National Conference on

Indigenous Engineering Solutions in Constructions of a Self-Reliant India

SPEAKERS

Sh. Rajneesh Sareen
Programme Director , CSE.

Dr. Chandan Ghosh
NIDM, MHA

Dr. Ashutosh Pathak
Former Advisor GRIHA

Sh. M. K. Sharma
Former ADG, CPWD

Dr. Rajeev Goel
Former Dy. CE, IRSE

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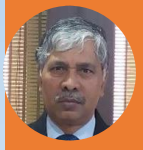
Sh. Dinesh Kumar
Former SDG, CPWD

Smt. Usha Batra
Former SDG, CPWD



Dr. K. M. Soni,
Former ADG, CPWD

Date: 28th October 2021

Organized by: National CPWD Academy, Ghaziabad

About the Conference

To keep pace with fast growing urbanization and industrialization and to fulfil the vision of an Atma Nirbhar Bharat, there is a need of promoting indigenous techniques for rapid construction using innovative and sustainable locally available materials in projects. This conference is aimed to create awareness among various stakeholders on such technologies and materials.

Schedule

Time(Hrs)	Subject
10.00 – 10.05	Felicitation of dignitaries
10.05 – 10.15	Welcome address by Sh. M.K.Mahobia, ADG(T&R) , National CPWD Academy
10.15 – 10.25	Address by Sh Shailendra Sharma, DG, CPWD
10.25 – 10.35	Opening address by Sh Durga Shanker Mishra, Secretary, MoHUA, GOI
10.35 – 11.00	Technical Presentation on "Climate appropriate and Indigenous building techniques and technology for self built housing: A knowledge repository" by Sh Rajneesh Sareen, CSE
11.00 – 11.25	Technical Presentation on "Disaster Paradigm and Damage Assessment " by Dr (Prof) Chandan Ghosh, NIDM,MHA
11.25 – 11.50	Technical Presentation on " Indigenous Engineering Solutions in Construction, Green Buildings and Sustainability" by Dr Ashutosh Pathak, Former Advisