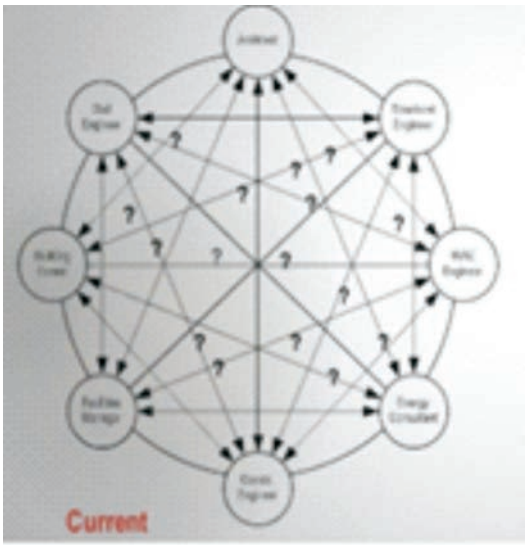
Forms of output information from the model

Information about the building contained by the model can be obtained in a large range of species for external use. Generally recognized forms of output information include 2D and 3D drawings, files for use in the internet, files with engineering task for producing components and structures, files-orders for the supply of equipment and materials, result of special calculations, videos showing the simulated process and files with visualization, animation and printing. All these forms of output information provide the universality and effectiveness of BIM as a new approach in the design of buildings and ensure the main position in the architectural and construction industry in the near future.

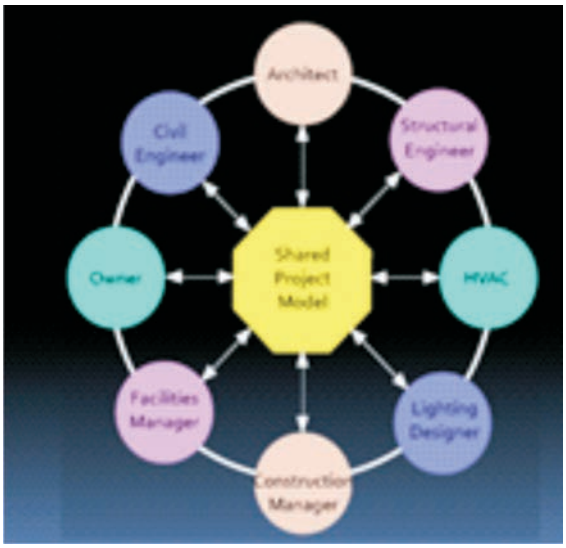
Difference in Working of Conventional System and BIM

In conventional system, each stake holder is interacting with all other stake holders, preparing its document / drawing / data, without a comprehensive document, whereas in BIM each stake holder is interacting and feeding its data in the centralized model only, which becomes a comprehensive document by itself without any extra effort. The system itself clarifies the level of complications and confusions involved in the conventional system to

arrive at an error free solution.



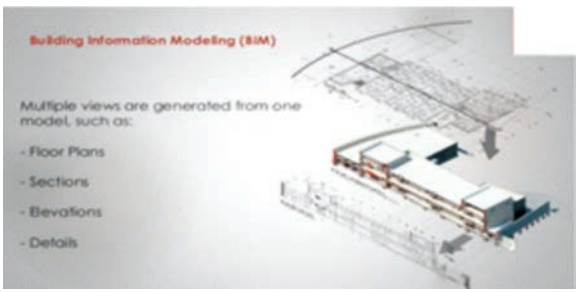
Conventional system



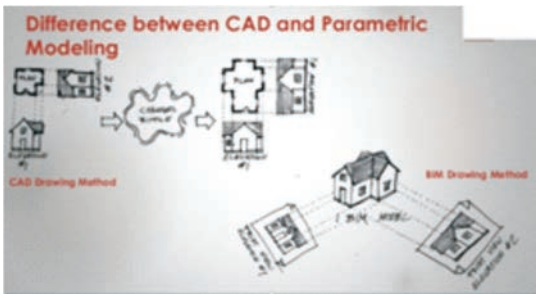
BIM system

In BIM, 3D model is prepared in REVIT software, with the basic sketches and complete specifications and is further improved by looking at what needs to be improved through various available and visualization options. The system by itself demands that detailed thinking is given to the project before start of construction. When decisions are finalized before start of construction, cost of design is reduced heavily. 2 D drawings are not required to be drawn but are simply generated from the same model through a command.

Although better visualization is possible in 3D model, 2D drawings are a must for carrying out construction. Through the same 3D model, perspectives and walk through can also be generated. Quantities of materials and cost can also be linked. Further energy efficiency calculations can also be made part of this model.



BIM- 3D model generates 2D drawings

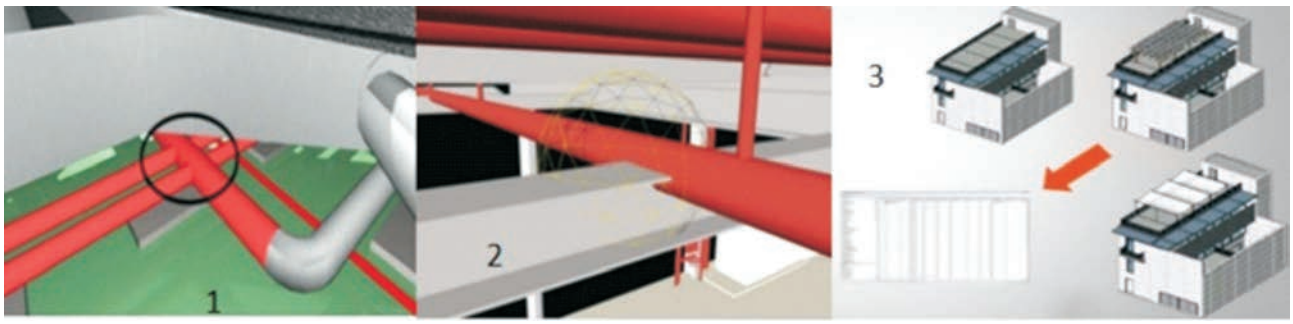


Difference between CAD and BIM

Advantages of using BIM

- It can prepare drawings more precisely and quickly.
- Can generate different design alternatives with cost in less time.

- It can generate various drawings from model created through Revit.
- Improves quality, reduces time and cost.
- Increases satisfaction due to better design understanding and communication.
- Provides satisfaction due to overall quality, speed of work, information transparency and consistency.
- Ensures better communication between various stake holders.



Checks clash detection

Reflects changes in quantities

- Checks clash detection tools inbuilt in the system reduces clashes between various stakeholders thereby reducing delays and saving time.
- Reflects changes in quantities due to change in design.
- Different design options and their impact on cost can be obtained easily without much effort and time.
- Material usage at different stages can be tracked using BIM.
- Can improve safety situation at site through simulation.
- During construction, it can show the difference between planning and actual construction schedules i.e. behind or ahead of schedule.
- It can make study of shadows and energy analysis for sustainable design.
- Using BIM, facility data as well as operation manuals of different building components can be stored in single model for use of renovation and maintenance.
- Construction site can be effectively managed using visualization. Crane location and operation can be visualized earlier and logistics organization planned better.

BIM Applications

Various models are available depending upon the application required starting from 3D to 7D. Minimum cost of consultancy in 3D model and maximum in 7D model. 3D Model is a visualization model showing existing conditions model, clash detection, animations, rendering, walk through and BIM driven prefabrication. 4D Model includes time model, which shows project phasing simulation and visual validation for approval of payment and as such useful to curtail time overrun. 5D Model is a cost model, which shows quantity extraction to support detailed cost analysis and as such useful if cost has to be incurred due to time overrun and deviations. 6D Model is an energy model, which shows various analysis related to sustainability e.g. energy performance, day lighting, shadows, airflow, climate and solar radiation while 7D model is facility management model, which shows BIM embedded O & M manuals, computerised building database for record, renovation and maintenance.

Use of BIM in CPWD

CPWD executes the works on contract basis where drawings are prepared by the architect, structural designer, E&M engineers and plumbing service designers. In case, all such drawings are prepared in BIM in 3D model, which can generate all the required 2d drawings for carrying out construction, before actual execution and any error or conflict can be detected and removed well before start of execution e.g. suppose, AC duct and sprinklers or fire detectors are conflicting with structural beam, BIM model will detect them in advance. Similarly all architectural, structural and services drawings can be integrated and errors detected through virtual construction. This is feasible even in 3D BIM model. 4 D BIM model can predict the time overrun and if the contractor takes adequate precautions as per resource utilization derived through BIM, time overrun can be avoided. 5 D model can estimate the cost factor also for the contractor due to deviations and time overrun. 6 D/7D models help during energy efficiency and facility management and as such where contracts include them and the contractor wants to estimate the effects due to energy efficiency /facility management, such models are helpful. In case of CPWD, mostly contract is awarded where contractor has to absorb all the risks hence 3 D model may be adequate if drawings are to be supplied by the Department. In case of EPC contracts, it helps the contractor also.

CPWD has made mandatory through OM no. DG/MAN/MISC/25 Dt. 15.03.2019, use of BIM in case of projects having multiple services. Since multiple services are expected in case of G+4 buildings, Chief Engineers and CPMs have been delegated authority to take decision based on the services involved in the projects. It has also been decided that the BIM consultants will be engaged by the Department in case of in house designs and by the construction agency/contractor in case of private consultants/EPC projects through

provisions made in NITs.

Conclusions

- BIM is an innovative way to virtually design and manage projects
- Simultaneous working by different teams can be seen / visualized in the same model and clashing points if any can be detected quickly.
- It accelerates collaboration with project teams leading to improved design with minimum or no conflicts in design, better time management and visualisation for non-technical persons giving better client satisfaction.
- Design conflict management through clash detection tools before execution saves time, energy and money.
- Different options with changes reflecting in quantities of materials and cost facilitate quick decision making.

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NEW TECHNOLOGIES USED IN EXPANSION OF NEHRU HOSPITAL PROJECT(334 BEDDED) AT PGIMER CHANDIGARH

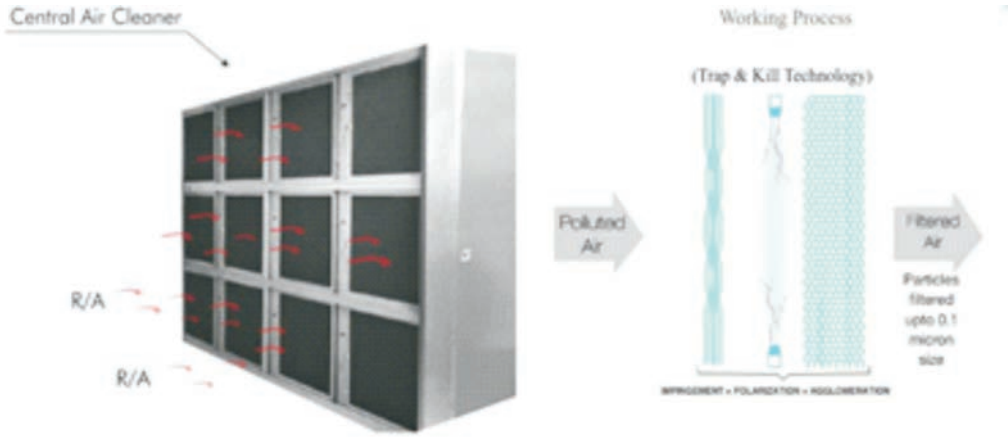
Rajeev Kumar Sao, SE Cum PD PGIMER Proj Chandigarh

Central Air Cleaners

Hospital Acquired Infections (HAI) is an infection that is acquired in a hospital .HAI are caused by viral,bacterial and fungal pathogens. Airborne Microorganisms(Bio Aerosols) are a major cause of spreading disease. When we sneeze millions of tiny droplets of water and mucus are expelled at about 100 metres per second).The droplets initially are about 10 -100 microns but they dry rapidly to droplet nuclei of 1 -4 microns containing virus particles or bacteria. This is a major means of transmission of several diseases in humans such as Tuberculosis, chickenpox, smallpox, infuenza - MRSA etc.

Tuberculosis: A single infected untreated person can spread the disease to 10-15 individuals. Poor Indoor Air Quality(IAQ) in the hospital buildings is one of the main factors leading to HAI and can lead to other building related illness such as headaches, fatigue, eye,skin irritations and other symptoms. So it is important for hospitals to ensure a good IAQ to safeguard patients, nursing staff and visitors from the hazards of occupational diseases and HAI.

In expansion of Nehru Hospital project at PGIMER Chandigarh we have provided Central Air Cleaners in the return air path of the AHUs to take care of the above problem.Multistage Air Purification - A multistage air purification (Impingement, Polarization & Agglomeration) along with active carbon filter ensure e□cient reduction in all the three pollutants of indoor air (Particulate matter, Pathogens & VOC's) resulting in complete Air Treatment.



Advantages:

Highly E cient in Reducing PM 2.5 - The advanced Air Treatment technology captures micro particles, which is similar as HEPA class of filtration. Low Pressure Drop - and saves lot of

energy. Trap & Kill Technology - Disease causing germs are not only trapped, but also killed. Energy Saving - Maintains cleaner coil with no bio-film, resulting in upto20% energy saving benefits. In addition, because of very low pressure drops (Very low 0.20" Wg @ 2.5 m/s airflow resistance) reduces the motor capacity of the AHU,and results in substantial energy saving when compared with any conventional filtration technique. Filter Cleaning Alarm - Inbuilt filter cleaning alarm helps in effective performance of the Central Air Cleaner.

Automated Materials Transport System(AMTS):It is an in-house means of transport, which conveys items of any kind to different goals within the system. AMTS are used for spontaneous transport and complement thus other in-house conveying systems. A distribution network of tubes(160 mm Dia) through which carriers of various sizes transport items to and from designated destinations. AMTS transport materials at speeds between 3 to 8 meters per second.



AMTS STATION

This system can be used for the transport of:

a. Drugs b. Blood Samples c. Organ & Tissue Samples d. Other samples (urine etc… e. Imaging Documents (x-rays etc.). f. Discharge Summary Documents g. Billing Documents h. Prescription Documents i. Standard errands j.Analysis Reports k. Surgical materials (instruments etc.). l. Cash m. Confidential & Classified Documents & more. .....

How does an AMTS function?

A blower generates suction or compression of air that propels the carriers through the tube network. Diverters create the possibility of extending the tube network in many directions,so that the carriers reach all the destinations of the system. Distance and height do not represent any obstacles. Efficient positioning and appropriate size of the blower units offer limitless possibilities.



AMTS PLANT ROOM

In a hospital of this size (334 beds) over 2000 runs are expected every day. A comparasion is shown below and it can be easily concluded that if we consider the various advantages including the life cycle cost AMTS system is much better then the Human dependent transport.

Particulars	Human Dependent Transport	Pneumatic Tube system
Capital Investment / Initial Investment	**Negligible**	**One Time Investment**
Recurring Annual Costs (Energy &Labour)	**Millions of Rupees Each Year**	**Nominal**
Transaction Time Per Run	**12 – 30 MINUTES***	**30 secs – 180 Secs***
Class IV Level Employment Related Problems	Very High	ZERO

Disobedience	High	ZERO
Mix-up, Breakages	High	ZERO
Confidentiality Breach	High	ZERO
Pilferage Possibility	High	ZERO
Bio Hazards	High	ZERO
Guarantee of Delivery	Medium	100%
Security	Low	Very HIGH
Safety	Low	Very HIGH
Economical	NO	YES
High-Tech, Facility Enhancement	NO	YES
Energy Effciency	Low	Extremely HIGH
Use of Elevators / Dumb Waiters	HIGH	ZERO

Human Carcadian Centric Lighting

Sunlight varies in Color Temperature throughout the day.

Thisis becauseof the scattering of light which variesdue to the variations in the length of the sunlight which passes through the atmosphere.when the Sun Rises sunlight has to travel larger distance through the atmosphere blue colorgets scattered and only yellow/orange color reaches us. Whereas in the afternoon sun comes directly over the earth,none of the colors are scattered and the Sunlight is white. Again as the sun sets, the Sunlight reaching us becomes devoid of blue, thus appears Orange.

By sensing, the blue component only in sunlight, the body can also infact tell the time of the day.

The body uses these cues from Sunlight to release appropriate hormones (such as appetite/hunger hormone in the afternoon), throughout the Circadian Cycle

How does light its color temperature&the darkness affect our body ?

Hormone production: Some of the harmones produced in the body are light color/intensity dependent.

-Dopamine: responsible for Day-pleasure,alertness,Muscle coordination

-Serotonin: responsible for Day-Impulse Control,Carbohydrates Cravings

Cortisol:Day-stress response

Melatonin: Night-sleep.

Disrupted circadian rhythm results in:

>Trouble getting a sound sleep

> Feeling down or depressed

>Crave carbohydrates

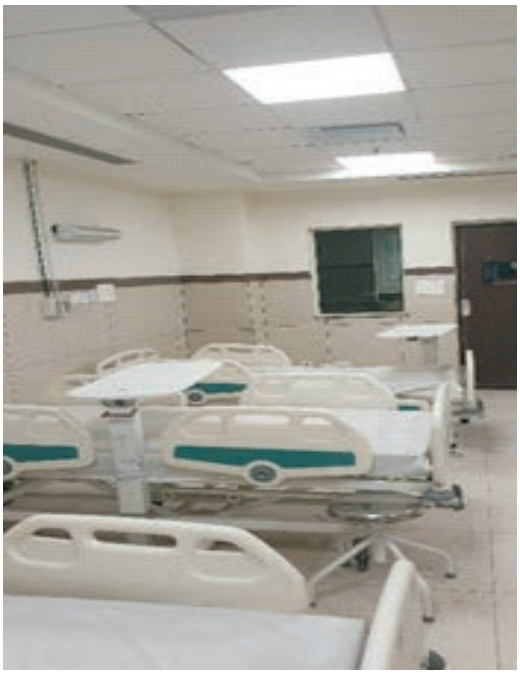
> Poor coordination

> Can't think straight

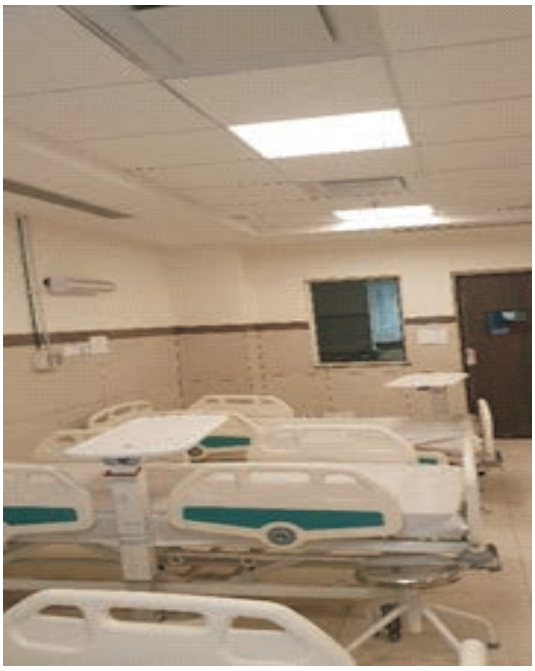
Patient orientation to windowsSpeedsup recovery time

And Needs less medication

Circadian lighting changes the ambient colour as per the outdoor lighting colour temperature and greatly helps in aligning patient's body clock with the natural one, which influences recovery.



High CCT and High Lumens
during Morning to Mid Afternoon



Convert to warm light in the night

In this project we have used Dali dimmable tunable white fixtures(Variable CCT from 3000K - 6000K) with suitable optics for glarefree and uniform illumination UGR<16.We have also used lighting Control units for the functionality of the indoor space with dynamic rhythm (biorhythm curves).

- Sleep better, so recover faster.
- Modern Lighting , while allowing us flexible work schedule , has unwittingly played a role in decreasing Human Health.
- Lighting controls our Hormone Cycle, hence incorrect (unnatural) lighting causes imbalance of Hormones which has resulted in a spurt in incidence of Health Disorders.
- By using Human Circadian Compatible Lighting we now have a chance to correct our health and be in synch with Nature.

EPS (BEADS) CEMENT PANELS

Ratan Singh, Director, Rising Japan Infra Pvt. Ltd.

EPS (BEADS) CEMENT PANELS – A introduction

EPS (Beads) Cement Panels are lightweight composite wall, floor and roof sandwich panels made of thin Calcium Silicate board as face cover boards and the core material as EPS granule balls, adhesive, cement, sand, fly ash and other bonding materials in mortar form.

These are ready to use panels which can be used with RCC or steel support structure of beams and columns. These panels are primarily used as walling material but can also be used as floor and roof panels. Up to two floors these panels can work as load bearing thereafter it is to be used with structural support frame.

- **Manufactruing Process**

The core material in slurry state is pushed under pressure into preset molds with Calcium Silicate Boards as cover and once filled is moved for curing.

Materials Used

Ordinary Portland Cement, Fly ash,

EPS beads, Calcium Silicate Board,

Fine sand, Water, Adage RD Powder,

Additives & Bonding agents

Production process Stage -1 - Raw materials preparation

- EPS granules are expanded into foam EPS by expanding Machine /system with suitable size and shall store the foam EPS in storage silos ready for next production stage.
- Cement, fly ash and sand are transported from the storage silos by the screw conveyors to the mixer according to the programmed ratio and water are fed into the mixer in designated proportion.
- The foamed EPS are transported through the blower in a programmed quantity at the same time into themixer and mixed with the slurry.
- Additives are added to the mixer at the same time.

- After about 8 minutes of mixing, the finished mixed materials are ready and discharged into the fillinghopper.

2 - Materials filling system

- During the materials mixing process, the molds are set and two covers of Calcium silicate board or Cementfiber board inserted one by one in each mold. Thereafter, the ready-set mold are moved under the fillingplatform by winch machine.

Material Filling

- Once the mold cars are under the filling hopper, the top platform open up and the material are filled intothe molds under pressure.

Curing

- After the filling is over, the filled mold cars are transported by the ferry car to the curing area for about 5to 6 hours curing. Curing time depends on the site temperature conditions.

De-molding process

- After required period of curing, the panels get enough strength and suitable for de-molding. The de-molding process can be automatic or manual depending on the mold car chosen.
- If the mold car is automatic type, de-molding machine are used to pull the panels out of the mold car automatically. In one step, one panel are pulled out from the car and stacked.
- After this process is completed, the mold cars are re-set for the next production cycle.



Panels for Walls, Roofing and Flooring

PHYSICAL SPECIFICATIONS

Items / Panels	Length mm	Width mm	Thickness mm	Density kg/m2
Sandwich Panel	2440	610	60,75, 90, 120, 150, 180	45, 54, 63, 81, 99, 117
Solid Panel	2440	610	60, 75, 90, 120 150, 180	41, 51, 61, 81, 101, 121
Hollow Panel	2440	610	90, 120, 150, 180	33, 52, 65, 77

TESTING SPECIFICATIONS

S/N	Items	Testing Indexes Thickness		
		60mm	90mm	120mm
1	Anti-impact performance / times	≥5	≥5	≥5
2	Anti-bending damage load / Times over deadweight	≥1.5	≥1.5	≥1.5
3	Anti-pressure strength / Mpa	≥3.5	≥3.5	≥3.5
4	Soften coefficient	≥0.80	≥0.80	≥0.80
5	Surface density kg/m2	≥70	≥90	≥110
6	Moisture / %	≥12 / 10 / 8		
7	Drying shrinkage mm / m	≥0.6	≥0.6	≥0.6
8	Signal point hanging strength / N	≥1000	≥1000	≥1000
9	Sound insulation capacity in the air Db	≥30	≥35	≥40
10	Fire proof limit / h	≥1	≥1	≥1

- **Meeting Building Standard requirements**

The construction materials from clay brick to non-clay, from solid to hollow, from small to large, from heavy to lightweight, from low intensity to high-strength, from high to low energy consumption has fueled the demand so much that today there is a big demand of EPS Cement Panels production facilities. The product meets all international building standards from **ASTM to EU to BBS to BMTPC, CPWD etc.**

- **Installation Process:**

All instructions given in the Construction and Installation Manual should be strictly followed along with the above preparations.Proper care should be taken in joining the panels together, fixing them with Pillars and beams and when placing them on the floor.

With Steel frame structure: If steel structure frame is used in the construction then 'U'type channels are used to hold the panels with the structure. In this case additional clips should be welded with the frame pillars and beams to hold the U cannel firmly with the pillars / beans and floor. Then only the panels should be inserted into the U channels. There after PU glue should be applied to hold the panels firmly.

With RCC frame structure: If RCC frame structure is used in the construction then the panels should be directly fixed on the walls, Pillars, Beams and Floor with the help of Cement glue and later Iron locking rods should be inserted in the panels and the pillars, beams and floors at 45° so that they are firmly locked with each other and becomes one single unit.

After installation of the panels in both systems all gaps should be checked and filled with additives, PU and cement mixers and later thin putty should be applied to give uniform smooth surface ready for paint.



Advantages of Infra EPS Cement panels:

1. Carbon-Negative utilizing fly-ash
2. Environment-friendly and Non-toxic
3. Significantly reduce Air and Noise pollution

4. Reduce construction waste
5. Saving water due to dry-construction
6. Increase in carpet area up to 20% which saves money
7. Lighter Building Structure and Foundation due to light panels
8. Labor Saving
9. Easy and Faster Construction
10. Cost Effective
11. High Banging Strength
12. Earthquake resistant
13. Fire Resistant
14. Water Proof and Dampness Resistant
15. Termite Resistant
16. High Sound Insulation
17. High Absorption Capacity
18. Low Shrinkage
19. Permeability Resistance
20. Smooth and Flat Surface, thus no plastering needed
21. Total Quality Control & Anti-Manipulation construction

Best Product To Use



INTRODUCTION TO PRECAST TECHNOLOGY

Shri N.N.S.S.Rao, CE/S.Z-II

Abstract

Precast concrete is construction product produced by casting concrete in a reusable mould or "form" which is then cured in a controlled environment, transported to the construction site and lifted and set into place.

In 1950, the first major precast concrete structure appeared in the United States — the Walnut Lane Memorial Bridge in Philadelphia. A few years later, the Precast Concrete Institute was formed to begin to set standards for this emerging industry.

Whereas, the concept of prestressing, even though utilized in structures like The Colosseum and everyday objects in the form of bows and tents, from the prehistoric times, was not put into practice at a large scale until World War II during which the conservation of materials being used was a top priority.

The idea of the application of prestressing to improve the performance of reinforced concrete structure became prevalent in the first half of the 20th century, during which the preliminary prestressed bridges were build across Europe and USA own to the work of pioneers like Hewett, Dyckerhoff & Widmann Co., and Freyssinet.

During the last 50 years advancement in precast prestressing technology meant that t h e most significant advantage of usage of precast prestressed concrete, creating longer spans than those achieved by ordinary reinforced concrete, was then applied for the production of beams and floor slabs which revolutionized the building construction industry.

Advatages of Precast Concrete

PRECAST BUILDINGS	CONVENTIONAL BUILDINGS
Designed, manufactured, and tested under supervision of experienced management.	Concrete cast at site where contractors do not take care of mix design proportions.
Entire concrete blocks are cured uniformly for the required amount of time.	Curing is not done uniformly at sites.
Production is not hampered with weather delays	Production is severely hampered.
Environment -friendly	Less environment-friendly
Stationary equipment efficiency designed for repetitive production. Cost of formwork per unit to be lower than for site-cast production.	Special design and features developed for each project at higher costs
Construction is faster.	Construction is comparatively slower.

PRECAT CONCRETE STRUCTURAL ELEMENTS

A precast building is constructed by assembling and connecting various prefabricated elements required in the building structure. These elements are:

- Precast slabs
- Precast beams
- Precast columns
- Precast walls
- Precast foundation

Precast Slab



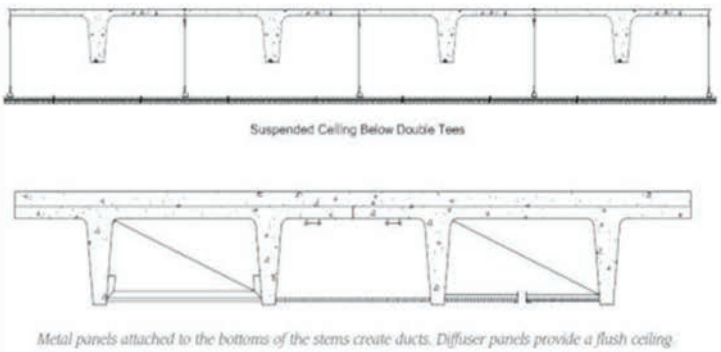
Double-Tee Units:

Double Tee (TT) slabs are two symmetrically placed beams interacting with a slab forming in one section with a “double tee” shape made in precast, prestressed concrete.

Resistant to moisture and corrosion. Parking garages, office buildings, commercial buildings, factories, industrial buildings, etc., are all ideal applications.

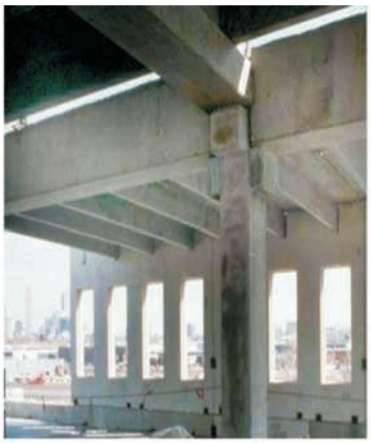
Made with G50 concrete and ½” strands ASTM A416 as standard, each double Tee slab is normally 2400mm wide.





Bearing Supports for Double Tee Slabs

Double tee slabs can be supported on many types of supports designed to carry the required dead and live loads. Precast beams, precast walls, poured concrete beams and walls, masonry walls, insulated concrete forming system walls and structural steel beams are all suitable for use with double tee slabs as load bearing systems.


Solid Concrete Units:

These are simple solid core slabs which appear same as solid slabs cast in situ; the only difference being that they are prefabricated.

Precast Beams

Beams and beam shells are both used for suspended flooring. Beams are typically used as ledges for other forms of precast flooring to sit on, but can also be used as a flooring option in their own right. They are generally manufactured to suit each particular situation and profiles can include

Tee-beams,

L-beams,

Rectangular beams,

U-beams and Beam shells.

Beams can be either reinforced or prestressed.

Precast Columns

Precast concrete columns are modular in design in order to be made into different heights.

Widths are 12", 18" and 24".

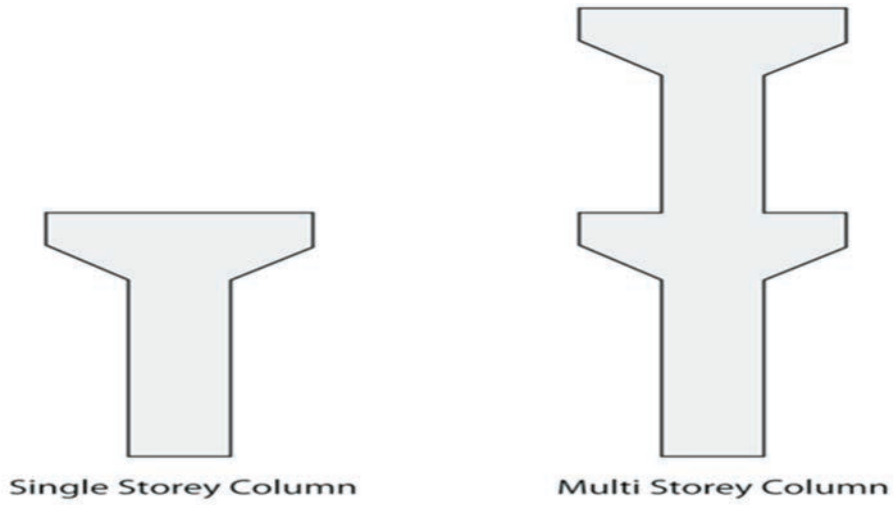
Precast column can be produced as either single storey corbel column or multi storey corbel column.



Columns can either be rectangular or circular in section.

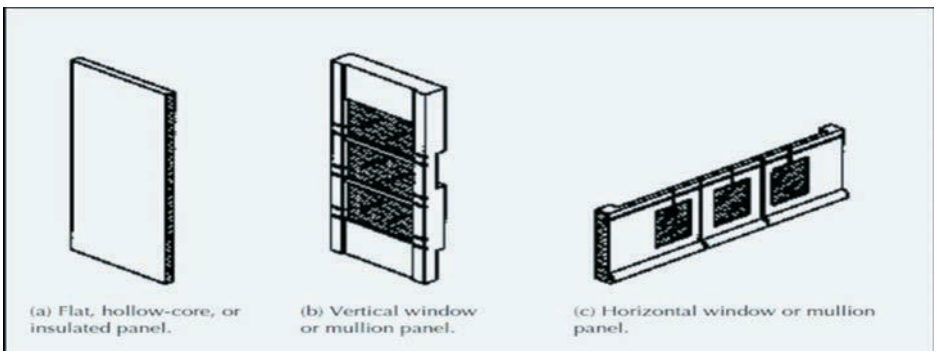
Projecting rebar can be provided for tying in to in-situ floors. Options for foundation connections include cast in base plates, dowel tubes or projections.

Beam support is achieved by either flared heads, corbels or bolt-on brackets.



Precast Walls

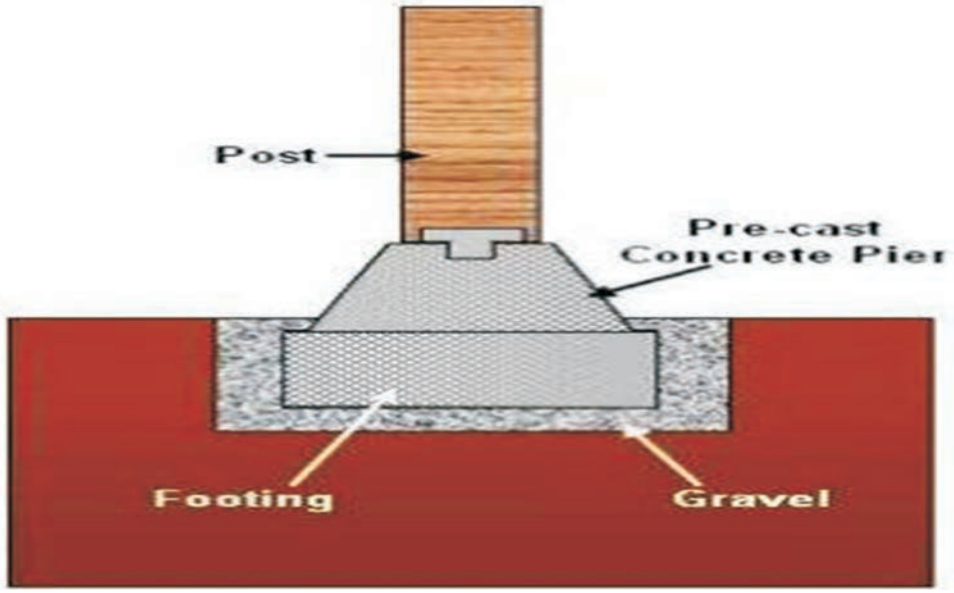
A wall system can be comprised of : flat or curved panels (solid, hollow-core, or insulated) ,window or mullion panels ,ribbed panels ,double-tee .



Precast Footings

Precast footings are a recent innovation.

Precast concrete foundations are pre-engineered systems manufactured in a controlled environment.



Types of Precast Systems

The type of structural system keeping in mind

The purpose of building,

The efficiency of the system,

The location and

The client's need.

Depending on the load-bearing structure, precast systems can be divided into the follow categories:

- Large-panel systems
- Frame systems
- Slab-column systems with walls
- Mixed systems

Large Panel System

Large-panel system" refers to multistory structures composed of large wall and floor concrete panels connected in the vertical and horizontal directions so that the wall panels enclose appropriate spaces for the rooms within a building.

Frame Systems

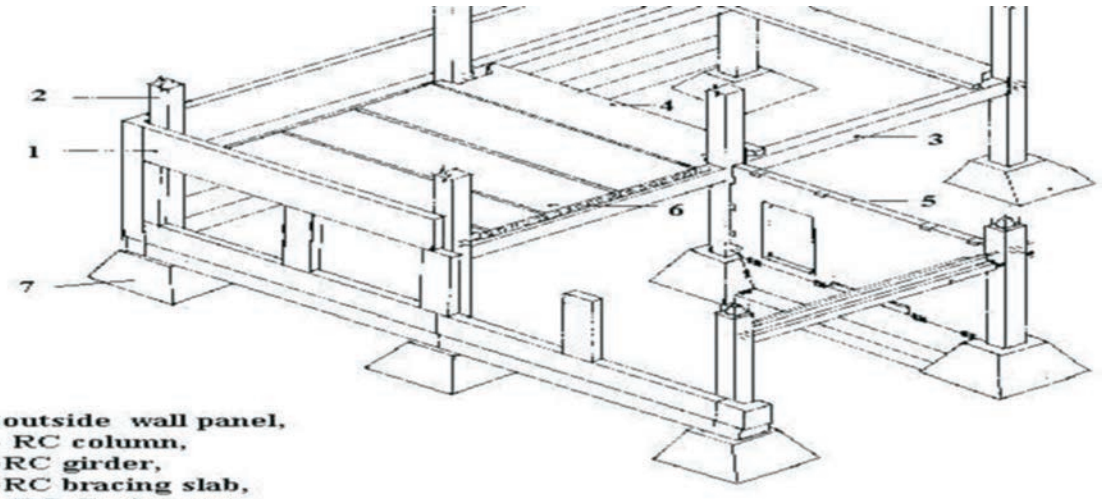
Precast frames can be constructed using either linear elements or spatial beam column sub-assemblages.

The use of linear elements generally means placing the connecting faces at the beam-column junctions. The beams can be seated on corbels at the columns, for ease of construction and to aid the shear transfer from the beam to the column.

The beam-column joints accomplished in this way are hinged.

However, rigid beam-column connections are used in some cases, when the continuity of longitudinal reinforcement through the beam-column joint needs to be ensured.

The components of a precast reinforced concrete frame are shown in Figure:



1-outside wall panel,
2- RC column,
3-RC girder,
4-RC bracing slab,
5- RC diaphragm,
6- RC ceiling slab,
7- RC foundation

Connections

- Connections are locations of high stress concentrations and are weak points in the structural systems.
- Connections of different precast concrete components like footing beams, columns, slabs and wall panels are very essential in precast concrete building.

- Depending upon the type of connection, a joint can be considered simply supported, fixed and hinged.
- Primarily precast building connections can be classified as:
- Typical European prefabrication.
- Equivalent monolithic moment resisting connection.
- Post-tensioned dry joint.
- Hybrid connection.

Construction Method For Precast System

Construction Considerations

- All safety issues on site when handling precast elements,
- The lifting capacity of the crane used.
- The working boom-radius of the crane.
- The suitability of construction materials for the purpose of use, i.e. sealant, grouting, shim plate, propping etc.
- Co-ordination with the precaster and specialist supplier to achieve the best performance and working method.

Sequence of Work

Quick Check

- Ensure the correct panel before hoisting.
- Ensure the crane lifting capacity before hoisting the panel
- Ensure the desired crane's working radius.
- Ensure the anchorage for the propping does not damage cast-in building services.
- Ensure the desired verticality/position is achieved.
- Estimated time to install a typical precast element is 1/2 to 3/4 hour
- CONSTRAINTS AND SOLUTIONS

- ACCESS

CONSTRAINTS	SOLUTIONS
❖ Small road in front of site may not allow crane and delivery trailers up to 3.5m wide to park.	❖ Use smaller crane and trailers to deliver and install small components.
❖ Crane and trailer are unable to negotiate small turning radius at junctions of small roads.	❖ Study the locality and look for available space for turning. Have one worker direct traffic while crane and trailer is turning.
❖ Diversion of existing services such as lamp-posts, fire hydrants and overhead electrical cables may be necessary.	❖ Diversion must be done before installation of precast components begins.
❖ Existing trees and shrubs in front of site require National Parks Board approval before they can be removed and later reinstated.	❖ The consultants must write in to National Parks Board for approval much earlier before construction begins.

- **Crane Capacity And Reach**

CONSTRAINTS	SOLUTIONS
❖ Lifting capacity of small crane not enough to lift heavy and far components.	❖ Hire bigger crane with longer boom to lift heavy and far components. Alternatively, plan the sequence such that the crane can park nearer to the heavier components.

COORDINATION

CONSTRAINTS	SOLUTIONS
❖ Wrong components delivered to site.	❖ Provide clear labels on components and drawings to avoid confusion.
❖ Wrong sequence of delivery (such as planks arrive first before the beams on the same day)	❖ Person ordering must maintain good communication with person delivering.

INSTALLATON

CONSTRAINTS	SOLUTIONS
❖ Lifting over neighbour's roof may cause anxiety over safety and damage to existing properties.	❖ Crane and trailer can be parked strategically to avoid such lifting. Crane operator can make use of boom angle to keep lifting within site boundary.
❖ Starter bars do not match with grouting holes or clashing of bars at connections between beams and columns.	❖ Equipment and workers to crank or bend the starter bars will be provided on site.

- **HANDLING**

CONSTRAINTS	SOLUTIONS
❖ Damage such as cracks and corners chipped-off occurred due to knocking during handling.	❖ If damage is minor, cracked components can be repaired using approved epoxy resin. Non-shrink grout can be used for chipped-off corners.

Various is Codes for Reference:

IS 15916 Building Design and Erection Using Prefabricated Concrete - Code of Practice

Is10297 Practice for Design and Construction of Floors and Roofs using precast Reinforced/prestressed concrete ribbed or cored slab units

Components of RCC structure shall be designed for loads in accordance with IS 875 (Parts I to 5) and IS 1893-Part 1 (latest version). In addition, loads that might be expected during

the construction shall also be considered in the design.

Case Study

- Details of Work Executed Under South Zone-II
- GENERAL INFORMATION

1. NAME OF WORK:	**Design and Construction of G+3 Storeyed Multi Level CAr Parking Block With precast Technology For SBI Data Centre At Gachbowli,Hyderbad,Telangana State.**
2. TOTAL BUILTUP AREA:	7595.00 sqm
3. SCOPE OF WORK :	Precast RCC framed structure with precast columns and precast - prestressed Beams / slabs including services.
4. A/A & E/S:	Rs.19,70,70,000/-
5. COMPLETION COST:	Rs.16,00,00,000/-

6. TIME ALLOWED FOR COMPLETION OF WORK: 180 DAYS.

Scope Of Work

1. RCC Work in Foundation & Plinth : RCC Work - Cast in –Situ.
2. Super structure: RCC Work – Precast / Pre-stressed.
3. Excavation & cast-in-situ foundation. The rcc in foundation done with m-25 concrete.
4. The casting of various members started at factory
5. Number of elements casted per day – 10 nos. Precast elements and 1 no. Bed hollow core slab of 150m / 180 sqm.
6. The precast / pre-stressed beam curing was done with steam curing for 3 days and curing of other members were done by manual curing method for 07 days at factory.

Cast In Situ Footing



Casting Of Prestressed Hallow Core Slabs At Plant



7-wire Strands



Casting of Prestressed beams At Plant



The members / elements transported after getting 75% of 28 days strength.

Due to restricted space available at site, the various precast elements were transported from fabrication yard (30 kms from site) in the trailers of 40 feet length during the night time and the same were erected in day time on next day.

Total 1158 nos. Of the elements casted at factory.

The weight of many elements was even more than 10 tons



MAXIMUM WEIGHT OF EACH TYPE ELEMENTS USED IN THE WORK			
SL NO	ELEMENT TYPE	DESIGNATION	WEIGHT IN TONNE
1	COLUMN	C2A-003	13.075
2	PRESTRESSED BEAM	PSB-110	10.225
3	PRECAST CUREVED BEAM	PRB-102	3.400
4	HALLOW CORE SLAB	H-20-10/02	3.500
5	STAIRCASE	STR-105	3.500
6	LANDING SLAB	L-02	4.725
7	SPANDRAL BEAM	SB1-203	10.250
8	200 MM THICK WALL PANEL	WP-005	10.225
9	250 MM THICK WALL PANEL	SWP-007	7.500
10	RAMP WALL PANEL	RWP-102	10.775
11	SOLID SLAB	SS-20-103	13.575
12	PRECAST GUTTER	PG	2.500

Erection of precast column for 2 floors on already prepared foundation base pads.

The beams were erected on columns and the hollow core slabs

Precast shear walls, lifts wall pannels, ramp and precast staircase, landing etc.

The grouting was done for the various joints of column-beam-slab-walls etc








14.12.2017 11:14


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THE GROUTING MATERIAL USED IN THE WORK IS “COMBEXTRA GP2 of FOSROC MAKE”

- Advantages

1. Conbextra GP2 is free flow, high strength, non shrink, cementitious precision grout.
2. Develops high early strength without the use of chlorides.
3. Free flow ensures high level of contact with load bearing area.
4. Consistency of grout mix.

flowable : 4.5 litres / 25 kg bag





The reinforcement was placed as per approved design for screeding.

The vaccum dewatered concrete with power floater is placed and cured

Load testing was done at factory & on part completed structure by iit, hyderabad.

The lift work was taken up only after completion of superstructu







Load Testing At Plant



Load Testing At Site






20 04 2018





THE COST COMPARISION IN BETWEEN NORMAL CONSTRUCTION (CAST-IN-SITU) AND PRECAST CONSTRUCTION

SL. NO.	NORMAL COSTRUCTION (COST)	PRE-CAST CONSTRUCTION (COST)
RCC IN SUPERSTRUCTURE	COST EXPENDITURE IS Rs.6,568/- PER SQM. MTR.	COST EXPENDITURE IS Rs.10,957/- PER SQM. MTR.
OVERALL COSTING	THE OVERALL COSTING FOR CIVIL WORK IS Rs.16,376/- PER SQM.	THE OVERALL COSTING FOR CIVIL Rs.20,765/- PER SQM.

TIME TAKEN BETWEEN THE NORMAL CONSTRUCTION AND THE PRECAST WORK

Foundation upto plinth beam: the time taken for structural designing, approved from designated external agency takes 2 to 3 months. It is additional to the normal construction, where, structural drawings are available with start of the work.

Superstructure: a lot of activities involve like, shop drawings, casting, transportation, erection, grouting, reinforcement, screeding, sealing, finishing. It took almost same time as in normal construction i.e., 1 month for completion of one floor for area of 1800 sqm.

- erection of various elements- 15 days.
- levelling & grouting – 5 days.
- reinforcement & screeding – 10 days.

Finishing activities: the time taken for finishing items is almost same in both the precast and normal construction.

Disadvantages of Precast Concrete

There are some disadvantages to precast concrete. They are discussed below.

1. High Initial Investment: For installing a Precast Concrete plant, heavy and sophisticated machines are necessary which requires a high initial investment. A large scale of precast construction projects must be available to ensure sufficient profit.

2. Transportation Issue: The construction site can be at a distant location from the Precast Concrete plant. In that case, the precast members must be carried to the site using trailers. In many cases, the reduced costs of Precast Concrete is compensated by the transportation cost.

3. Handling Difficulties: Proper care and precaution have to be taken for handling precast concrete. Usually, precast members are heavy and large which makes it difficult to handle without damage. Generally, portable or tower cranes are used to handle precast members.

4. Modification: Limitation In case of precast structures, it is difficult to modify the structure. For example, if a structural wall is to be dismantled for modification it will impact the overall stability of the structure.

5. Sensitive Connection Works: Assembling of the precast members is one of the key points for ensuring strong structural behavior. Connections between several structural members must be supervised and done properly to ensure the intended behavior of the connection such as simple, semi-rigid or rigid connections. Besides this, faulty connections may lead to water leakage and fail sound insulation.

IBS INDUSTRIALISED BUILDING SYSTEMS TO IBS (INTERMEDIATE BUILDING SYSTEMS)

Mr. Pramod Adlkaha, Designated Partner Aap Ka Awas & M.D.,
Adlakha Associates Pvt. Ltd.
Mr. Saket Mehra, Designated Partner Aap Ka Awas & M.D., The Engage Enterprises

In the 4th Generation Social housing for weaker sections (EWS and LIG) need to be focussed on incremental improvement in existing skill and technology rather than drastically changes to Industrialised Mechanisation. The solution lies in implementing the existing and researched intermediate technologies at site near site for serial production. Then slowly bring in Industrialised Mechanisation. By the 5th Generation.

The key element for “Low income Housing” is the Realisation of their hard earned savings, defining the characteristics of people's lives. Comfort, level, aspirations and necessities. Bring in Mechanisation and Industrialisation have to respect the traditional culture. The Country has to focus on “incremental technological improvement, rather than drastically change. At present, for “low income housing” the man-made traditional technologies be upgraded to “indigenous mechanisation”.

The intermediate technologies require the production to be done at site or near the site. The community develops confidence on quality and strength, when the production is done in their vicinity.

Increasing the productivity & quality level with indigenous intermediate technology caters to the synthesis of “traditional practice” and “modern technology” with scientifically integrated Design approach and integrated Team approach.

With a smaller modular of units, of components, assemblage is easy and simple. Even altering and replacing component is also easier.

Keeping the cost reduction through focus on “cost drivers of the process”, the adoption of technology to optimise lies in construction principle of load bearing walls.

In the above context, for low income housing in low rise development upto G+3. Aap Ka Awas has developed packages of an 'Integrated Hybrid Solution.

“Integrated Hybrid Solution – One”, has 3 main components :

- Walls : Hydraform Prefab Interlocking Technology (without mortar).
- Floors & Roof : Mechanised precast RC Planks & Joists system.

- Ferrocement staircase & other elements.

1.0 Sub-Components :-

1.1 Walls : 'Hydraform' prefab interlocking technology blocks manufactured onsite / off site with cement, coarse sand, fly ash and gypsum.

The blocks have male and female locking in horizontal direction and a ridge and bed in vertical direction. The System interlocks both in X and Y axis.

1.1.1 Production :

- Blocks are produced in a special Block Making Machine of different production capacity.
- Ingredients (sand, flyash and gypsum) are mixed dry in pan mixer for one minute. Then cement is added. When homogenous mixing is achieved, water is mixed.
- The moisture in the mix is checked with drop test.
- The sequence of operation of machine is :
- Lower the main ram
- Open the pre-compression ram
- Fill the compression chamber with raw material mixture in the hopper.
- Close the pre-compression ram.
- Raise the main ram to compress the block
- Open the pre-compression ram
- Raise the main ram fully to eject the blocks.
- Remove and stack the blocks
- Curing done for 14 days.

1.1.2 Testing :

- The strength of blocks are checked with a specially designed tool in a Compression Testing Machine.

1.1.3 Laying (Superstructure) :

- The first course of blocks is laid to line and level on cement mortar bed.
- The next course are laid dry
- Each course is laid in the opposite direction from the course below.
- At stilt level and lintel level and the course below floor slab level are laid in mortar.
- For earthquake resistance provisions for lintel band, roof band, vertical reinforcement are provided as per IS : 4326 : 1993

1.2 Floors / Roof :

- Precast RC Planks & Joists System
- R C Planks are casted with moulds on vibrating tables
- R C Joists are partially pre-casted with egg laying casting machine or with steel moulds on levelled platform.
- All castings done at site under controlled supervision.
- The Joists are erected with light cranes and erected on walls as per the spacing required.
- The partially precast planks are placed joist to joists or joist to wall.
- The reinforcement is provided in haunches and then haunches are filled with concrete.
- IS : 13990 : 1994 (Precast reinforced concrete planks and joists for roofing and flooring – specifications) is followed.
- IS : 13994 : 1994 (Design and construction of floor and roof with precast reinforced concrete planks and joists code of practice) is followed E.
- With the past experience of more than 40 years of the use of this technology, improvements have been made in mechanisation and for better quality and safety of product.
- The deflection tests are conducted at site for planks and for assembled casted slab.

1.3 Ferrocement Staircase :

The staircase has two components : the landings and the flight.

The landings are provided with precast RC Planks and Joists technology.

The flight is of precast tread riser unit in ferrocement and fixed with cement mortar from wall to wall spacing.

Ferrocement consists of cement mortar mix, reinforcement, wired mesh chicken mesh, casted on a vibrating table with added admixtures.

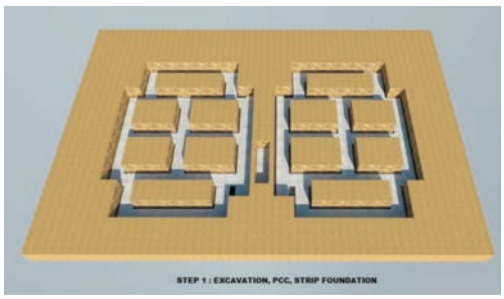
The thickness is 25 to 30 mm. The L-junction of tread-riser is rounded, during casting with the mould, for better stiffness.

1.4 Other building elements :

The Kitchen working slab, sunshades, shelves etc. are also precasted with ferrocement.

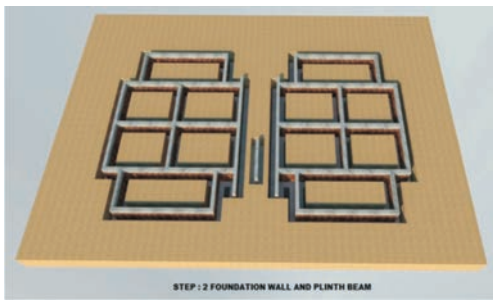
2.0

2.1 Fig. 1 to 7 show the animated sequence of construction



STEP 1 : EXCAVATION, PCC, STRIP FOUNDATION

Fig. 1



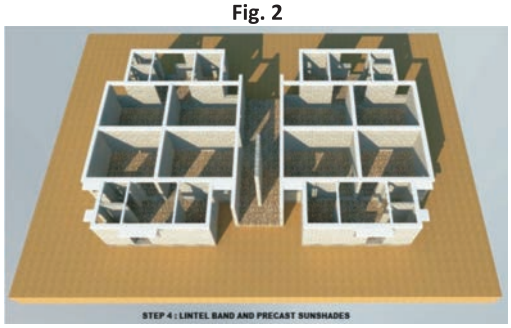
STEP 2 : FOUNDATION WALL AND PLINTH BEAM

Fig. 2



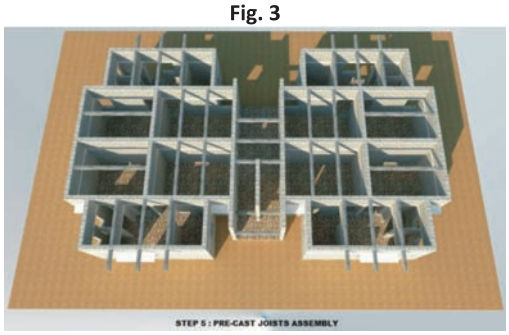
STEP 3 : BACKFILL AND RAISING WALL TILL LINTEL LEVEL

Fig. 3



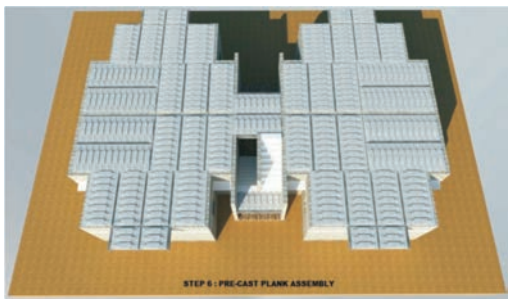
STEP 4 : LINTEL BAND AND PRECAST SUNSHADES

Fig. 4



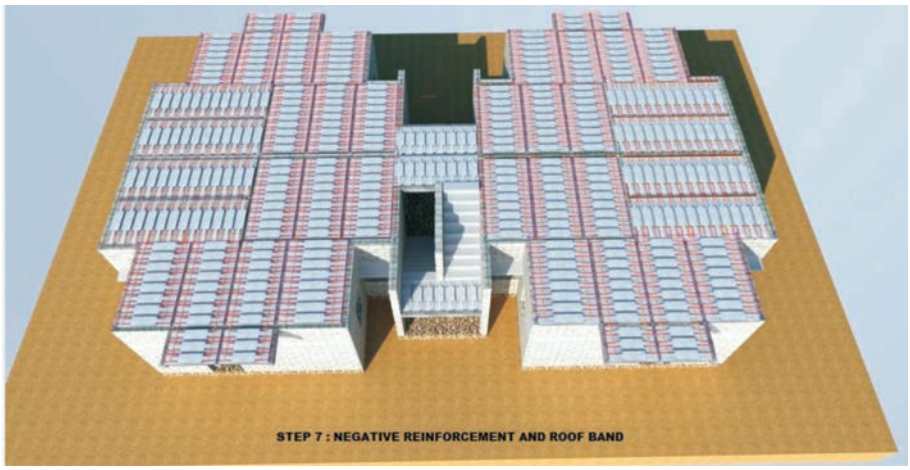
STEP 5 : PRECAST JOINTS ASSEMBLY

Fig.5



STEP 6 : PRECAST PLANKS ASSEMBLY

Fig. 6



STEP 7 : NEGATIVE REINFORCEMENT AND ROOF BAND

Fig. 7

2.2 Fig. 8 to 16 show the sequences of Block production and the steps for laying of interlocking blocks



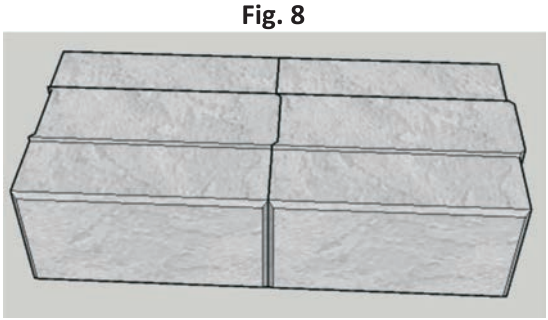
Blocks under production

Fig. 8



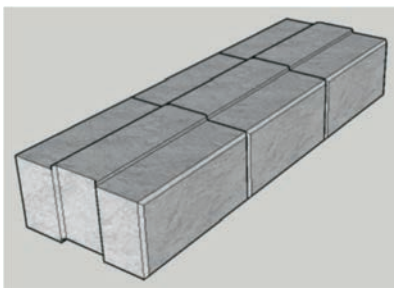
Blocks under production

Fig. 9



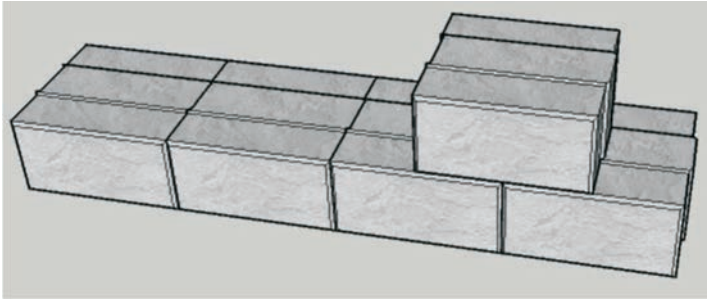
Block laying

Fig. 10



Block laying

Fig. 11



Block laying second Course
Fig. 12



Block laying at site
Fig. 13



Vertical reinforcement
Fig. 14



Block laying T-Junctions
Fig. 15



Block laying L-Junctions & Lintel band
Fig. 16

2.3 Fig. 17 to 26 Show the steps of casting and erecting of Floor / Roof with RC Planks and Joists system.



Precasting of planks on Vibrating table and mould

Fig. 17



Planks casted on vibrating table

Fig. 18



planks stored with pallets

Fig. 19



Precasting of joists

Fig. 20



Mechanised casting of joists

Fig. 21



Hoisting of joists

Fig. 22



Lifting of planks mechanically

Fig. 23



Planks placed over joists & walls

Fig. 24



Casting in-situ concrete in haunches

Fig. 25



Finished Ceiling view

Fig. 26

2.4 Fig. 27 to 30 Show sequence of construction with ferrocement for stairs, sunshades shelves etc.



Precasting of staircase steps (tred & riser unit)

Fig. 27



COMPLETED VIEW PRECAST FERROCEMENT STAIRCASE IN HYDRAFORM BLOCK WALLING

Fig. 28



Precasting Kitchen platform

Fig. 29



Precasting Sunshade

Fig. 30

2.5 Fig.31 to 32 show a few completed projects with the Integrated Solution.



Inno Geocity, Chennai

Fig. 31



Housing Welspun Group Gujarat

Fig. 32

NEW MATERIALS AND TECHNOLOGIES ADOPTED IN CPWD AT MUMBAI

Dr K M Soni, Additional DG (TD), CPWD, New Delhi
Usha Batra, Special DG (WR), CPWD, Mumbai

Abstract

Using new materials and analysing their performance has always been the endeavour of CPWD. Mumbai, being the commercial capital of the country and having large scarcity of land, has been witnessing construction of high rise buildings and use of new materials and technologies from pre-independence era. CPWD has also been following such tradition. Probably Pratishtha Bhawan constructed in 1976 having G+18 storeys was the first multi-storeyed building of such height constructed by CPWD.

CPWD has constructed many buildings in Mumbai, both office and residential. Some important office buildings constructed by CPWD include Pratishtha Bhawan, Nishtha Bhawan, Aayakar Bhawan, Kendriya Sadan, CGO building, SEBI Bhawan, GST Bhawan, NISM campus, National Test House campus, NITIE buildings, Income tax buildings, CAG buildings, Punjab National Bank building at BKC, IDBI Bank buildings at BKC and Belapur, Videsh Bhawan at BKC, CBI building at BKC, Canara Bank building at BKC etc.

CPWD in Mumbai has been using new materials due to their requirements as well as to follow innovation. In the buildings recently constructed, CPWD has adopted Post Tensioned slab construction, Autoclaved Aerated Concrete (AAC) blocks, Dry Stone cladding, Double stack car parking, Glass Fibre Reinforced Concrete blocks, Stamped Finish concrete floorings, Geofoam blocks, Glass in structural glazing and other interior applications, Modern floorings and false ceilings, and Namaste furniture etc. These are briefly described in the paper.

Post Tensioned Slab

Post tensioned, a pre-stressed concrete has the advantage over reinforced cement concrete in serviceability, safety and durability. Pre-stressed concrete design is more suitable for long span structures and those carrying heavy loads. Such structures are more slender avoiding deep beams thus yielding to higher clearance for air-conditioning ducts or adjusting additional storeys within the same height of building. They also do not crack under working loads and under dead loads as the deflection is reduced due to cambering effect of pre-stress.

Though both reinforced concrete and pre-stressed concrete will be safe when designed for the conditions but in pre-stressed concrete, there is partial testing of both the steel and

concrete during pre-stressing operations and when materials can stand pre-stressing, they are likely to possess sufficient strength for the design service loads also. The resistance to corrosion is better in pre-stressed than that in reinforced concrete due to denser concrete, encased tendons, and non existence of cracks. However, pre-stressed concrete members require more care in design, construction and erection than reinforced concrete. Pre-stressed concrete is economical when same unit is repeated number of times, and in heavily loaded structures particularly having long spans.

Pre-stressing concrete can either be pre tensioned concrete or post tensioned concrete. Pre-tensioned concrete is cast around steel tendons, while they are under tension. The concrete bonds to the tendons on getting cured and when the tension is released it is transferred to the concrete as compression by static friction. Tension subsequently imposed on the concrete is transferred directly to the tendons. In post tensioned concrete, tension in tendons is applied after the concrete is cast during the curing process. Design of pre-stressed concrete structures has already been included in NBC 2016.





Post tensioned (PT) slab construction leads to material savings due to reduction in concrete on account of thinner sizes of members, reduction of reinforcement bars in floor elements, and reduction in dead load and building height leading to savings in brickwork, cladding, plaster, concrete, paints etc as the case may be. Further, such construction is faster, and improves seismic behavior and crack control.

PT slab construction technology is being adopted in most of the buildings in Mumbai such as CBI office building, National Institute of Securities Markets (NISM) academic blocks, IDBI Bank building, Belapur, and Income Tax building, BKC.

Autoclaved Aerated Concrete (AAC) Blocks

AAC blocks are now being commonly used in Mumbai in all CPWD constructed buildings. Such blocks have density around 550 – 600 kg per cum, much less compared to bricks having density about 1950 kg per cum thus reducing the dead load of the structure. They are available in different thicknesses such as 100, 150, 200, and 250 mm. They also qualify to be green building material as made of flyash.

Depending upon the thickness, they offer fire resistance from 2 hours to 6 hours. The Sound Transmission Class (STC) rating of the AAC blocks up to 45 db, thus AAC blocks are good for construction of walls in auditorium, hotels, hospitals, studios, etc. They are safe against termite, more reliable and safer during earthquakes due to light weight. Large size of blocks results in faster construction. CPWD has already issued directions to use them in multi-storeyed buildings in many cities for non structural members.





Dry Stone Cladding

Dry stone cladding with stone blocks or tiles is also being used in few buildings in Mumbai. Granite dry stone cladding supported on stainless steel fasteners over RCC substrate has been provided in CBI office and Income Tax building at BKC. The holes were drilled in granite blocks and the fasteners having pin protruding on both opposite sides, are inserted in two stone blocks installed on upper and lower levels. Dry stone cladding has the advantage of not getting removed from the substrate on account of mortar leaving the surface due to temperature variation, poor workmanship or any other reason. Fasteners need to be corrosion resistance, durable and safe.

It allows for expansion and contraction of stone in extreme weather conditions. The dry cladding creates a gap of around 30 to 45 mm in between wall and stone lining, providing a

layer of air cushion which acts as a thermal barrier, giving advantage of energy efficiency. The appearance of dry cladding work looks aesthetically pleasing as stone fixed with mortar may change in colour due to absorption of water from back mortar layer.





Glass Fibre Reinforced Concrete (GFRC) Panels

GFRC panels/blocks are lightweight, durable and can be cast into nearly unlimited shapes, colors and textures. They are also fire, weather and corrosion resistant and can be moulded in any form and as such suitable for architectural mouldings and claddings. They require low maintenance, and are quick to install, cost effective, economical and energy efficient.

Being used as replacement of natural stones, they also qualify for being green material. They are light compared to natural stones and can be moulded in curved or any other desired shape. In Orientation Block of NISM, they have been used in facade work.




Stamped Finish Concrete Flooring

Stamped or textured or imprint concrete is decorative concrete used in the flooring, particularly for external development. Various patterns can be achieved with desired colours

by stamping/imprinting resembling to bricks, stones, tiles or even wood. The process includes preparation of sub-grade, placing of forms, providing reinforcement for stability, placing the concrete, screeding and finishing the concrete, applying colour, and stamping the concrete using desired moulds. Such finishes have been provided in NISM.





Some of the advantages of stamped concrete are;

i. It is aesthetically pleasing as different patterns can be achieved with stamped concrete resembling from bricks to tiles to stones. It has lot to offer in terms of availability of patterns, colours, longevity, performance, speed of installation, and customization.

ii. It can be made available in many colours as per the architect's choice.

iii. It can be laid on any sub grade over plain cement concrete base or RCC base as per the available sub grade characteristics.

iv. It is durable and long lasting and almost free from maintenance.

v. Customised designs and patterns can be achieved.

vi. Since it can be laid over RCC, it has better resistance to water and pressure uplift due to water and may prove to be durable even in case of occasional submergence.

vii. It does not have large number of joints like bricks, tiles and stones, hence is aesthetically better and also durable compared to bricks, tiles or stones.

viii. Laying of stamped concrete is easier than traditional materials like bricks, tiles and stones and provide better and consistent surface.

ix. Since it saves natural stone, it can be categorised as a green material.

Expanded Polystyrene Geofoam Blocks

Geofoam blocks are light, sturdy, and easy to cut hence suitable for construction of steps in lecture halls/auditoriums/theatres etc. In the lecture halls of NISM, light weight geofoam blocks having density of 21.6 kg per cum were provided. Their use reduces the time of construction, and also load on structure when used on floors other than the ground floor. Wire mesh is provided over the blocks to bind them together and also acts as reinforcement. Concrete layer is placed over the same and final flooring laid as desired.





EPS Geofoam blocks are available in various sizes, generally in 1.2mx1.2m and 1.2mx2.4m but can be manufactured even in large sizes. Thickness of the blocks can be manufactured up to 36 inches. Standard blocks come as rectangles but can be custom cut in the factory to meet various job requirements, including sloped or curved pieces. Additionally, EPS Geofoam blocks are easy to cut in the field, as needed, using saws or a hot-wire cutting tool to install various services or as per the requirements.

Typical density of EPS geofoam may vary minimum from 11 to 46 kg per cum as per ASTM C303 for different types of foams hence the blocks are very light and thus suitable for areas where weight reduction is required. Due to light weight, their handling and placing is also easy. The compressive resistance of EPS Geofoam blocks ranges from about 15 kPa to 18.6 kPa at 1% deformation as per ASTM D1621 for different types of foams. As long as combined dead/live loads do not exceed one percent strain, EPS Geofoam blocks will not creep or experience plastic yield. Minimum flexural strength of EPS Geofoam blocks vary from 69 kPa to 517 kPa as per ASTM C203.

Properly selected and installed EPS Geofoam blocks are durable. They do not get decomposed and last for long. It is advisable to cover the blocks and not to keep exposed to sun to avoid degradation. In the steps, they are restrained from displacements by providing GI wire mesh/GI wire fabric which also acts as reinforcement for the concrete being overlaid.

EPS is combustible and as such also, it is important to cover it with non-combustible material like cement concrete, RCC, stone or tiles. In case, it is required, fire retardant paint should be applied over such blocks.

EPS geofoam blocks can be successfully used in stairs, seating of class rooms, lecture halls, auditoriums, theatres and stadia and rooftop pools or plaza decks with pavers or cast-in-place slabs. Such blocks were used in the steps of lecture halls of NISM, Mumbai. After laying the blocks, wire mesh was installed over that concreting was done. Finally flooring was provided. Another advantage of such blocks is that they can be cut in desired shapes to install the services.

Another use of such blocks which can be thought is in filling of sunken floors of toilets, kitchen and in similar locations as the material is light, low water absorbent and easy to be installed.

Geofoam blocks can be an ideal option to reduce dead and lateral loads on underground pipes, culverts, and tunnels, while at the same time providing high thermal insulation values that protect against temperature fluctuations. Geofoam blocks can also protect utilities during seismic activity by reducing in-situ vertical/lateral stresses.

False Ceiling

In NISM, various types of false ceilings have been provided as per the design of the architect including cloud false ceiling, tongue and groove jointed acoustic false ceiling and wall panelling. Hanging acoustic panels have been provided in the library of NISM.



Dining Hall, NISM



Recreation Hall, NISM



Orientation Block, NISM



Auditorium, NISM



Library, NISM

Mechanised Stack Car Parking System

Due to space constraints in Mumbai, mechanised car parking is being provided in the basements. Double stack car parking has been provided in CBI office and Income Tax building at BKC. This has the advantage of making surface free from parking simultaneously following parking norms of the local bodies, and very helpful in small plot areas however it is difficult to operate and may require regular maintenance.





Glass

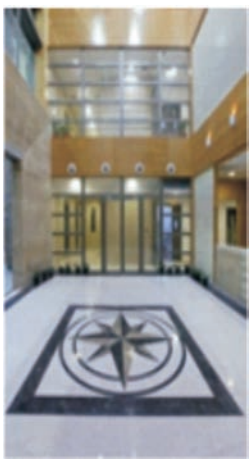
Glass is a traditional material but new generation glass is being used in various applications like interiors, structural glazing, fire resistant locations, doors, staircase, railings, murals, swimming pools etc. in some form. Glass has been used in structural glazing and interiors in many office buildings in Mumbai. Now NBC 2016 has full section on glass and glazing applications. It should be used considering functional and aesthetic requirements.



Videsh Bhawan,
BKC, Mumbai



Staircase of Library
NISM



Lobby of CBI office,
BKC

Namaste Furniture

Namaste furniture offers foldable desks and seats designed for space saving which creates walking aisle space when folded in. It has easy plug and play features built into the system enabling use of laptops, audio visual equipment facilitating interactive learning and broadcasted lectures. Due to ergonomic design, one maintains correct posture while sitting on such furniture, using laptop or writing and thus is comfortable leading to healthier environment. Such furniture has been provided in all the lecture halls of NISM.





Concluding Remarks

CPWD is adopting new materials and technologies in its construction in Mumbai, particularly in large projects to make the buildings more aesthetical, and functional to provide environment for better productivity and comforts. The materials are selected accordingly taking the client into confidence before adopting them.

Post tensioned slab construction technology has additional advantages in multi-storeyed construction, stamped concrete in external development, geofoam blocks in reduction of load in stepped construction, dry cladding as better mode of fixing and insulation, and glass in making aesthetic buildings.

Post tensioned slab, mechanical parking and Namaste furniture are perfect examples of best utilization of restricted available spaces/volumes for different activities. GFRC, stone cladding, stamped concrete, cloud false ceiling and geofoam blocks are best examples for combination of function, aesthetics and sustainability.

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3. Soni, K M (2018). New Materials and Techniques in Construction of CBI Office in Mumbai. CE&CR, 31(2), Feb issue, 54-56.

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PRECAST PAVEMENTS – FUTURE ROAD CONSTRUCTION TOWARDS SAFE, SMART AND SUSTAINABLE INFRASTRUCTURE IN INDIA

G SREENIVASA, VP & Head – WT & RMDT, UltraTech Cement Limited

History:

Soviet technical literature of the 1960's and 1970's includes a number of generally favourable descriptions of PCP use for temporary road construction, under heavy industrial traffic in the Donbass, on the Kiev-Odessa highway, under urban traffic in Moscow, and elsewhere.

By 1962, standardized precast panel designs had been approved for airfields. By 1970, the PAG XIV slab system had been approved as a standard panel for airfields and a number of precast plants were capable of producing this system.

The PCP technology is an emerging technology in the US. Russia and Japan have a longer experience with the use of this technology.Japan still has an active program to use the PCPS for specific needs. The Netherlands, France, USA, Indonesia, Malaysia and Japan are recent users of the technology.

The approaches used for developing the PCP systems are unique to each country and within each country, the PCPS continue to evolve and continue to be refined and continue to be applied to new applications

Introduction:

Prefabrication of any structural component made off-site during highway/road construction (or reconstruction) offers major time and user cost savings in comparison with the traditional cast-in-place methods of construction.

'Precast Pre-stressed road pavement technology offers increase in durability, substantially decreasing construction time and cost.

Using the precast concrete parts for the road's pavement speeds up the construction time such pavement can be used by vehicles the very next day after installation as no further curing of the newly laid road surface is necessary.

It also brings substantial safety advantages, lowers disruption to traffic and increases overall convenience for the road users.

Why Precast Pavements?

- As traffic volumes continue to rise on Indian Roads, users are demanding more comfort and quality roads.
- The massive maintenance, repair and reconstruction of Asphalts Roads will be major challenge for respective Authorities.
- Bad pavement conditions accounts for large no of accidents and deaths –almost 10/day
- Even after huge planning, the highway construction struggling to reach the set target of 40kms/day
- The methods of construction & material used by road sector never seen much progress compared to the methods and new materials used by building sector
- In view of the limited capacities of the construction industry, prefabrication and pre-cast pavements methods seem to offer the sustainable, cost effective and suitable solutions.

Precast Pavement Systems:

In precast concrete pavement construction, adjacent panels are assembled sequentially and tied together onsite through post tensioning or cast in load transfer systems

Precast concrete pavement systems can be used for single lane replacements, multiple lane replacement (an additional lane may be needed to accommodate materials and equipment) or full width road construction

Using the precast concrete panels for the road's pavement, speeds up the construction time 2 to 3 times against the traditional cast in place, if well-organized such a pavement can be used by vehicles the very next day after installation as no further curing of the newly laid road surface is necessary.

Advantages of Precast Pavement:

- Most obvious benefit is that, its ability to open to traffic immediately after installation of precast panels
- Prestressing also permits a significance in reduction of pavement thickness (up to 20 cm against 30 cm) and also saving in material
- Modular panels make the construction process safer and more efficient because roadwork can be completed during off peak hour's thus faster pace of construction to cut

time of traffic flow limitation

- Because they are precast, the panels can be fabricated under environmentally controlled conditions, which can result in products with better engineering properties
- Workers develop skill and knowledge that improves productivity and quality
- All weather construction since it made in factory.
- Ability to span voids/unsound support layers
- Proven Long-Term Performance
- Long-term durability due to higher quality materials used
- Less frequent maintenance of critical parts of the highway pavements and bridges
- Economy of scale due to mass production of all standardized elements (mainly pavement panels and bridge elements).

Primary Systems:

Precast pre-stressed concrete pavement (PPCP):

- PPCP utilizes pre-stressing to put the pavement slab in compression in order to reduce tensile stresses and the potential for cracking.
- Pre-stressing can be incorporated through pre-tensioning at the fabrication plant and through post tensioning on site
- PPCP systems can be used for continuous Applications.



Fig: PPCP System

Jointed precast concrete pavement (JPCP):

- JPCP systems replicate conventional cast in place concrete pavement, using precast panels of similar dimensions to jointed plain concrete pavement slabs, and dowels for load transfer between panels.
- The precast panels are heavily reinforced for handling purposes and to keep any cracks that may form during construction or over time held tightly closed.
- JPP systems are most commonly used forintermittent applications.

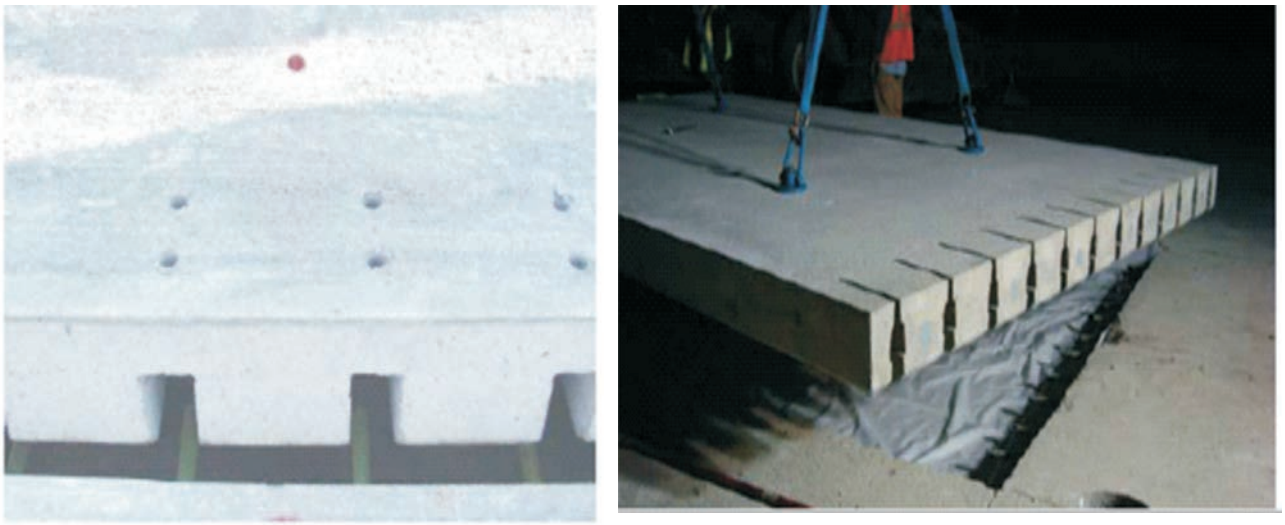


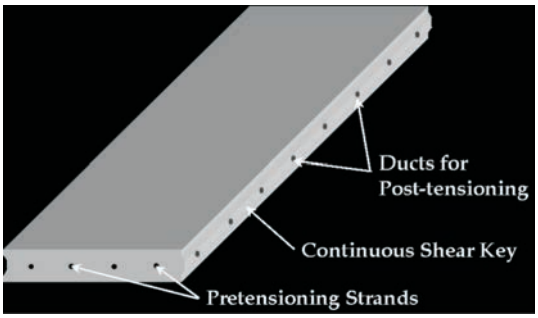
Fig: JPCP System

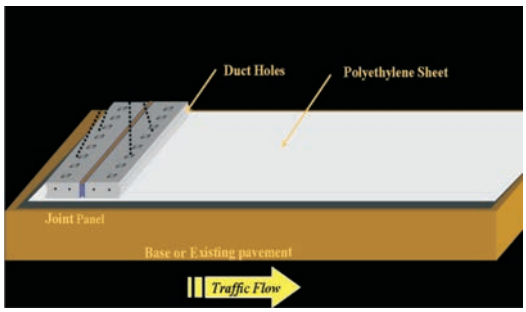
Precast Concrete Panels Pavement (PCPP):

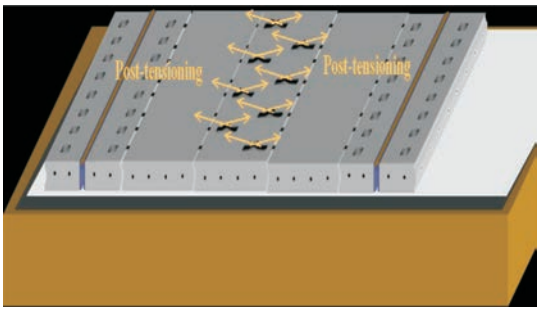
Pre stressed Precast Concrete Panels (are generally provided in sizes to match the width of one, two, or three lanes of the pavement permitting one or multiple lanes of an existing pavement to be reconstructed at one time, depending on site clearance constraints.

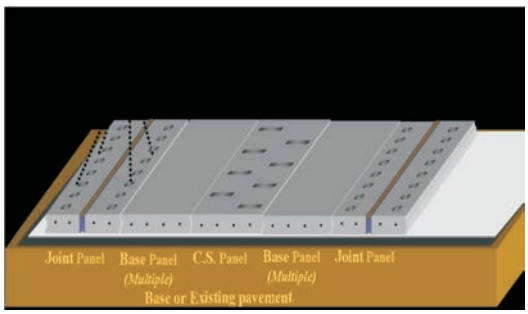
The precast panels are commonly oriented perpendicular to the roadway centre line, and may also include one or both shoulders In general, the panels are pre tensioned in the longer direction during fabrication, and post tensioned together in groups longitudinally, in the direction of traffic, to act as continuous slabs after installation.

In some applications, the panels can be post tensioned together in both directions during construction in addition to plant pre tensioning Regardless of the configuration, it is important that the pre stressing is provided in both directions if the maximum benefits of pre stressing are to be realized The panels are installed on a prepared base, post tensioned together, and opened to traffic The below shows a schematic view of a typical PPCP.









Jointed Precast Concrete Pavement Systems:

Typical Characteristics:

Slab sizes customized for specific applications (e.g., joint repair, lane reconstruction, etc.)

- Full lane width
- Similar thickness
- Lengths up to 16 ft

Generally reinforced for transportation and handling

- 0.2 to 0.4% steel and/or fibre reinforcing

Pre-stressing and/or structural fibre reinforcing options

Joints treated like cast in place construction joints (i.e., doweled, tied or butt)

Standard steel dowel load transfer systems

Useful for intermittent, continuous and airfield applications

Useful in complex geometric situations

Joint Load Transfer & Support (Bedding) Considerations:

-Joint Load Transfer

Dowel bar based load transfer system

- 4 dowel bars per wheel path is generally adequate
- Relative defl . < 2 mils for load transfer system approval

Typically achieved using dowel bar slots at panel bottom or at panel surface

- Full DBR both sides of joint have surface slots.
- Partial DBR only one side of joint has slots at panel bottom or at panel surface

Bedding Considerations

- Good, uniform support is key to precast concrete pavement performance.
- Without good support, a PCP system (repair or continuous) cannot be expected to provide expected long term performance.

Critical Activities:

- Levelling- Precision grading, shims, lift systems, grout or urethane injection
- Methods of achieving support- Grade supported, grout supported, urethane supported
- Load transfer system -Top slots (various), bottom slots; various dowels and connectors
- Achieving surface geometry - Non planar slabs, plane slabs, diamond grinding

Stages of Installation - Bed preparation





Final Grade Pass

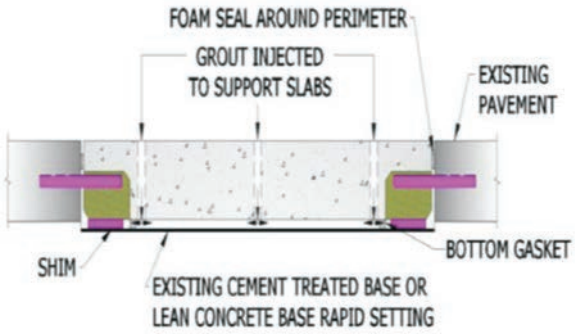


Placement of Bedding Material

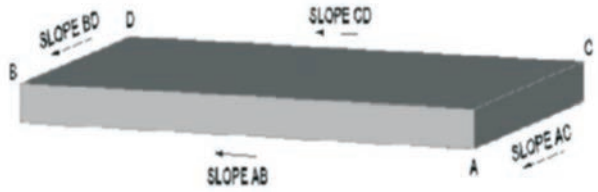
Grade control with Shims – Grout supported panels:

- Set shims to grade prior to placing panels
- Use surrounding pavement as a reference when appropriate
- A surveyor and grades may be necessary for complex or large installations

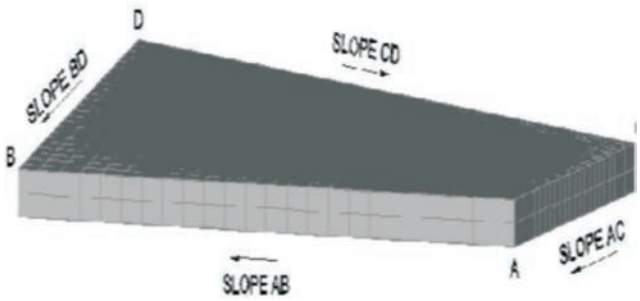




Matching pavement surface geometry:

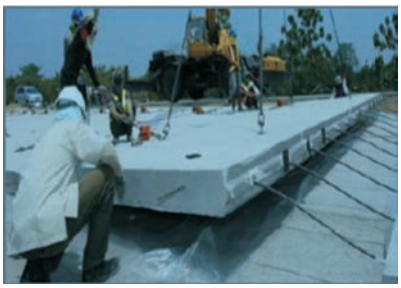


Single Panel
Slopes of opposite sides are equal



Warped Panel
Slopes of opposite sides are not equal

Panels Placement and Posttension:



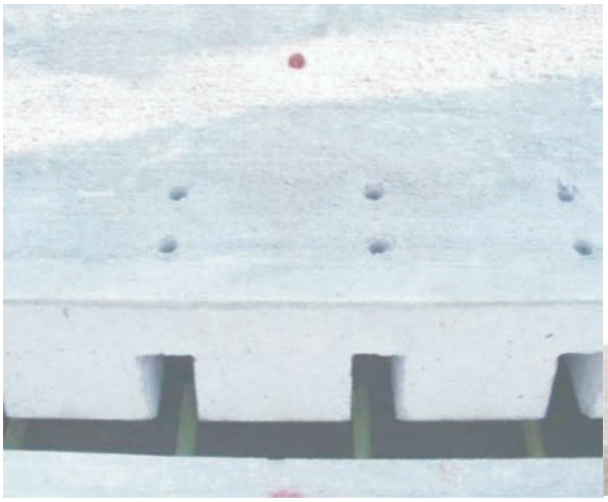




Bottom Slot Grouting System:

- Dowels engage slots in adjacent slab

- Pump dowel grout into port
- Fill slots and joint between slab
- Dove tail slot resists bar pop out
- Clean pavement surface





Completed precast roads in Indonesia & USA









Learnings of PPCP & JPCP:

The performance of projects constructed in the US indicate that sufficient advances have been made to reliably achieve the following four key attributes of PCPs:

- Constructability
- Concrete durability
- Load transfer at joints
- Panel support condition

However, a few JPPCP projects have exhibited some early-age cracking –design details & construction practices are under investigation by the highway agencies

Precast Pavement Application:

- National Highway
- State Highway /Major District Roads
- City Roads / Urban roads
- Village Roads /PMGSY
- Sea-Port Roads
- Air-Port Pavements

Conclusion:

- The Industrialization of Road sector is the future by incorporating Precast Concrete Pavement technology for all kind of pavement application
- The greener, cooler, sustainable pavements are the need of the hour considering the exponential growth of the road use.
- The Cost, Speed, Quality, Durability of the roads is the critical for the day.
- It is hoped that public demand for quality and comfortable highway travel will make the highway administrations exploit the potential that the precast pre stressed pavement method has.
- Precast Concrete Pavement Roads are “The Way to Go Sustainability much Lower Maintenance, Lower Costs.

Way Forward:

- Precast Industry is growing fast around World and India
- Focus on understanding Industry requirement in terms of standards & specifications
- Developing the tailor made products to suit the various road applications
- Solar Concrete Panel Road Construction
- UHSC (150-170MPa) Panels for Road Construction





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For more information, please visit:

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4. http://precastconcretepavement.com/
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1. Roman Stone Construction Company:http://www.romanstoneco.com/pavement-slab.html
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FAST TRACK BUILDING CONSTRUCTION USING LGSFS WITH EPS INFILL - FERRO CONCRETE PANEL TECHNOLOGY

Dr. R.Gopalan, Executive Director, Society for Development of Composites

Summary

LGSFS with EPS Infill Ferro Concrete Panel Technology is an innovative, fast track and cost effective building construction technology. The LGS frame is a 'C' Section, Cold formed Galvanized Iron with built in web notch, dimpling, slots, service holes, etc, for easy assembly and erection, produced by computerized roll forming machine. These frames are assembled using galvanized metal screws to form LGSF wall Structure (LGSFS) of a building. Typical LGSFS Wall is shown in Fig.1 Provisions for doors, windows, ventilators and other cutouts as required are incorporated in the LGSF structures. The LGSFS walls are transported to the site and erected on the floor using expanded anchor bolts. The space between the LGSF members is filled with EPS foam blocks which acts as insulation material for the wall. Electrical and plumbing conduits are provided on the LGS wall frames. Galvanized Weld mesh is fixed on both sides of the LGS wall frames using self-tapping screws. Concrete plastering is done on the both sides of the wall using mechanized shot creteing machine. After curing, the weld mesh combined with concrete plaster forms into a Ferro concrete panel, firmly fixed on both sides of the LGSF wall structure. Schematic diagram of LGSFS with EPS Infill Ferro concrete wall panel is shown in Fig.2.

The roof structure of the building shall be LGS joists with heavy duty metal deck sheet with reinforced concrete. The LGS joists are fixed on the wall over which GI metal deck sheet are fixed along with necessary steel reinforcement and then concrete is poured. The metal decking sheet and concrete forms light weight and strong roof slab.

Doors and window frames are fixed to the LGS frames and then the door shutters with necessary accessories are fixed. After completion of the ground floor, the first floor of the building is constructed using the same procedure that of the Ground Floor. Vitrified/ceramic tiles are fixed on to the floor, wall and kitchen using conventional method. Staircase, chejja and parapet wallS of the building are also constructed using LGSFS-Concrete Panel technology. The entire building is then painted and finished.

The technology is suitable for construction of multistoried building. However, depending on the number of floors, the thickness and profile of steel frames are changed. Hot rolled steel columns and beams can be used to provide addition strength to the LGS wall and roof structure to meet the structural design requirements due to increase in loads. Detail Design Report comprising: structural analysis design report, architectural drawings, structural

drawings, services details, construction methodology, material specification, inspection and quality control test etc, should be submitted for each building.

Materials used for Light Steel – Concrete Building:

1. Cold Formed LGS wall frame structure made of 'C' type GI Sections (A215 GSM Aluminium Zinc Alloy coated Steel having 550Mpa yield strength)
2. Fire Retard rent grade EPS foam blocks of 75 mm to acts like barrier of the LGS wall frame structure.
3. GI Weld mesh of 55 X 55 mm spacing and 2.3 mm
4. Plastering thickness 20 mm on both sides of the wall (A mixture of fly ash/M.sand, cement, water and Admixtures) having density – 1800-2000 kg/m3 and compressive strength >5.0 Mpa.
5. Doors and Windows: Eco-friendly non-wood WPC / GRP door frames, HDF /GRP Sandwich composite door shutters and UPVC windows.
6. Finishing & Painting: Weather resistant wall putty and paint.

Salient features of the Light Steel – Concrete Building:

1. Light weight and strong.
2. Better Thermal and Sound Insulation.
3. Faster Construction.
4. Energy Efficient.
5. Long Life and Durability.
6. Earth quake, fire and cyclonic wind/tornado resistance.
7. Cost Effective.
8. Minimum Manpower.
9. Environmental friendly and sustainable.
10. Versatility in construction.

1.0 Case Study Presentation : Construction of G+1 Building using LGSFS - Ferro Concrete Panel Technology

In order to demonstrate the LGSFS-FCP technology developed by Society for Development of Composites, A 2 PC Quarters (Ground + One) building with a built up area of 161 m2 was constructed for Karnataka State Police Housing Corporation Ltd. The construction was carried out by SDC in collaboration with its approved licensed companies. Photographs of the fully finished building is presented in Figs.3.

2.0 Structural Analysis of G+1 demo building.

Structural analysis using FEM and FEA for the G+1 demo building was carried out.. Design loads namely dead load, live load, wind load and seismic loads as per the building code was considered for the analysis. The analysis revealed that the two storied building successfully passed all the design requirements.

3.0 Testing and Certification of a Demo Building constructed using LGSFS–FCP Technology at CTP

A G+1 demo building constructed using LGSFS – FCP Technology at CTP was subjected to various tests for structural performance and evaluation. The tests were conducted by M/s. Civil Aid Technoclinic Pvt. Ltd., a Bureau Veritas company and NABC accredited laboratory, Bangalore. The building was subjected to the following investigative tests:

1. Observation of housing unit.
2. Core Test
3. Load test on roof slab
4. Ponding test on roof slab
5. Rain simulation test on wall surface
6. Nailing test
7. Door tests
8. Acoustic comfort test
9. Thermal comfort test.
10. Fire resistance test.

The Building has successfully passed all the tests and based on the results, the following concluding remarks were made.

4.0 Receipt of Award and Patent Filed:

4The 2 PC quarters constructed for Karnataka State Police Housing Corporation by SDC received "Birla Super Endowment Award for Outstanding Concrete Structure of Karnataka 2013 from ICI-KBC. An Indian patent has been filed on this innovative technology by SDC. The BMTPC has issued PAC Certificate in the year 2016. The technology is also introduced in the Karnataka PWD Schedule odf Rates in the year 2016-17.

5.0 Conclusion

The LGSFS – Infill Concrete Panels technology has been successfully developed and demonstrated by constructing a G+1 building by SDC in the year 2013. Till date over 3,50,000 Sft buildings are constructed using this technology. The technology has received user acceptance from private and government departments who are gradually coming forward to use this technology for residential and commercial buildings.

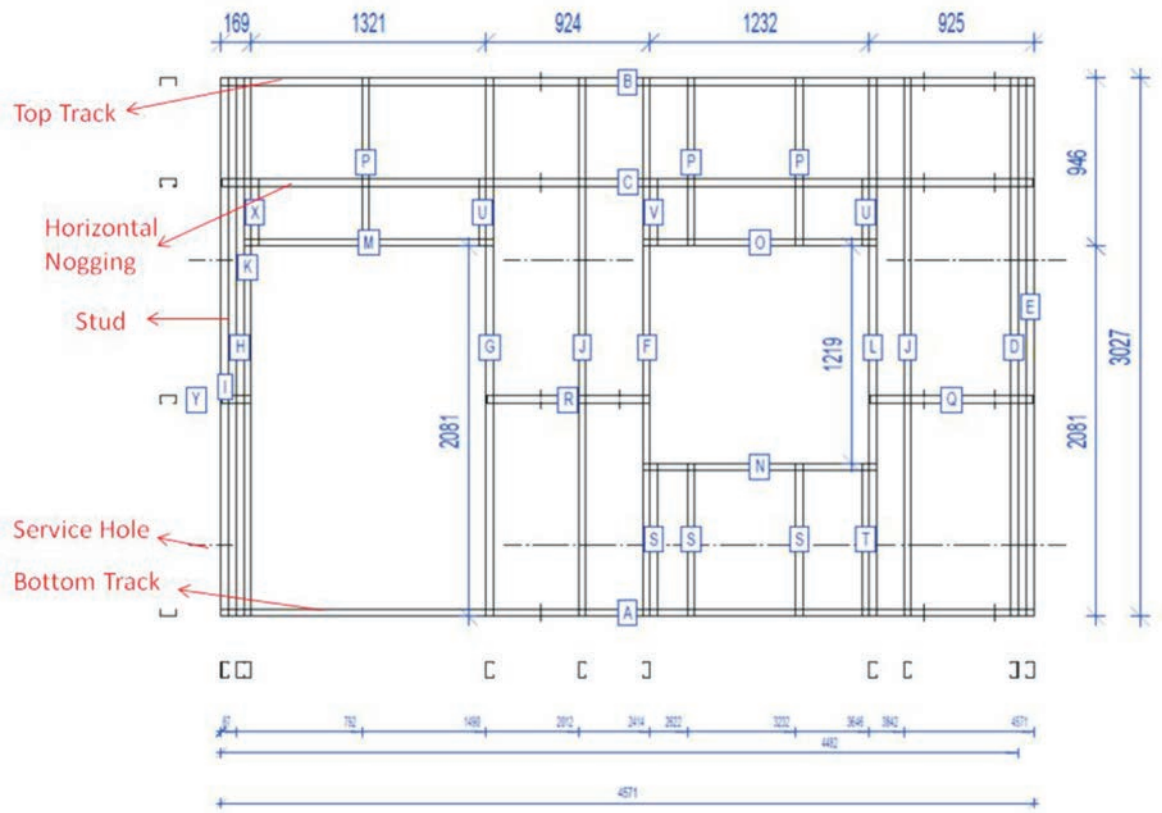


Fig.1 Typical LGSFS Wall

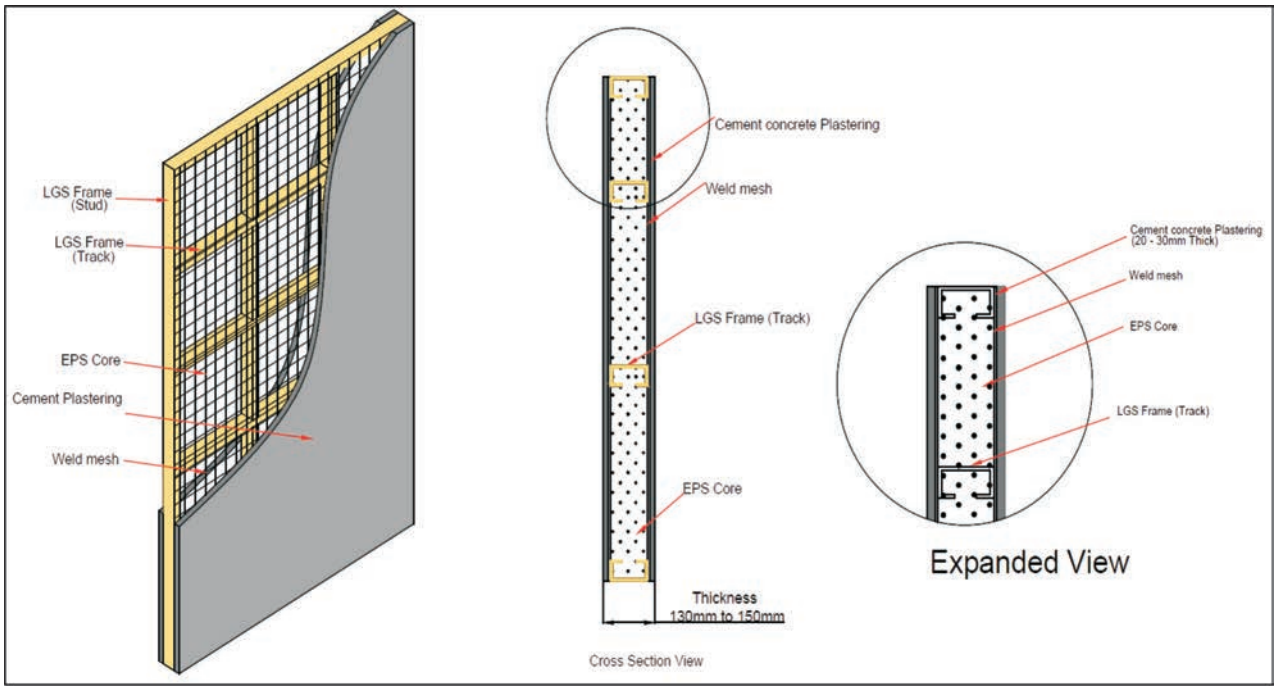


Fig.2 Schematic diagram of LGSFS with EPS Infill Ferro concrete Wall Panel





Fig.3 Fully Completed G+1 Building

ROBOTICS IN CONSTRUCTION: A DISTINCT TECHNOLOGY OPTION

C.K.Varma, CE CSQ(E), CPWD

Abstract

Whenever construction is conceived; pollution containing dust ,dirt, fumes of paints, noise generated by way of vehicular movements, crowding of space by construction workers, huge money spending, labor absentee during festive season resulting in stopping of construction temporarily and delaying the completion of work, menace of unskilled labor, contract subletting, safety violations etc all are perceived. Time and cost overruns are simply implied and dispute is inbuilt whenever any construction project is envisaged. To avoid all this, many new construction technologies have been in place where either construction takes place in factories and assembly takes place at site or construction work happens at site but as per the pre conceived design so that high speed of construction is maintained. This when combined with construction materials of low or zero energy embedded materials like C&D waste, fly ash and materials covered under technical textile etc give birth to many new construction technologies with mass, rapid and sustainable construction.

However, these have their own limitations while having the advantages of mass construction rapidly with green materials. Use of Robotics adds new dimension to the already existing construction practices as well as new construction technologies which are coming up very fast in construction domain. This paper analyses how this solution will work equally well with existing as well as new construction technologies and will thus provide an insight into this Technology and its various aspects associated with field of construction.

Introduction

Robotics being one amongst the advanced technologies of the modern times has found a very important place in every sphere of human life, whether it is Manufacturing Processes, Industrial Production, Environmental challenges, Repetitive Tasks, Tasks requiring Special Safety considerations, Precision Tasks, Remote Tasks etc. Everywhere use of Robotics is involved with added advantages associated with this technology . In short, all tasks where human intervention has to be avoided can be swiftly carried out using this technology. In other words, human presence can very easily be substituted with Robots and even where humans are unavoidable, robots can take the human form and shape and are better known as Humanoids. This Unique applicability of human like machines better known as Robots can also be applied in the domain of construction as well.



Fig.1 A few facets of Robotics

What is Robotics?

The question which emerges now is what is robotics? The answer lies in the fact that it is a combination of numerous branches of science, engineering and technologies. Mechanical Engineering together with Electronics Engineering, Information Technology, computer Science and many other fields have given rise to this technology better known as Robotics. The design, construction, operation, use of robots, use of computer System in their control, information, sensory feedback etc all and many more are included in Robotics. A useful substitute of humans since it can replicate human actions to the great precision and accuracy, a Robot can be employed in numerous situations and for various purposes. The biggest usefulness of Robots lies when work/task is to be performed in difficult and unsafe environments, where repetitive type of work is to be performed, where high level of precision is required in the finished task, in manufacturing processes and so on and so forth. Where only human presence is acceptable and the task is repetitive and is required to be learnt; even there Robots can replace humans by taking their shape and are better known as Humanoids. The algorithm which replicates walking, lifting, speech, cognition and basically what all a human being can do is the key to development of such Robots which are also inspired by Nature. It means Robots can take the form and shape of any living or non-living creature on this planet called Earth. The concept of a machine which can imitate a human being in form and can perform all the tasks asked to perform without any complaint is not new but dates back to good old golden days of our existence. In short it dates back to very early days of our civilization when human mind faced opposition from another human mind. However, the real work on the functionality and potential use of Robots grew substantially only during 20th Century and thereafter. Although various scholars, inventors , engineers and technicians had the conviction that a day will surely come in human civilization when a machine lookalike of human being will be able to mimic human behavior and will execute the tasks in human like way. This belief developed only now and today Robotics is a growing turf only due to many technological advances in almost every field. There are many Practical aspects in research, design and building of new Robots in almost all field of operation that is Military, Commercial or Domestic. The interesting facts are that development of Robotics is

also developing Nano- Robots and Microscopic Robots which can be injected into human body and can thus revolutionize the field of medicine and thus the arena of human health. Science, Technology, Engineering and Mathematics have used Robotics as a teaching aid while defusing Bombs, finding survivors in case of fire or natural calamities like earthquake, Tsunami etc, exploring mines and shipwrecks are also the areas where use of Robots can be greatly appreciated and employed.

Evolution of Robots –

The history of robotics is also as interesting as evolution of human beings. However, it is devoid of the theory of Darwin so far. While its origin can be traced to the ancient world in the form of artificial servant and companion, the modern day Robot began to be developed with the beginning of the Industrial Revolution in England where the concept of complex machines was developed and the subsequent introduction of electricity provided required boost in this direction. Thus power machines with small compact motors were created.

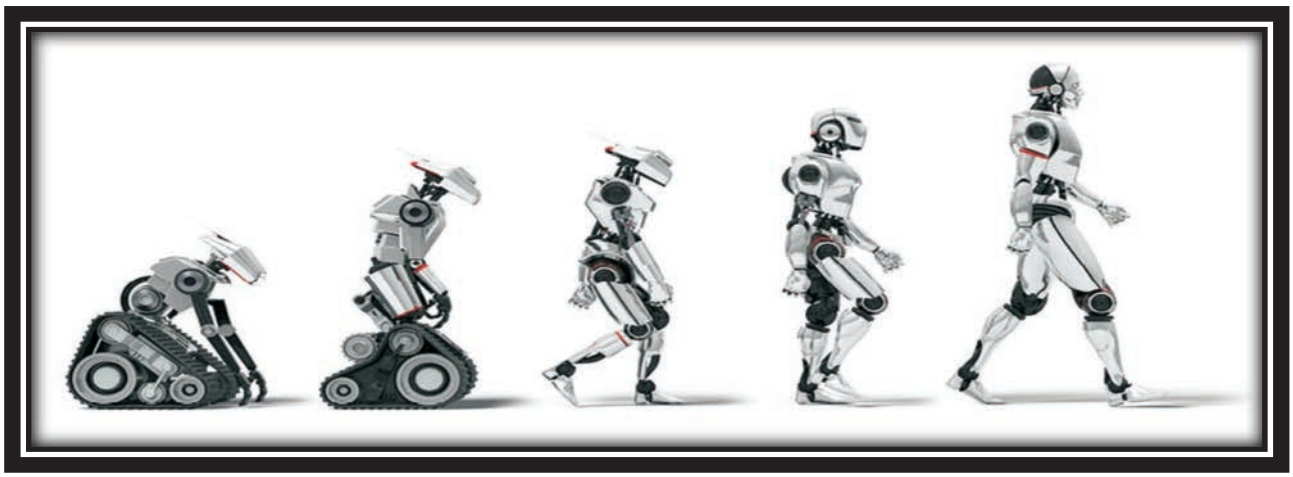


Fig. 2 Evolution of Robots

In the early 20th Century, notion of humanoid was developed and today, human-sized robots with the capacity for near-human thoughts and movement have been developed thanks to the development of Artificial Intelligence. Initially the modern robots have been employed in factories as industrial robots which were simple fixed machines capable of manufacturing tasks which speeded up production with lesser needs for human backing. Subsequently Digitally controlled industrial robots and robots using artificial intelligence have been developed and introduced later since early 21st Century. Thus history of robots combines best of science fiction and real life technologies.

Construction Space & Robotics

Time and cost are the two important confines within which any Construction space is required to function; but it always surpasses these boundaries. Such is the space function of

construction and therefore every endeavour is made to avoid time and cost over runs. The new and emerging construction technologies provide the answer to the gaps between conventional construction and the required pace of construction necessitated by the pressure of population as well as economic development. Yet these technologies bring with them the limitations in one way or the other like non-flexibility of electrical, plumbing and furniture layout, seismic zone of construction due to vulnerability owing to possibility of occurrence of earthquakes, number of floors etc. Robotics is the latest and modern day approach in this direction which due to its universality obviates the limitations of conventional as well as New Technologies.

In fact, what Robots can do in the construction domain, humans or any other technology can't. Further Robots can contribute to the conventional construction space as well as new technology construction space equally well. Further as the construction space covers both “construction” as well as “demolition & then construction” approach; there are construction as well as demolition robots both. Obviously, it is because Robot is a machine that can be programmed to do a specific work and can be designed and built according to the activity it is proposed and supposed to perform.



Fig.3 Robots carrying out different construction activities

Further within the construction robots, there are specialized robots like brick laying robots, Plastering robots, welding Robots, Cleaning Robots, concrete paver Robots, Security Robots, Inspection Robots etc. Even there are robots which can lay a street with pavered blocks on its both sides. Thus Robots can do a construction activity with much ease, precision, safely, speedily etc. Similarly, in the domain of demolition too, Demolition Robots can take up the work of demolition with much accuracy, can perform demolition day and night to complete the job much faster while recovering the materials which can be re used thus saving precious waste , energy and space of land refill.



Fig.4 Robots carrying out different finishing construction activities

In fact, Robots can build a wall six times faster than a mason-beldar duo. Then there is 3d Printing Robot which can build large buildings on demand. In short, the Robot industry is developing Robots of all hue and sizes,for doing any activity whether repetitive or innovative thanks to Artificial Intelligence besides Robotics, of any perfection, of any time frame etc.



Fig.5 Robots carrying out different demolition activities

Acceptability and Other Challenges

The acceptability of this technology is the biggest challenge. It is a common thinking that Robots will one day replace the entire manual processes involved in all human endeavors. This fear is however unfounded as the manual skill in repetitive processes will shift to better ones like development of robots, operation of Robots , maintenance of robots, software and hardware development of Robots, Employment in advanced Computer developments like Machine Learning, Deep Learning, Neural Networks etc. In addition, there are various other challenges like exorbitant cost of acquiring, updating and maintaining the construction robots and related technology. Besides, the cost to train and retrain the Robots and upgrading their skills will be prohibitive initially. The very nature of Construction industry like financial constraints, fragmented nature of the industry, varying size of work at different work places etc will also provide initial roadblocks. Not only this but some ethical issues like reduced human control, lessening of human responsibility, erosion of human construction skills etc will always be associated with this technology. But once the right eco system has been created , there will not be any going back for this technology since the advantages associated with this technology are numerous and the pace of construction which will be achieved will be tremendous. Not only pace but other advantages will outnumber the issues and challenges arising out of the adoption of this technology.

Conclusion

The time overrun in large projects is around 20% while cost overrun may be as high as 80% according to a rough estimate. This technology can bring sea changes in this perception by the ways and manners it works i.e. through the programmable machines carrying out the manual jobs. There is therefore, a need to go in for advanced automation of construction

industry where Robots are seen doing the various activities of construction which is still regarded as least automated. Automation using Robotics is in itself a technology option which is comfortable with both Conventional as well as New Construction Technologies. This is another added advantage associated with Robotics. The need is to comprehend its various features and take those actions proactively which will support the disruptions this technology will bring like mass unemployment of masons, Beldars, Supervisors, Construction managers etc., shifting of skill generally construction specific to the construction, Programming and maintenance of the robots etc. Robots can also work as COBOTS i.e. Collaborative Robots in tandem with Human beings for the places which are dangerous to human beings hence the fear of replacement of manual labour by switching over to this technology can be detached completely .

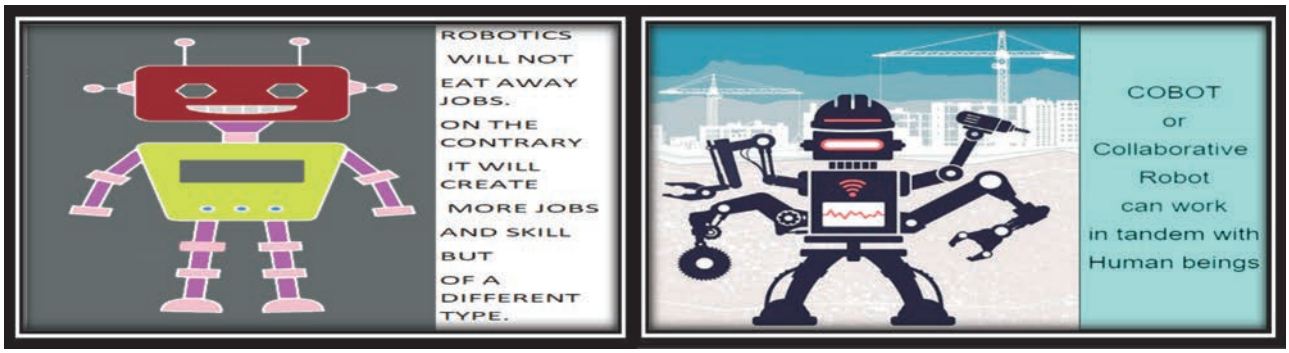


Fig.6 Challenge of unemployment and its Solution

Recommendations

1. Robotics is a technology which can do wonders in the field of construction in terms of speed, flexibility, safety, quality etc. In other words “You name it and We do it for You” is the central theme of this technology; hence there should be progressive use of this technology to avoid construction related accidents which we hear almost on daily basis.

2. CPWD being the Principal Technical Advisor to the Government of India should try this technology as a proto type and comprehend its various implications and then proliferate it if it is of significance.

3. A white paper should also be published by CPWD on this technology on behalf of Government of India clearly spelling out its good and ill effects.

References

http://www.google.co.in

INNOVATIVE CONSTRUCTION MATERIALS: FOR SUSTAINABLE CONSTRUCTION

C.K.Varma, CE CSQ(E), CPWD

Abstract

Advances in material science had provided to the mankind a plethora of materials which are lighter, stronger, more durable than their existing counterparts, sustainable, innovative and serving more than one purpose. In short, these are smarter and more useful innovative interventions which have come out of laboratories recently or with some lapse of time and have already or are about to change our built habitat. In other words, influencing substantially the way we live, think and move in space and time dimensions.These advances are poised to make wonders the way we conceive our built environment and perceive construction technologies available to human beings at present or are going to sweep in the days to come. This paper provides a glance of few innovative building materials to give an insight of our future habitat.

Introduction

Imagine a building or construction space where building materials are so advanced and innovative that the entire construction has altogether different dimensions. For instance, the building is a framed structure but the concrete used is self-healing type so that structure repairs itself after getting damaged; the bricks used are combination of woollen & pollution absorbing bricks so that thermal discomfort and menace of pollution is taken care of by walls themselves, the glazing besides providing sun light also produces energy from it, the Aluminium used in windows and doors is transparently stronger than steel , the inner walls require less artificial light not because more sunlight is tapped by right orientation of the building or bigger size windows are provided but the inner wall itself emits light due to its inherent property, the evaporative shelter itself covers for reducing energy requirements of thermal comfortand so on and on. This is the vision of future built spaces where conventional design practices will be simply outdone by innovative use of new and smart building materials.

Material Science Advancements

The development of materials has revolutionised our lifestyle radically in this era of modern age and the credit goes to the advancements in Material Science.The way human beings live today is altogether different than when human civilisation began to settle. Even prior to this, the human mind always innovated and improved the circumstances of our living. The

changes brought however were systematic initially. But now the drasticity is visible due to number of choices available to mankind at one go.This all is possible due to large number of innovations and advancements in material science. The options available today are numerous and enormous.

The age of Human civilisation once upon a time wascategorised as stone age, metal age etc. So, what it should be known today?Probably the Smart Age. The transition however was not easy and has passed through many phases of hard and tiring work.Many materials have come out of the laboratories and have made a dent into our lives already while many others are in the process of rolling out. Many are in the process of being developed while many others are taking shape in scientists' minds still. Nevertheless, what has come out for human consumption is economical, strong,smart, serves more than one purpose etc.

Glimpse of A few Innovative and Smart Materials

A brief description of a few building materials will provide a glimpse into what is in the offing in the days to come.

Concrete

Concrete is a widely used construction material and is made up from gravel, sand, cement and water which hardens with time. It is filled in foundation, roof slab, columns and beams in different mixes which is then reinforced with steel bars of different grades. There are different concrete varieties depending on the applications and so there isCement concrete, Ready mix concrete, Reinforced cement concrete etc. But now many innovations are available in this important building constituent to add different values and to make it more versatile. Below are some of the variants:

a) Self -Healing Concrete

As the name itself indicates, this type of concrete repairs itself whenever some cracks develop. So one can very well imagine how interesting and useful a self- healing concrete will be. But how is that possible? The answer lies in the bacterial reaction that takes place within the concrete itself.

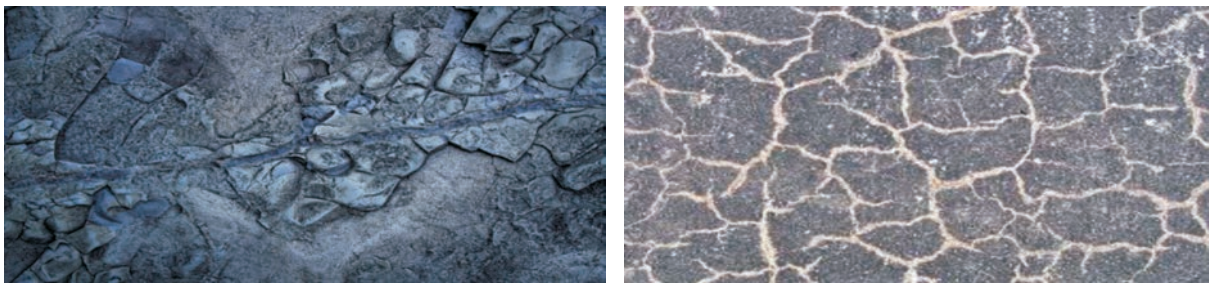


Fig 1. Self Healing Concrete

Self-healing concrete could solve the problem of concrete structures deteriorating well before the end of their service life. Concrete is still one of the main materials used in the construction industry, from the foundation of buildings to the super structure and underground basements etc.

b) Light-generating/Translucent concrete-

The concept of Energy Efficiency has been greatly instrumental in this innovation called "Light Generating Concrete". So, this concrete has the capacity to absorb light and emit it whenever there is darkness. The concept is not new but putting it into practice is what makes it innovative. As different ingredients of the concrete give it the desired properties, same way the material which absorbs light and emit/transmits it when needed provides the required effect of light emission. Due to embedded light optical elements - usually optical fibers, light is conducted through the stone from one end to the other. Therefore, the fibers have to go through the whole object. This results in a certain light pattern on the other surface, depending on the fibre structure. The application of such concrete is very vast like in building facades, swimming pools, kitchen, bathrooms, parking lots, stairs, corridors etc.

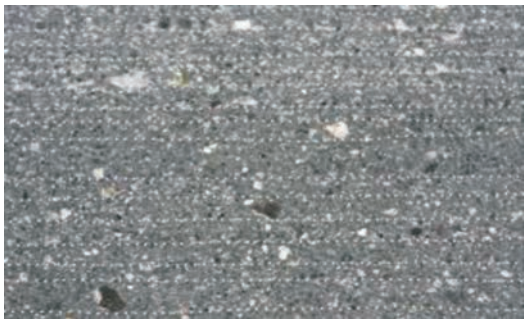
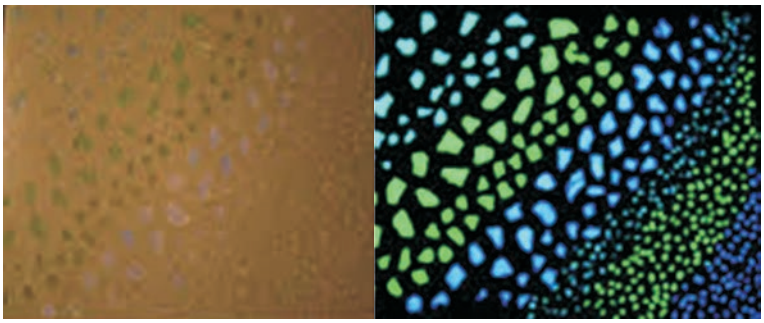


Fig 2. Light Generating Concrete



(a) Under artificial light (b) Under Darkness

Fig 3. Translucent Concrete

Brick

Brick is an often-used building material used to make walls, pavements and other elements in masonry construction. Basically, it is a rectangular unit generally red in color, of a standard size and is made out of clay. It has a designated strength and provide the desired strength to the wall/ pavement when arranged in different bond formations and plastered with cement on both sides. However, innovations in its constituent materials provide it the multiple uses. Below are some of the examples:

a) Wool Brick

As the name itself indicates, this brick is laden with woolen material. This innovation is used to provide the thermal insulation to the built habitat. Again an innovation inspired by Energy efficiency , wool is added in these bricks.



Fig 4. Wool Brick

b) Pollution-absorbing brick

Bricks can also absorb pollution. Believe it or not, such type of bricks is not only conceptualized but manufactured, tested and put into beneficial use.



Fig 5. Pollution-absorbing brick

Glazing

Glazing means a lot and not merely providing glass to the doors and windows of a building to improve window to wall ratio. Technically it refers to the glass component of a building's façade or internal surfaces. Glazing provides a complete make over of any modern building if used in façade. There are many aspects and descriptions of Glazing. However, following are some of the innovations in this field as well.

a) Low emissivity Glazing

This glazing emits low heat energy. Planck's law normally determines the absorption, emission of heat energy. However to defy this law, the thin film coatings are applied during the making of low emissivity glass.



Fig 6. Low emissivity Glazing

b) Invisible Solar Cells

The development of this new incredible material has led people to believe and change the way solar energy was harnessed so far. So why one should be shy in tapping solar energy from all facets of the building. Consisting of a see through solar material, now the glasses used in a building can also serve to harness solar energy whenever it is available. And the biggest advantage of these is that they work at much lower temperature . So what will one say when his windows besides providing outside vision generate electricity also. Incredible!



Fig 7. Invisible solar cells

Aluminum

Aluminum is also a much used building material in construction sector . It is more often used in doors and window frames etc.

Transparent aluminum-

The combination of the strength and durability of metal with crystal clear purity of glass appears fiction but transparent Aluminum marketed under the name ALON has made it possible. It is a ceramic chemically known as Aluminum Oxy nitride composed of Aluminum oxygen and Nitrogen.It is the hardest polycrystalline transparent ceramic available commercially. It can be used as a blast resistant window. It is a dream innovation developed by material scientists.This can be used to construct skyscrapers with high glass-walls that require minimal internal support. Secured military buildings and huge aquarium you could built with this can have great visual value besides extra ordinary strength.



Fig 7. Transparent aluminum

Aluminum Foam-

It is a low density, high strength material with controlled stress-strain Characteristics and is finding applications in acoustics for noise absorption, providing shield to the Electro Magnetic Radiations etc. Both noise and EMR are the great menace in today's advanced age.



Fig 8. Aluminum Foam

Wiring through Conductive ink

Wiring in Buildings as of now is a very tedious and contentious process. Selection of Conduit material, size, its laying through slab and walls involves lots of exercise, caution and restraint. However, soon it may be a thing of past as due to Low voltage LED fittings, 230 V AC will be out and Low Voltage DC will be in for lighting, fans , mobile charging, vehicle charging etc. Only for ACs and other power equipments like AC, Referigerators etc , power will be required but soon its solution will also be worked out and then wiring will be carried out simply through the conductive ink over the walls and slab.

Likewise, there is a flood of materials available which can work wonders in building construction. It may not be possible to accommodate their mention and brief description here due to paucity of space.

Conclusion

It is a fact that with the flooding of numerous innovative construction materials in the market, construction sector itself will have a new and different outlook. There is now no going back on old and trusted building materials. Already many new and innovative variants of building materials are in use like fly ash bricks, AAC Blocks etc. Now is the time to replace all of them systemically with new breed and brand of building materials which are not only economical, smart, innovative but durable, strong and serve more than one purpose.The only word of caution is to ascertain that the claims made by these materials is for all seasons and locations with the desirable properties and strength .

Recommendations

1. CPWD being the Premier Construction Agency to the Government of India should take a lead in this direction and should set up a cell which may continuously strive to test the efficacy of all innovative building materials.
2. Not only this, it should also test use them in some of its projects in a limited way and carry out their live testing.
3. All tested and thus trusted new and smart building materials should be promoted under the name "Innovation" so that general people can build a trust on the claims of these materials and their brands.

References

www.google.com

INSULATED CONCRETE FORMWORK TECHNOLOGY

Sh. M.M. Roy, Reliable Insupacks

This technology replaces the conventional RCC frame structure of columns and beams, that are filled up with masonry walls. Fully load bearing, monolithic, fire and disaster resistant walls with 150 mm monolithic concrete core, sandwiched inside two layers of EPS (Expanded Polystyrene panels) create the load bearing structure.

Thus, a speedily erected shuttering system subsequent to concrete pour (which cures adiabatically using the water in concrete mix and the heat of hydration retained within insulated shuttering) provides a high degree of thermal and acoustic protection along with very high level of air tightness, making the structure up to 80% energy efficient (in terms of HVAC Load).

Formwork

Lightweight, inter-locking blocks of Six types (Standard, Corner, Lintel, Half height, Floor Edge & End piece) moulded from high density, non toxic and self extinguishing grade EPS are held together with hard plastic ties. They are easily stacked on site to hold reinforced concrete. Edges (Openings like door & windows)are sealed with end pieces and Lintels in combination with half height blocks carry the lintel beams over openings. Roof slabs are contained in the floor edge blocks for complete thermal protection and zero thermal bridges. These blocks can be cut using a simple wood saw along moulded lines every 50mm to facilitate any design or size requirement.

Footings

The footings for ICF buildings are usually reinforced concrete rafts or strips that are flat and even enough to enable stacking of the EPS moulded panels, with reinforcement starter bars set ready to connect with the wall vertical reinforcement.

Concrete

Walls are strong as they are made of joint free, monolithic concrete Core, designed as per IS456:2000 and IS:875. Concrete poured is of grade M-20/ 25 with a slump factor of 150 and aggregate size of 10mm. During concrete pouring, vibrators are used to further consolidate the wall concrete.

Reinforcement

Steel bars of dimensions conforming to structural design as per IS456 are used. Horizontal

steel bars are placed during ICF Block stacking, in each layer, vertical reinforcement steel bars placed from top after completion of shuttering parallel to the footing reinforcement bars. Non contact splicing norms are followed as per AC318. 25.5.1.3 “For noncontact splices in flexural members, the transverse center-to-center spacing of spliced bars shall not exceed the lesser of one-fifth the required lap splice length and 6 in.”

Roof

Roof can be either flat RCC slab or sloping and this is also uniformly insulated on the external surface with our patented interlocking EPS moulded KOOLTILEs over waterproofing layer. This is covered by suitable gradient made of mud phaska/PCC to complete the terrace

Wall finishing

Final finishing layer on walls is a glass fibre reinforced waterproof polymerized cement coat or fibre cement sheets screwed on to the plastic webs embedded in the ICF Blocks. However all standard wall cladding materials can be applied.

Accessories

Trestles designed for support from inner side during concrete pouring to ensure straight walls are used every 1-1.5m apart.

Time and cost reduction when compared with conventional systems

Conventional systems today are frame structures made of column and beams, built on top of isolated footings and the structure is subsequently filled with masonry walls. This is extremely laborious , time consuming and hence costlier both during construction stage as well as operative stage due to periodic maintenance costs

	Conventional	Reliable ICF
Footings	• Footings deeper and wider as building load distributed over few isolated footings. • Digging deeper takes longer time. • Digging deeper increases chance of water logging • Contractors reuse shuttering, concrete casting takes longer time. • Building estimates up to 15% extra concrete	• Footings shallower and thinner as building load distributed over an entire strip or raft. • Footing cast in two steps (footing & pedestal) but has to be in one go each time, hence quicker
Columns & Beams	• More concrete and steel to take care of earthquake • Shear wall of concrete and steel with proper anchoring required in mid to high rise buildings • Shuttering of columns and beams is time consuming due to repetition requirements. • Need to be cured with copious quantities of water • Hard water usage in curing causes steel corrosion	• not required as the walls act as load bearing members, • Shuttering using lightweight, interlocking, ICF blocks is child's play and can be effected by un/semi skilled labor very fast. • ICF walls act as shear walls in all directions as they are monolithic and joints free. • Walls being insulated no steel requirement for countering thermal stress fractures. • Steel in walls can be significantly minimized. • Beams required structurally can be incorporated as part of roof shuttering, and concrete placed in one go.

Walls	• Masonry walls are labor intensive. • Steel rebars have to be placed periodically to meet earthquake norms • Lintel beams have to be cast and placed over door and window openings reducing mason's speed • Due to masonry "facing" issue, one side of the wall has unevenness, needs thick plaster. • Brick walls need curing labor and water • Chasing for service lines difficult as brick is hard	• Walls with openings come up fast and straight. • Thin layer of plaster required to cover surface. • Concrete placed in walls cures adiabatically using heat of hydration retained inside the insulated shuttering and the water available in concrete mix which does not leak out of the water tight shuttering. • No waiting period for concrete to gain strength through curing. Roof shuttering can begin day after wall concrete pour. • Chasing easy as eps is a soft material it cuts easily.
Wall Finishing or covering	• Plastering required to cover walls made manually dependent on mason skills, time consuming • frames and walls made of separate materials, one after the other, could have significant gaps • Openings never perfectly rectangular leading to air gaps all around after windows/doors are placed. • Thick layer of cement sand plaster can have significant thermal stress cracks if not cured properly.	• Straight walls need very thin layer of plaster covering. • Openings created out of modular ICF blocks checked to be in perfect plumb before concrete pour. • Plaster, a thin layer of polymerized single component mix reinforced with fiber glass mesh, needs no curing

Benefits when compared with other concrete formwork systems

- No huge initial investment in formwork system as required for each building design
- No cost overruns if required repetitions of capital intensive formworks are not met
- No Curing of concrete is required
- No need for heavy cranes etc. for lifting formwork at construction site
- Perfect thermal & acoustic comfort as un insulated concrete is highly conductive thermally as well as acoustically.

Performance evaluation for sustainability & green aspects

Resource optimization

- New age technology with resource optimization at its heart. Saves natural and construction resources both at pre and post construction stages.
- Saves water used in construction in a big way Other than during casting of foundation this system does not use water at site
- Structural concrete cures adiabatically without extra water and the polymerized cementitious cladding also needs no curing.
- Formwork is modular, can be calculated exactly and procured locally (EPS manufacturing companies within 200 Kms from all sites).
- Can be easily cut with hand saw and leave no wastages at site.
- Shallow footings ,box like connected concrete walls on all side and zero thermal stress

on concrete, reduces concrete & steel consumption

- Labour gets optimized in terms of skill set as well as the quantum.
- HVAC systems capacity can be down sized by up to 75% resulting in similar downsizing of Diesel generators, electrical cables and switching systems.
- Such downsizing makes non conventional air conditioning systems like evaporative cooling or geothermal cooling possible. Hence solar energy can run a commercial building HVAC system. Not possible with conventional due to high starting loads of such I HVACs

Energy efficiency

- Structure of ICF building provides a thermal resistance value (R-Value) of R-19(US) or 3.28 0C.m2/W(SI) against R-2 to R-4 for other building systems.
- ICF systems are zero thermal bridge buildings. Most buildings while using insulation materials, lose significant amounts of energy through thermal bridges, which are made of highly conductive connection between inner and outer ambiences e.g the lintel beams and roof slabs made of highly conductive concrete in conventional buildings or the welded wire mesh connectors in case of 3D panel buildings.
- Another big thermal comfort enemy is the convection currents in un insulated • conventional buildings. Thermal bridges like lintel and un insulated slab roofs set up uncomfortable chilly drafts during severe winters and loss of energy.
- Conventional buildings lose interior ambience @ 8 ACH (air change/hour) due to their leaky constructions. ICF buildings have uniform temperature all around and due to its 5 layered construction system, are totally airtight with ambience loss rate @ 0.5 ACH.
- ICF concrete core offers the characteristic thermal mass/ inertia qualities of heat absorption and thermal lag. This combination serves to reduce and delay peak loads, which may result in lower off-peak energy pricing and reduced HVAC equipment size. In climates with large diurnal temperatures swings, the mass wall can release absorbed heat energy to the cooler night air, a process called heat flow reversal

Use, reuse & reduce waste material

ICF by its very system design can use a lot of waste material in its concrete including fly ash and building waste aggregates. As the concrete inside is thermal stress free because of the insulated formwork, green concrete can be easily used. The construction process itself

generates minimal waste and even the embodied energy of the entire constructed building is recouped through its energy efficiency within 12 months.

Durability and safety

Fire resistivity

Concrete is one of the most resistant building materials to heat and fire. They are more resistant to allowing fire to pass from one side of the wall to the other. The fire wall test measures how well the wall slows the passage of heat and fire from the side with the flame to the other side. The ICF walls do not allow flames to pass directly through. It takes 3 hours before the ICF walls allows enough heat through to start a fire on the cool side. The insulation in ICFs are manufactured with self extinguishing additives. These prevent it from burning by themselves. If you hold a match to the material, it will melt away without appearance of flames.

Impact and natural disasters resistance

ICF walls are undamaged by the direct impact of the debris at over 100 mph. The concrete stops the debris from travelling through the wall. Exterior finishes may get damaged by the impact, but the concrete wall itself remains unscathed. The strength and durability of concrete walls formed with ICFs offer unmatched resistance to the devastation of major storms.

SEISMIC PERFORMANCE In reinforced concrete construction, the combination of concrete and steel provides the three most important properties for earthquake resistance : stiffness, strength, and ductility. Reinforced concrete walls are a composite system: Concrete resists compression forces, and reinforcing steel resists tensile forces produced by an earthquake. The concrete is cast around the bars, locking them into place. The exceptional ductility of the steel to resist tensile forces, coupled with the rock-like ability of concrete to resist compression. Studies of earthquake damage consistently show well-anchored shear walls are the key to earthquake resistance in low-rise buildings. In ICF walls, these elements are designed to survive severe sideways (in-plane) forces, called racking and shear, without being damaged or bent far out of position. Shear walls also must be well anchored to the foundation structure to work effectively. Properly installed steel reinforcing bars extend across the joint between the walls and the foundation to provide secure anchorage to the foundation.

Blast resistance

Concrete has demonstrated blast resistance through tests. The blast-resistant properties of

ICF building systems have been successfully demonstrated in tests in the US, including those carried out in Marine Corps Base. Eleven separate ICF boxes, weighing 13 tons apiece and with walls measuring 8 feet tall and 6 inches thick were subjected to explosion from 50 lbs of TNT at differing distances (3.5 feet to 10 feet) and to pressures from 300 pounds per square inch (psi) to over 7,000 psi. Known for decades for its impact resistant properties, expanded polystyrene (eps), the primary material in ICFs, has recently shown great potential as a blast-resistant product. In each instance during six different blast demonstrations, EPS compressed against the face of the concrete wall and reduced the pressure of the blast. The concretes in ICF often have a compressive strength exceeding 14,500 psi (1020 Kgf/cm2) and contain steel fibers. These blast-resistant structures are often used in bank vaults and military applications.

http://www.concretethinker.com/solutions/Disaster-Resistance.aspx

Acoustic behaviour

The level of sound attenuation achieved is a function of wall thickness, mass, component materials and air tightness. ICF walls have much lower rates of acoustic transmission. Standard thickness ICF walls have shown sound transmission coefficients (STC) between 46 and 72.

Experience of ICF Technology

ICF is a generic technology with a large number of companies all over the world (US, Canada, Europe, China, Australia-NZ, Middle East and now India) producing similar panels to create the ICF constructions from single family homes to multi storied apartments, hospitals and hotels. In India, where the entire ecosystem of such buildings is yet to be fully in place especially in terms of approved schedule of rates etc., we could establish and build eight buildings till date and are in the process of building two more. These being:

S.No.	Location	Nature	Storeys	Area (Sqft)	Year	Construction time frame	Scope
	Buildings already constructed						
1	Manesar (Vill. Pachgaon)	Farmhouse	1	2500	2015	3 months	Fully Finished
2	Surajpur, Greater Noida	Guardroom	1	700	2015	15 days	Fully Finished
3	Indore	Car Showroom	4	10000	2016	1 month	Only ICF fixing+plaster
4	Delhi, Mansarovar Garden	Residential	5	10000	2016	6 months	Basement, Stilt+3 Storeys
5	Theog, Himanchal Pradesh	Hill top farmhouse	2	3000	2017	3 months	Fully Finished
6	surajpur, Greater Noida	Basement+workshop	2	6000	2017	3 months	Fully Finished
7	Surajpur, Greater Noida	Office+Godown	2	18000	2017	5 months	Fully Finished
8	Khammam, Telengana	Residential	2	2500	2017	1 months	only ICF fixing+support
				52,700			
	Projects Approved but yet to begin						
1	CBRI Roorkee	Residential (Demo)	2	1200			
2	RITES building in Delhi	Institutional	3	18000			

In the process of creating these buildings we have been able to create the essential eco system and knowledge base of creating the whole building, from structural design to concrete design for suitable slump and development of cementitious coating material and its application system. All these building product ecosystem is widely available in the countries mentioned and is also available to us in India. Hence we do not see bottlenecks in construction of buildings using this internationally proven 50 year old technology.

COMPOSITE STEEL STRUCTURE CONSTRUCTION

Varun Thareja, Jindal Steel Pvt. Ltd.

In composite construction, the bare steel sections support the initial construction loads and self-weight of the structure. Also the weight of the structure is less than the traditional RCC structure leading to economical foundations.

The composite sections refer to structures having:

1. Composite Columns
2. Steel Beams with Speedfloor slabs

Composite Columns

Composite columns are the compression members comprising of hot-rolled or built-up steel sections encased in concrete or a concrete filled steel sections shown in Fig. 1. The additional reinforcing steel is for fire resistance and in encased sections is to prevent excess spalling of concrete.

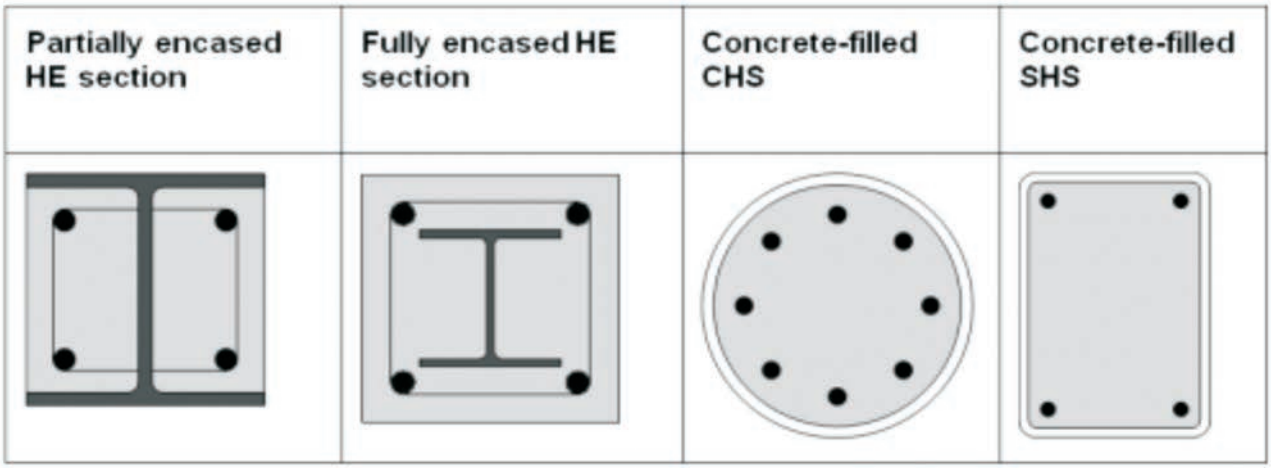


Figure 1: Types of Composite Columns

The steel and concrete give a composite behavior by resisting the loads by both friction and bonds. Additional shear studs are installed in encased steel sections for transferring the longitudinal shear due to external loads such that both materials are utilized effectively.

The steel sections are transported to the site and erected. Subsequently concrete is cast in-situ enabling the whole section to limit sway and adding strength. The buckling is effectively restrained in the encased columns eliminating one of the biggest weakness of the steel sections. Moreover, fire resistance is increased exponentially saving the exorbitant cost spent for fire protection of bare steel sections.

The design of composite sections has to be according to AISC 360-10 or Eurocode 4 as the Indian code has yet issued only the draft copy of the code. The analysis of the buildings should preferably done by the Indian codes using all the Indian load factors, combinations and material strength factors as they are more conservative than the foreign codes and are more relevant to Indian construction methods.

The concrete grade can be used as high as M 70 and structural steel of yield strength 550. The materials should conform to IS 456-2000 and IS 2062-1992. The reinforcing steel should conform to IS 432-1982 (Part 1) and/or IS 1786:1985.

Composite Beams

In the construction of buildings and bridges, steel beams often support concrete slabs. If there is no provision of shear transfer between the two, each component will act independently with relative moment or slip occurring at the interface. In composite construction, the concrete slab and the steel beam act together as a single unit and the longitudinal shear is transferred by the means of shear connectors. This results in increase in strength and stiffness and the whole beam can be termed as composite beam.

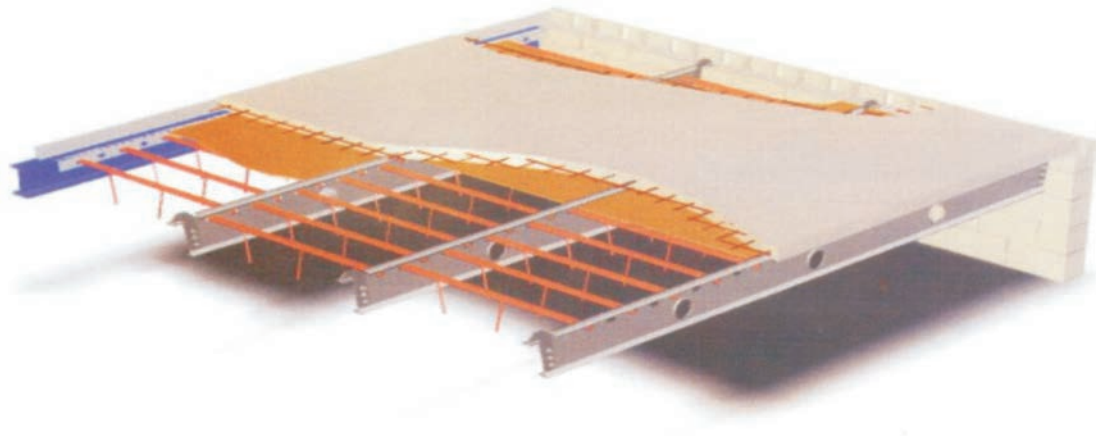


Figure 2: Jindal Speedfloor

Jindal speed floor are placed over the top of rolled/built up I sections and for the speed floor both on-site and shop installation of shear stud/channels can be done. The Speed floor can typically span up to 4.3 m un-propped which is important for fast-track construction. A light reinforcement mesh is added in slab to control cracking, spread the load and provide continuity.

The design of composite sections should be according to Eurocode 4 due to advancement of this code in design of composite beams. The analysis of the buildings should be done by the Indian codes using all the Indian load factors, combinations and material strength factors as they are more conservative than the foreign codes and are more relevant to Indian

construction methods. The materials should conform to IS 456-2000 and IS 2062-1992. The reinforcing steel should conform to IS 432-1982 (Part 1) and/or IS 1786:1985.

Composite Construction

With the use of composite columns along with Speedfloor slab system it is possible to erect high rise structures in an extremely efficient manner. There is quite a vertical spread of construction activity carried out simultaneously at any one time, with numerous trades working simultaneously. For example

- One group of workers will be erecting the steel beams and columns for one or two storeys at the top of frame.
- Two or three storeys below, another group of workers will be fixing the Speed floor slab system for the floors.
- As we go down the building, another group will be tying the column reinforcing bars in cages.
- Yet another group below them will be fixing the formwork, placing the concrete into the column moulds etc. and another group will be concreting the floors.

Brief of Speedfloor Slab System

Speedfloor system is a suspended concrete flooring system using a roll formed steel joist as an integral part of the final concrete and steel composite floor. The Speedfloor system essentially is a hybrid concrete/steel tee-beam in one direction and an integrated continuous one-way slab in other direction. The joists of different depths are manufactured from pre-galvanized high tensile steel in a one pass roll former, where it is roll formed, punched, pressed and slotted in a fully computerized machine manufactured in New Zealand. The joist depth and the concrete thickness are varied depending on the span, imposed loads and other functional considerations. The Speed floor composite floor system is suitable for use in all types of construction. The Speed floor joists are custom manufactured to suit particular job conditions.

There are various advantages of Composite construction using Speed floor Slab system:

a. Fast construction leads to early return of investment. 7-8 days slab cycle can be achieved
b. Steel is factory made quality product which has higher strength to weight ratio result lighter structure
c. As the strength is higher the member sizes in steel building are less as compared to

concrete buildings result in better spaces.

d. Due to light weight it leads to economy of foundation and reduce earthquake forces also.

e. It also reduces human labour component and hence reduce error to greater extent.

List of projects using Speed floor system:

S.No	Project Name	Description (In Kg)	Location
1	Alphathum, Noida	1400000	Noida, UP
2	Mist Avenue, Noida	700000	Noida, UP
3	H20 IT Park (Imperia)	140000	Greater Noida, UP
4	Mahavir Farm	1969	RAIPUR, CHATTISGARH
5	MFAR Holdings	18820	BANGALORE
6	Retail Infra	135920	HYDERABAD
7	Accra Ghana	122204	ACCRA GHANA, WEST AFRICA
8	IREO Club House	10610	LUDHIANA, PUNJAB
9	Reliable Insupack	11300	GREATER NOIDA, UTTAR PRADESH
10	PHOENIX ETNA	112743	HYDERABAD
11	VK Trading, Bargarh	3260	BARGARH
12	Minerals Management, Mansingh Road	300	NEW DELHI
13	KUMAR ENGINEERING PATNA	13320	PATNA
14	Ramaya College Bangalore	2860	BANGALORE
15	A&V associates Bangalore (Ramya College)	4980	BANGALORE
16	Automotive Accessories Show Room, Cochin	3180	CHENNAI
17	Sri City Chennai	960	CHENNAI
18	PGCIL, Faridabad	5200	FARIDABAD
19	GD Goenka Gurgaon	3860	GURGAON
20	Medicity Gurgaon	27740	GURGAON
21	APIDC HYDERABAD	117740	HYDERABAD
22	HRC Hyderabad	22340	HYDERABAD

23	Phoenix ETNA	60880	HYDERABAD
24	Sigma Town Jabalpur	2720	JABALPUR
25	Rajeev Bhawan Bhubaneswar	5480	RAIGARH
26	Stock Yard Ludhiana	3840	LUDHIANA
27	Admin Building JISS OMAN	41680	OMAN
28	School Extension Building Angul	19940	ANGUL
29	BAR MILL PROJECT	248	ANGUL
30	BOF Control Room JSPL ANGUL	4155	ANGUL
31	BOF project JSPL Angul	47328	ANGUL
32	Canteen Building, JSPL Angul	12660	ANGUL
33	CEN TRAL UTILITY PH 1B	1305	ANGUL
34	CENTRAL UTILITY PH 1B	3855	ANGUL
35	CGP Plant Angul	1852	ANGUL
36	Chairman's Kothi JSPL Angul	5760	ANGUL
37	COKE OVEN	5185	ANGUL
38	COKE OVEN 200 BLDG	556	ANGUL
39	COKE OVEN 202 BLDG	673	ANGUL
40	COKE OVEN 203 BLDG	673	ANGUL
41	COKE OVEN 204 BLDG	917	ANGUL
42	COKE OVEN 213 BLDG	3405	ANGUL
43	Coke Oven Building JSPL Angul	84764	ANGUL
44	CPU Regeneration Building, JPL Tamnar	10386.6	ANGUL
45	ECR 1	6523.79	ANGUL
46	ECR 2	5346.78	ANGUL
47	ECR 3	3389.43	ANGUL
48	ECR Bar Mill JSPL Angul	678	ANGUL
49	F Type G+11 Building JSPL ANGUL	2615.68	ANGUL
50	G Type G+11 Building JSPL ANGUL	1312.32	ANGUL
51	G+11 Building F Type JSPL Angul	181189	ANGUL
52	G+11 Building F Type JSPL Angul	19100	ANGUL
53	G+11 Building G Type JSPL Angul	32115	ANGUL
54	G+11 Building JSPL Angul	272038	ANGUL
55	Gym ANGUL	1060	ANGUL
56	HTSS BOF BLDG	2000	ANGUL
57	HTSS BOF BLDG JSPL ANGUL	30544	ANGUL
58	HTSS Building JSPL ANGUL	272	ANGUL

59	HTSS UTILITY BLDG	967	ANGUL
60	HTSS Utility Building JSPL Angul	14295	ANGUL
61	HTSS, Building	5670	ANGUL
62	HYDRAULIC BUILDING(NEAR WSU) &(NEAR H Grid)	7780	ANGUL
63	JSPL ANGUL SUBSTATION	30540	ANGUL
64	Main Control Building JSPL Angul	2061.04	ANGUL
65	Main Control Building, Billet caster	16147.29	ANGUL
66	MS Building	7068	ANGUL
67	MS Building JSPL ANUGL	1359	ANGUL
68	MSDS Building JSPL ANGUL	3870	ANGUL
69	SA Building Sinter Plant	9800	ANGUL
70	SB Building	3098.3	ANGUL
71	SC BUILDING JSPL ANGUL	35220	ANGUL
72	Security Guard Room	160	ANGUL
73	SINTER PLANT	5956	ANGUL
74	SSI BUILDING JSPL ANGUL	10440	ANGUL
75	Stock House JSPL ANGUL	15621	ANGUL
76	Substation HTSS Building JSPL ANGUL	25550	ANGUL
77	Substation SC & SD Building JSPL Angul	5638	ANGUL
78	Substation Sinter Plant	12012	ANGUL
79	Switch Gear Bnuilding JSPL ANGUL	648	ANGUL
80	Switch Gear JSPL ANGUL	16420	ANGUL
81	Type CDD JSPL Angul	12630.91	ANGUL
82	Type DDD JSPL Angul	53061	ANGUL
83	Type EEE JSPL Angul	14614	ANGUL
84	Welfare Building JSPL ANGUL	2772	ANGUL
85	Bangalore Stock Yard	6800	BANGALORE
86	School Bldg Sharda Mines Barbil	8820	BARBIL
87	Type-A Dormotory JSPL Barbil	15180	BARBIL
88	Security Dormitories ,Kurushetra	1320	KURUKSHETRA
89	OPJC Patratu	8200	PATRATU
90	MLSM MCC ROOM	920	RAIGARH
91	11 KV Prasada	1160	RAIGARH
92	A1 Dormitory	4662	RAIGARH
93	A1 Dormitory Punjipatra	180	RAIGARH

94	AD HOSPITAL EXTENSION RAIPUR	211	RAIGARH
95	Administrative Building, SSD	5740	RAIGARH
96	Ash Compressor Building Tamnar	360	RAIGARH
97	Ash Compressor Building, JPL Tamnar	580	RAIGARH
98	Ash Compressor house, JPL Tamnar	12886	RAIGARH
99	Ash Silo Electrical building, JPL Tamnar	4644	RAIGARH
100	Ash Silo Pump House, JPL Tamnar	1587	RAIGARH
101	Ash Slurry pump house, JPL Tamnar	27340	RAIGARH
102	Ash Water Pump House, JPL Tamnar	4535	RAIGARH
103	Automotive Accessories Show Room, Cochin	3880	RAIGARH
104	BARGARH	4780	RAIGARH
105	C Room Raigarh	400	RAIGARH
106	Cafe Block, Hospital Urjanagar	2367	RAIGARH
107	CPU Regeneration Building, JPL Tamnar	3909	RAIGARH
108	DG House, JPL Tamnar	820	RAIGARH
109	Dining Hall OPJIT	12040	RAIGARH
110	Dormitory Building Punjipatra	24060	RAIGARH
111	Dormitory Housing Prasada	47980	RAIGARH
112	ECR Building Raigarh	5900	RAIGARH
113	ESP Building JPL Tamnar	10080	RAIGARH
114	G+3 Housing Prasada	20880	RAIGARH
115	G+3 School Housing Prasada	3280	RAIGARH
116	G+3 School Housing Raigarh	12300	RAIGARH
117	Gas Analyzer Room, Raigarh	1080	RAIGARH
118	GD Goenka Gurgaon	1900	RAIGARH
119	Hospital Main Block, Urjanagar	24735	RAIGARH
120	HRC Hyderabad	6640	RAIGARH
121	Jindal Centre raigarh	440	RAIGARH
122	JRPL, Sonipat	60	RAIGARH
123	LT Switch Gear building Tamnar	2960	RAIGARH
124	MCR Building, JPL Tamnar	2680	RAIGARH
125	Nalwa Control Room	480	RAIGARH
126	Nalwa Lunch Room	4400	RAIGARH
127	OPJC Patratu	6360	RAIGARH
128	OPJCC Punjipatra	1800	RAIGARH

129	OPJIT Punjipatra	1500	RAIGARH
130	RUBM Project	5300	RAIGARH
131	RUBM Raigarh	12280	RAIGARH
132	Security Dormitories ,Kurushetra	1900	RAIGARH
133	Service Block, Hospital Urjanagar	2698	RAIGARH
134	Shopping Complex Dormitory Punjipatra	1240	RAIGARH
135	Shopping Complex Prasada	2240	RAIGARH
136	Shopping Complex Punjipatra	4140	RAIGARH
137	SSD Housing Temple, Punjipatra	150	RAIGARH
138	Switch Yard Building Urjanagar	1140	RAIGARH
139	Toilet Complex, Punjipatra	330	RAIGARH
140	Type A1 Dormitory Punjipatra	19700	RAIGARH
141	Type-A Dormotory JSPL Barbil	3260	RAIGARH
142	Urja Nagar,JPL	13320	RAIGARH
143	Waste Block, Hospital Bldg Urjanagar	733	RAIGARH
144	AD HOSPITAL EXTENSION RAIPUR	400	RAIPUR
145	MAHAVIR FIRM, RAIPUR	2400	RAIPUR
146	OPJC Patratu	15040	RAMGARH
147	JRPL, Sonipat	560	SONEPAT
148	Hyderabad Stock yard	23180	VELLUMALA
149	Ghaziabad Stock Yard	20880	GHAZIABAD
150	Stock Yard Ghaziabad	6280	GHAZIABAD

MIVAN FORMWORK USING IN MONOLITHIC CONSTRUCTION

A.K. Sharma, Chief Engineer-NZII, CPWD, Lucknow, U.P.
V.K.Gupta, Executive Engineer, APD,CPWD Amethi, U.P.

1.0 Abstract

The aluminum formwork system was developed by Malaysian Company and that's why the aluminum formwork technology is named after it. Mivan is new construction technology upcoming for successful completion of mass housing project in India. In this project i.e we have discussed about benefit of Mivan technology with conventional construction technology. The Mivan technology is absolutely fine with cost quality and time saving as compare to conventional. In this project we have taken practical output v/s parameters as claimed by Mivan. The project also include all quality parameters which are superior than convention concrete.

2.0 Introduction

MIVAN formwork system has been a growing trend in recent years in many countries. The development of country could be depended on progress made by construction industry of that country. Further, the number of houses built in any country could also be a measure of development of that country. While there has been a progressive rise in stock of housing in India since independence, the speed has not kept pace with the rapid growth of population and urbanization of India. As a result, the accommodation shortage is increasing continuously and the situation has become problematic in urban areas .Innovative technologies are essential which are capable of fast construction and are able to give good quality and durable structure in economical manner for mass housing.

Construction is important part of development and it is significant sectors of Indian economy. India is having second largest population in world and in future demand of housing increases desperately with this problem India should desperately need to plan for acquisition of land and rapid creation of dwelling units. Today there is growth in population for that speed of construction needs to be given greater importance especially for large housing projects. Fortunately, some of the advanced technologies for faster speed of construction are already available in the country for e.g. Prefabrication, autoclaved blocks, tunnel formwork, aluminum formwork (MIVAN Technology) of construction etc. The use of MIVAN formwork in construction industry is very low in India compared to other countries. The use of MIVAN formwork in construction having great potential, especially needs for current developing India and not using MIVAN formwork as an alternative construction material and not using it where it is economical is a heavy loss for the country. This new method of construction by

MIVAN technology can increase productivity, quality and performance of work through the use of better construction equipment, materials, and time saving compared to conventional. MIVAN technology is new construction technology upcoming for successful completion of mass housing project in India. To construct mass housing building(Type-II &Type-III) in CRPF campus Amethi ,CPWD are using this technology.

3.0 Mivan Formwork

The Mivan formwork is made up of an aluminum alloy. During Construction in process, the formwork has to bear its own weight along with the weight of wet concrete, live load of labor & workmen and the impact of pouring of concert and so on. The vibration caused during vibrating the concrete for compaction should also be taken care off. The design of form work with consideration of forces to be bearded is an essential part during designing the formwork and the construction of buildings. The Mivan form work should be designed to be able to take up all the loads to the tune of about 370 kg/cm2. It is however usual to work with a small factor of safety in the design of form work. The surface of form work should be dressed in such a manner that after deflection due to weight of concrete and reinforcement the surface should be remain horizontal, or as desired by designer. The modular nature of the Mivan formwork should allow easy fixing and removal of formwork and the construction can proceed speedily with very little deviation in dimensional tolerances.

4.0 Salient Feature of Project

Name of work:	Construction of 938 Nos. Family Quarters (900 Nos. Type-II & 38 Nos. Type-III) and Development Work including Internal Electrical Installation, at GC, CRPF, Amethi (UP) on EPC basis.
Type of contract:	Engineering, Procurement and Construct (EPC)
Tendered Amount:	112.54 Cr.
Time Allowed :	24 Months (02 months for planning and designing & 22 months for execution)
Date of Start :	21.07.2017
Target completion :	12.12.2019
Blockof Type-II Qtrs :-	57 Blocks - 900 no. flats, *(54 Block G+ 3(total 864 flats),3 Block G+2 (total 36 flats)*
Block of TypeIII Qtrs :-	3 Blocks - 38 flats *(2 Block G+ 2 (total 24 flats), 1 Block G+3 (total 12 flats)*

5.0 Design & Scope Related To Mivan Form Work

- The agency shall prepare architectural and structural design & drawing, compatible to monolithic construction
- The agency shall prepare design and drawings for all services such as electrical conduit, plumbing & sanitary etc. compatible to monolithic construction.
- All blocks to be G+2 & G+ 3 floors with RCC monolithic construction using aluminum form work including foundation on Raft/ Isolated/ Combined footings. The minimum height of each floor shall be 3150 MM (from floor to floor).

- The building shall be constructed by using RCC only. There is no provision for brick wall and plastering.
- Stairs and kitchen counter slabs shall be casted monolithic with super-structure.
- Toilet and kitchen sunk to be designed in the monolithic shuttering.

6.0 Parameters of Mivan Formwork

1. When Mivan formwork is suitable
2. Mivan Formwork Assembly
3. Simplicity with use of pin and wedge system
4. Components of Mivan Formwork
5. Work cycle (Speed of Construction)
6. Comparison between Mivan Formwork & Conventional Formwork systems
7. Advantage of Mivan Formwork
8. Limitations of Mivan Formwork
9. Design Mix Parameter adopted
10. Conclusion

6.1 When Mivan Formwork is Suitable

- Mass Housing with Typical Floors
- No. of Repetitions are More (up to 300)
- Fast Construction Required
- High Quality
- Column less Structure`
- High performance toward seismic required

6.2 Mivan Formwork Assembly

Mivan shuttering aims in using modern construction techniques and equipment in all its projects. On leaving the factory all panels are clearly leveled to ensure that they are easily identifiable on site and can be smoothly fitted together using the formwork modulation drawings. All formwork proceeds from a corner.

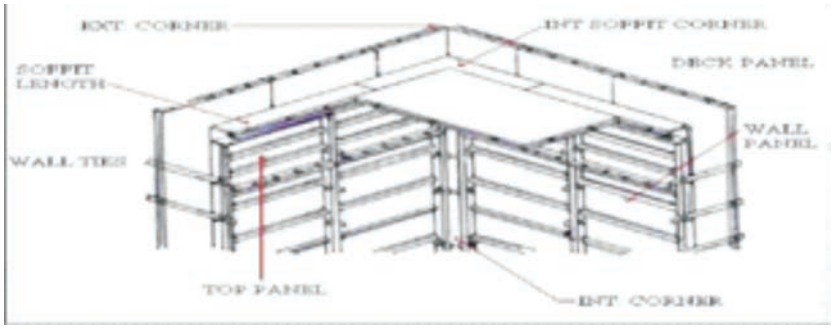


Fig.1 – Wall Assembly Details

6.3 Simplicity – With Use of Pin and Wedge System

The panels are held in position by a simple pin and wedge system that passes through holes in the outside rib of each panel. The panels fit precisely, simply and securely and require no bracing.

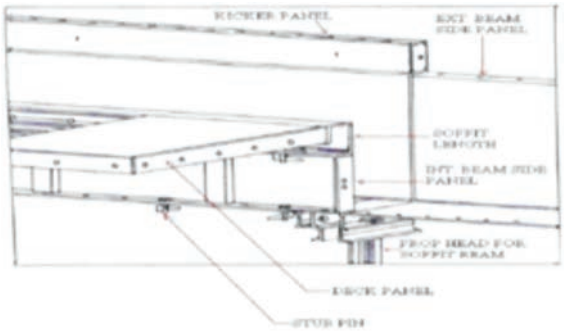
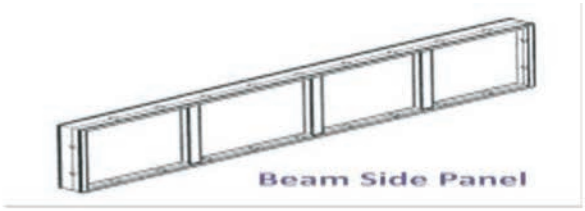


Fig.2 – Beam Assembly Detail

6.4 Components of Mivan Formwork

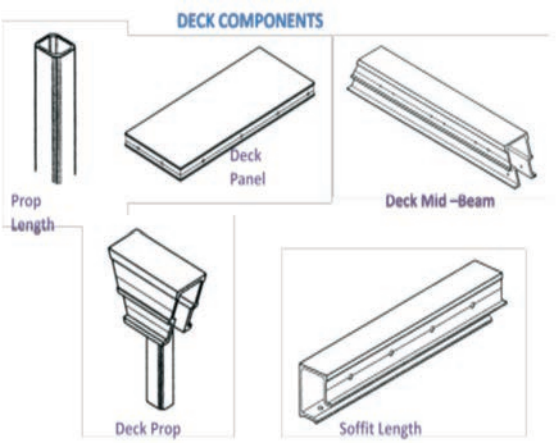
- The basic element of the formwork is the panel, which is an extruded Mivan rail section, welded to an Mivan sheet. This produces a lightweight panel with an excellent stiffness to weight ratio, yielding minimum deflection under concrete loading. Panels are manufactured in the size and shape to suit the requirements of specific projects.
- The panels are made from high strength Mivan alloy with a 4 mm thick skin plate and 6mm thick ribbing behind to stiffen the panels. Once they are assembled they are subjected to a trial erection in order to eliminate any dimensional or on site problems.
- Total Lead time fabrication time is nearly three month.

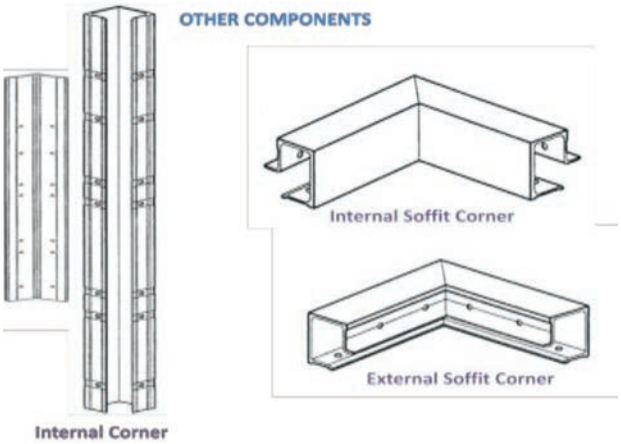

Prop Head

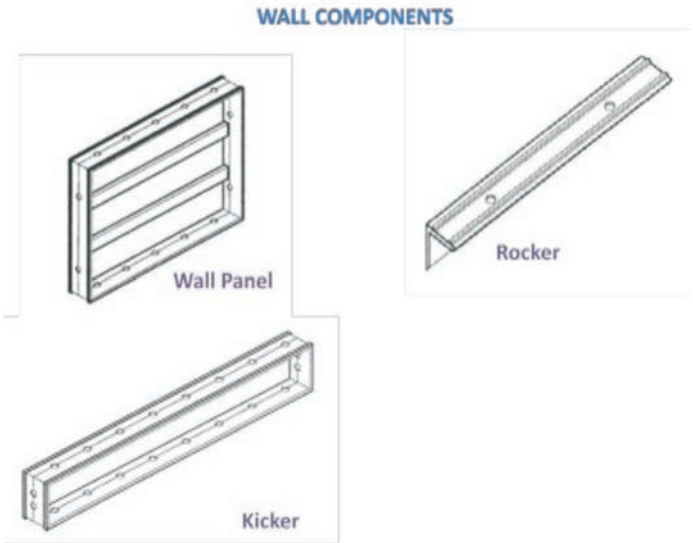

Beam Side Panel

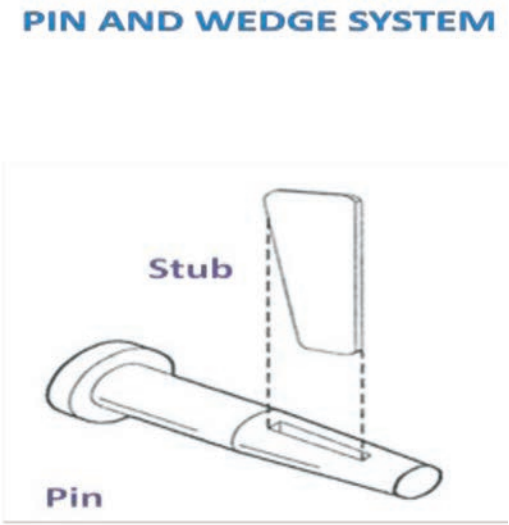

Beam Soffit Bulkhead


Beam Soffit Panel


DECK COMPONENTS
Prop Length
Deck Panel
Deck Mid –Beam
Deck Prop
Soffit Length


OTHER COMPONENTS
Internal Corner
Internal Soffit Corner
External Soffit Corner


WALL COMPONENTS
Wall Panel
Rocker
Kicker

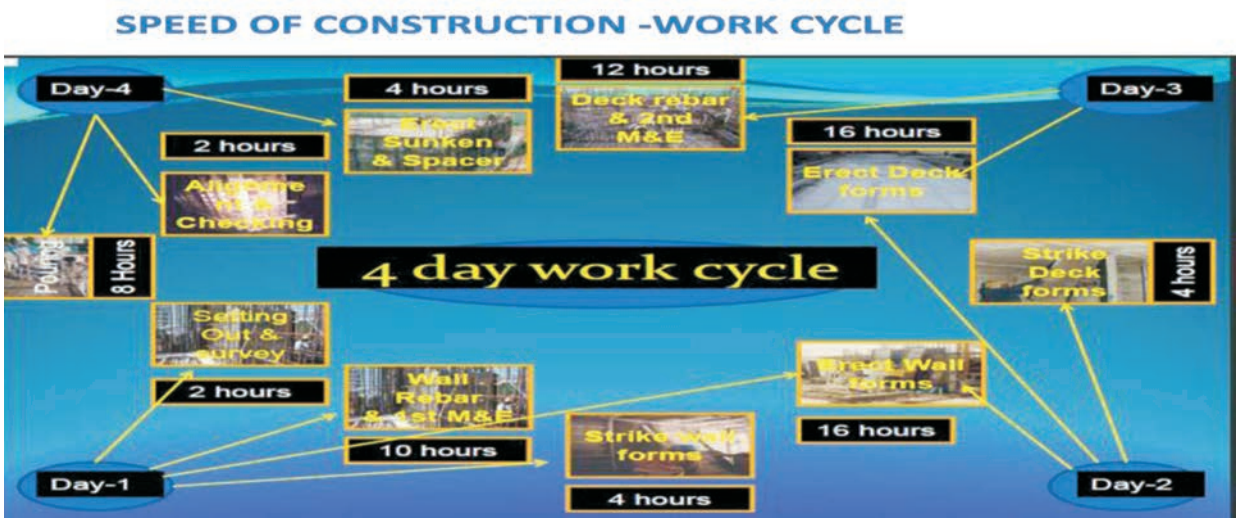

PIN AND WEDGE SYSTEM
Stub
Pin

6.5 Work Cycle (speed Of Construction)

6.5.1Site Management

- The essence of the system is that it provides a production line approach in the construction industry. The labourers are grouped together to form small teams to carry out various tasks within a certain time frame such as, reinforcement, fabrication and erection, formwork erection, concreting etc.
- Scheduling involves the design and development of the work cycle required to maximize efficiency in the field. The establishment of a daily cycle of work, which when fully coordinated with different trades.
- Optimum use of the labour force is made by ensuring that each trade has sufficient work on each working day.
- The improved coordination and construction management enables the equipment to be used at optimum speed and efficiency and speed of the output are outstanding. Thus a disciplined and systemized approach to construction is achieved.

6.5.2 Speed Of Construction -work Cycle As Claimed By Mivan



Day 1: The first activity consists of erection of vertical reinforcement bars and one side of the vertical formwork for the entire floor or a part of one floor.

Day 2: The second activity involves erection of the second side of the vertical formwork and formwork for the floor

Day 3: Fixing reinforcement bars for floor slabs and casting of walls and slabs.

Day 4: Removal of vertical form work panels after 24 hours, leaving the props in place for 7

days and floor slab formwork in place for 2.5 days.

6.5.3 Speed of Construction – Work Cycle as Achieved At CRPF Campus, Amethi.

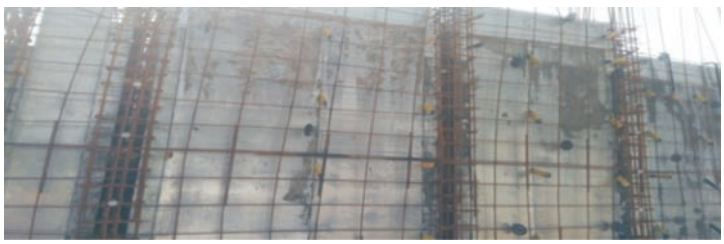
- De-shuttered panels lifted & fixed on floor-6 to 8 hrs.
- Wall shutters are erected in 8-10 hrs.
- Shuttering of slab panels- 5 to 6 hrs.
- Kicker & external shutters fixed in position -7 to 8 hrs.
- Reinforcement of slab– 7 to 8 hrs.
- Electrical conduit on slab -4 hrs.
- Pouring concrete- 5 hrs.
- De-shuttering of the panels – 16 to 18 hrs

SL. NO.	SET OF SHUTTERING	DURATION	DAY	NO. OF REPETITION	AVG. DAYS OF REPETATION
1	SET 1(TYPE III)	27/3/18 TO 23/07/18	118	19	6.2
2	SET 2(TYPE II)	18/04/18 TO 19/04/19	366	105	3.8
3	SET 3(TYPE II)	16/05/2018 TO 30/04/19	349	105	3.32
4	SET 4(TYPE II)	28/06/18 TO 04/05/19	310	105	2.95
5	SET 5(TYPE II)	15/07/18 TO 10/05/19	299	105	2.84
6	SET 1 (MODIFIED FROM TYPE III TO TYPE II)	29/10/18 TO 18/03/19	140	30	4.66
				AVERAGE REPETETION	**3.37**

6.5.4 Work Cycle Achieved At Site

With rigorous planning and deploying additional resources, we could be able to reduce the specified repetition cycle of 4 days to around 3 days: -

Day 1: Shifting of de-shuttered shuttering panels and erecting the wall shuttering



Day2:-Slab shuttering, reinforcement, electrical conduit and concrete pouring





Day 3 : - De-shuttering of wall panels and shifting to next pour





6.6 Comparison Between Mivan Formwork & Conventional Formwork Systems.

S. No	Characteristic	Mivan form work system	Conventional Formwork system
1	Speed of construction	Four days cycle per floor	Ten days cycle per floor
2	Quality of surface finish	Excellent plastering is not required	Ordinary and plastering is required
3	Pre-planning of form work system	Scientifically Required	Required ordinarily
4	Type of construction	Cast in situ cellular construction	Simple RCC framed construction
5	Wastage of form work material	Very less	In great amount
6	Accuracy in construction	Accurate construction	Not as in Alum-form
7	Coordination between different agencies	Acutely essential	Required ordinarily
8	Resistance to earthquake	Good resistant	Less resistant
9	Re-usage value	250-300 repetitions	8-15 repetitions

6.7 Advantage of Mivan Formwork

The Mivan formwork is specifically designed to allow rapid construction of all types of architectural layouts.

- Total system forms the complete concrete structure.
- Custom designed to suit project requirements.
- Unsurpassed construction speed.
- High quality finish.
- Cost effective.
- Panels can be reused up to 250 times.
- Erected using semi-skilled labour.

6.8 Limitations of Mivan Formwork

Despite so many advantages of Mivan formwork there are certain limitations as well. These are as follows:-

- Because of small sizes of panels as compared to wall/ slab size, jointing lines are visible on the concrete surfaces.
- Concealed services become difficult due to small thickness of components.
- It requires uniform planning as well as uniform elevations to be cost effective. As such, there are limitations on architectural play.
- Modifications are not possible as all members are cast in RCC.
- Large volume of work is necessary to be cost effective (at least 200 repetitions of the forms).
- Architectural changes not possible on the structure (but some walls of brick work or openings can be entertained).
- Due to tremendous speed of construction, working capital finance needs to be planned in advance.
- Number of holes will be more in the outer wall, which is in direct contact with the rain. Holes need to be grouted with Non Shrink compound.
- Due to box-type construction shrinkage cracks are likely to appear.
- Heat of Hydration is high due to shear walls.

However, these limitations do not pose any serious problems and can be handled easily.

6.9 Concrete Design Mix Used At CRPF Amethi Project

Need to use Different Mix Designs to make Monolithic construction Compatible

Sl. No.	Grade of Concrete	Type of concrete	Component	Requirement
1	M30	Ordinary Portland Cement Concrete	Foundations ,columns, U.G. Tank and plingth Beams	As per design
2	M25	Ordinary Portland Cement Concrete	Slabs& Drains	As per design
3	M25	Ordinary Portland Cement Concrete((SCC)	Shear walls, stair case, mumty and parapet wall	To achieve slump/flow 500 -700 mm.

Mix Design Parameters															
S.No.	Grade of Concrete	Design Parameters							Content of Concrete Components (per cum)						
		Slump /Flow (mm)	Target Mean Strength (28 days)	Cement	Admixture	20 mm aggregate	10 mm agg.	Fine agg.	Cement (kgs)	Fly Ash (kgs)	Water (lts.)	Admixture (kgs)	20 mm agg. (kgs)	10 mm agg. (kgs)	Fine agg. (kgs)
1	M30	75-100	38.25	OPC 43 grade - Ultratech	BASF-Master Rheobuild	Crushed Lime Stone	Crushed Lime Stone	Zone II natural sand	340	65	166	6.075	426	639	801.05
2	M25	75-100	31.6	OPC 43 grade - Ultratech	BASF-Master Rheobuild	Crushed Lime Stone	Crushed Lime Stone	Zone II natural sand	320	60	166	5.7	427	641	824.3
3	M25 SCC	500-700	31.6	OPC 43 grade - Ultratech	BASF-Master Glenium SKY 8632	Crushed Lime Stone	Crushed Lime Stone	Zone II natural sand	320	160	200	5.76	170	640	960

6.10 Conclusion

The aim of this above is to give an overview of Mivan formwork system along with condition & constraints governing its use and not to provide a detailed comparison or explain the technical features of Mivan formwork system in depth.

The modern methods of construction such as 'Mivan formwork system' are the key to meeting the demand for efficient, sustainable housing.

INNOVATIVE TECHNOLOGIES AND MATERIALS IN CONSTRUCTION USE OF POST TENSIONING IN SLABS OF INCOME TAX OFFICE BUILDING, BKC MUMBAI

P. K. Dixit, SE, ITP, CPWD, Mumbai

Abstract

In the field of civil Engineering world in changing, economy is changing and architectural practice is changing with emphasis on providing large uninterrupted floor space in large spans. Today the building industry is taking the next step in concrete technology by introducing the post tension system to slab construction with the use of systematic form work, high strength concrete and high tension steel. Multi-storey construction has become essential due to scarcity of land. Large modules and spans are preferred especially in office and commercial building due to economy and efficiency of usable area. In this scenario it is much more beneficial if more number of floors are accommodated in the given restricted height for better efficiency of space utilization. Post tensioned concrete has proven to be a preferred method of construction for commercial and office building, residential apartment, parking systems, hotels etc.

The main advantage of prestressed concrete over conventionally reinforced concrete is its ability to span greater distances without resorting to thick slab and beams. Using Post tensioning system thinner slabs /beams are designed resulting into increased head rooms, saving in construction time and associated labour and material reduction in overall building mass which is also important in zones of high seismicity.

Basic concept of prestressing – post tensioning

Prestressed concrete is a concrete in which internal stresses of a suitable magnitude & distributions are introduced so that the stresses resulting from external loads are counteracted to a desired degree.

Concrete is strong in compression but weak in tension. In normal RCC, consisting of concrete and steel as basic components, the compressive stresses are borne by concrete while tensile stresses are borne entirely by steel. The concrete surrounding steel reinforcement does not take part in resisting the external forces since it is week in tension. Only the portion of concrete which lies above the neutral axis is considered to be useful in resisting external forces. This results into heavy sections. In prestressed concrete both steel and concrete are stressed prior to application of external loads. Since such induced pre-stress in concrete is of compressive nature it will balance the tensile stress produced in concrete surrounding the steel due to external loads. Due to this, whole section of the

concrete participates in resisting the external loads.

Need for high strength concrete and steel in post tensioning.

High strength concrete is required to be used which offers high resistance in tension, shear, bond & Bearing. Due to large prestressing force to be applied by tendons, large bearing stress get developed in the concrete by anchorage devices, these large stresses and bursting stresses can be effectively resisted by high strength concrete only. In addition to this high strength concrete is less liable to shrinkage cracks and has high modulus of elasticity, small ultimate creep strength resulting into smaller loss of prestress in steel.

There is considerable loss in stress in prestressed concrete due to shrinkage, deep of concrete and relaxation of steel and it's magnitude is generally 100 to 240 N/mm2, it is apparent that if this loss of stress is to be small portion by initial stress, the stress in steel in the initial stages must be very high about 1500 to 2000 N/mm2. These high stress ranges are possible only with the use of high strength steel.

Advantages of PT slabs

- Post tensioning allows Column free Larger span
- It leads to speedy Floor to Floor construction cycle time(15-18 days per slab) due to simplified Formwork & less steel
- leads to reduction in Dead load due to thinner slab which will make cost savings in foundation & columns.
- leads to reduction of reinforcement quantity. Easy handling of Post Tensioning Materials in congested site areas.
- leads to less no of work force engaged for Post Tensioning works than conventional RCC slabs.
- More floors can be accommodated compared with conventional RCC within given building height due to lesser depth of beams/slabs.



Conventional RCC Beam slab



PT Flat slab

- Reduction in sizes and cost of vertical structural element like columns.
- More clear space is available which allows alteration in building work. Flexibility in providing service ducts, Pipe lines and false ceilings
- Flexibility for providing service ducts and False ceilings.





Case study of income tax project, bkc, mumbai

Introduction

Income Tax Office Building at B.K.C., Mumbai completed in September, 2018 is a prestigious project completed by CPWD over a plot area of 9500 sqm. It is RCC building ground + 10 storey with total built up area of 6.32 lakhs sqft including two basements of 1.54 lakhs sqft to accommodate 600 cars in double and triple stacks mechanized parking system.

This building has all modern amenities like revolving glass door, panoramic glam lifts, double height porch entrance with glass ceiling, high performance glass façade system, , 24 x 18 mts wide atrium in centre covered with laminated DGU system at a height of 55 mts.



PT system in slabs and beams was effectively used in Income Tax office building at BKC for super structure using M40 grade RMC concrete and High tensile steel with UTS1860 N/mm2.

Building was designed in a grid system within column to column spacing from 9 to 12 mts. Post Tensioning system in slabs was used to achieve better floor heights and speedy construction.

Slab was designed for 250 to 275mm thick and beams for 500 to 550 mm depth at required places only. For conventional RCC beam slab system for the same span and loads, the minimum depth of beams would have been 900 to 1000 mm. Therefore with PT slab total clear space from slab top to the bottom of beam was increased by about 400-450 mm in each floor having floor to floor height of 3.9 mt. With saving of 400-450 mm ht in each floor one additional floor could be accommodated with in same building height.

Typical floor of the building generally consist office, lift lobby, corridors, staircase etc. Out of about 4000 sq. mtr. area on each floor ,about 3200 has been provided with PT slab/beams system. In rest of the area like staircase, toilets, conventional RCC slab was used. This PT area was divided into 4 segments using four no. of pour strip. Concreting in each segment was done continuously using concrete pumps.. Total time taken for slab cycle about 15-18 days. Concreting in pour strips was done immediately after prestressing of adjoining slabs with the same grade of concrete admixed with non shrink compound. R.C.C frame work using PT slab beam system for floors was completed in 8 months.



Material used in post tensioning

Patented PT system of Utracon Corporation Singapore was used having following components.

1) High Tensile Steel – H T Strand,

Uncoated stress relieved low relaxation seven-ply strand class II as per IS 14268 : 1995 are used. These are 12.7mm dia HT wires having UTS 1860 N/mm2. It is a combination of 7 wires having a centre wire and surrounding 6 wires which are helically placed over centre wire. HT wires are wound on to a reel.



HT Strands of 12.7 mm dia having capacity of 18.3 T, 7 wire strand

2) G.I Sheathing

Machine manufactured galvanized corrugated steel tubing from galvanized steel strip of 0.3mm thickness used. It has to be mortar tight to prevent ingress of water laitance during concreting.



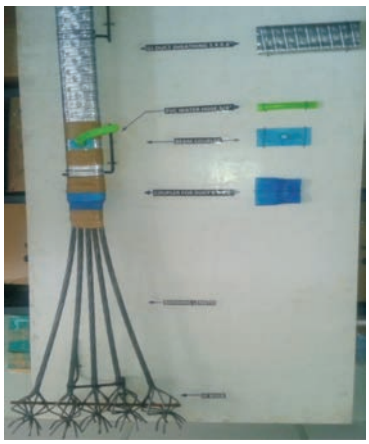
GI DUCT

3) Anchorage

Combination of casting, wedge plate and conical wedges is called anchorage. This combination is used as seating for prestressing the strands and imparting prestressed force from HT wires to concrete.



4) PT tendons used in PT slab/beams are formed by assembling 3/5 HT strands, GI sheathing and anchorages. Fix end of PT tendon having bulbs is called dead end and other end where stressing is done is called live end.



Dead / Fix End



Live / Stressing End

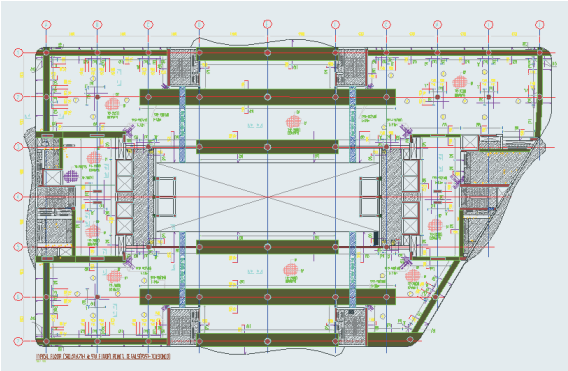
PROCESS FOLLOWED FOR POST TENSIONING

Post tension tendons were installed in accordance with the "approved drawings issued for constructions" as under

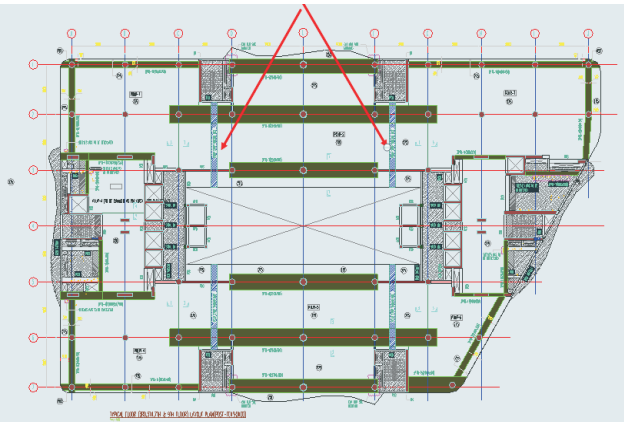
a) Installation of reinforcement and tendons

- Laying bottom slab reinforcement after slab form work was ready.
- anchorages were fixed to the end form work to avoid any displacement during concreting.
- Casting part of anchorage were oriented perpendicular to the cable axis.
- Tendons installation in accordance with shop drawings. Tendon alignment shall take precedent over reinforcement .
- tolerance for vertical tendon profile are +/- 5 mm and +/- 100mm for horizontal tendon.
- Tendons support bars and bar chairs were places at 1 mtr. Interval and secured with binding wires to avoid movement during concreting.
- Duct joints were sealed with tape and straightness of tendons were checked visually before concreting
- Installed top reinforcement

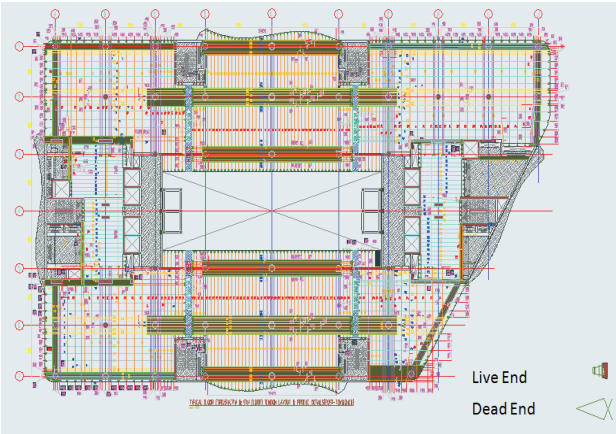




Form work Drawing – Typical Floors



Reinforcement Drawing – Typical Floors



Tendon Layout Drawing – Typical Floors





TENDON LAYING WORK IN PROGRESS AT INCOME TAX PROJECT

b) Concreting

- After thorough checking of tendon profiles and reinforcement concreting was done with M40 grade RMC using concrete pumps
- During concreting ducts were handled with care to ensure no displacement and no stepping on ducts.

- Care was taken that grout pipes (for grouting purpose after stressing) left from tendons be protected from being embedded during concreting

c) Stressing of stands in tendons

- Stressing was permitted only after 7 days when the concrete achieves minimum 25 mm N/mm2 compressive strength
- side form work and anchorage black outs (polyform) were removed
- Wedge plates were secured perfectly over casting ensuring that protruding strand length is sufficient for stressing.
- Only calibrated Jacks and dial gauges were used
- initially 25% of stressing force was applied to the tendon to remove slack in the strand one by one.
- Proceeded with the stressing to the full force i.e 75% of UTS and elongation recorded,

if the results confirmed to designed standards then only stressing length of strands were cut with high speed abrasive cutters and patch up was done by concrete. De-shuttering process started after 24 hours of stressing.

D) Grouting of tendons

- Objective of grouting is corrosion protection of HT strands and bonding between HT strands and the structure.
- Grouting of tendons with non shrink cement grout having water cement ratio 0.45 at pressure of 0.7 N/mm2 was done after 24 hours of patching the live end by concrete but not later than 7 days.
- Grout was checked for viscosity and compressive strength. Minimum compressive strength of 100 mm cube should not be less than 17 N/mm2 in 7 days and 32 N/mm2 in 28 days.
- Grout was injected from the lowest point so that air and water in the duct being less dense then grout is pushed ahead.

Equipments used in post tensioning



Dispenser / De coiler for decoiling the strand from reel

Mix Design Parameters

S.No.	Grade of Concrete	Design Parameters							Content of Concrete Components (per cum)						
		Slump /Flow (mm)	Target Mean Strength (28 days)	Cement	Admixture	20 mm aggregate	10 mm agg.	Fine agg.	Cement (kgs)	Fly Ash (kgs)	Water (lts.)	Admixture (kgs)	20 mm agg. (kgs)	10 mm agg. (kgs)	Fine agg. (kgs)
1	M30	75-100	38.25	OPC 43 grade - Ultratech	BASF-Master Rheobuild	Crushed Lime Stone	Crushed Lime Stone	Zone II natural sand	340	65	166	6.075	426	639	801.05
2	M25	75-100	31.6	OPC 43 grade - Ultratech	BASF-Master Rheobuild	Crushed Lime Stone	Crushed Lime Stone	Zone II natural sand	320	60	166	5.7	427	641	824.3
3	M25 SCC	500-700	31.6	OPC 43 grade - Ultratech	BASF-Master Glenium SKY 8632	Crushed Lime Stone	Crushed Lime Stone	Zone II natural sand	320	160	200	5.76	170	640	960

H- Bulb / Onion Machine for making bulb at dead end of strand



Stressing Jack to pull HT strand



Stressing pump



Grout Pump to inject non shrink cement grout

Checklist for installation and operation of pt slab

All reading as per design requirements during post tensioning were recorded in prescribed Performa. Detailed checklist for installation operation, stressing operation, tendon stressing report, grouting operations standard checklist were maintained at site for installation operation, stressing operation, grout operation and tendon stressing report .

Income Tax Project, CPWD

Checklist for PT work – Installation Operation

PROJECT :
LOCATION :
DRG. No. :
Date :
Sl. No. :

	ITEMS TO CHECK	Checked and confirmed? (Yes/No)	If No. Date when Defect is Rectified	Remarks
(a)	No. of tendons			
(b)	Tendon profile (vertical)			
(c)	Tendon spacing (horizontal)			
(d)	Position of anchorages			
(e)	Grout inlets and outlets			
(f)	Stressing and dead end length			
(g)	Bursting reinforcement			
(h)	No. of strands per tendon			
(i)	Cleanlines of tendons			
(j)	Cleanlines of strand			

Remarks:

USS REPRESENTATIVE	WITNESSED BY CPWD
Name :	Name :
Designation:	Designation:
Date :	Date :

Income Tax Project, CPWD

Checklist for PT work – Stressing Operation

PROJECT : LOCATION : DRG. No. :		Date : Sl. No. :		
ITEMS TO CHECK		Checked and confirmed? (Yes/No)	If No. Date when Defect is Rectified	Remarks
(a)	Cube Strength (>25N/mm²)			
(b)	Jack no			
(c)	Pressure gauge no			
(d)	Stressing pressure			
(e)	Stressing record			
Remarks:				
USS REPRESENTATIVE		WITNESSED BY CPWD		
Name : Designation: Date :		Name : Designation: Date :		

Conclusion:

1) Post Tensioning used in this Project was very effective to reduce the time and cost of construction

2) More number of floors are accommodated in the given height.

3) Huge column les areas have provided good layout of office space and more number of persons.

4) Post tensioning technique prevents tension cracks which are responsible for corrosion of steel in concrete, thus produce quality construction.

References:

1) Prestressed concrete 5th edition by N. Krishna Raju

2) IS 14268 : 1995 for Uncoated stress relieved low relaxation seven-ply strand for prestressed concrete specification.

3) IS 1343 – 1980 code of practice for prestressed concrete

4) Specification and methodology used for post tensioned work in slabs/beams in Income Tax Project.

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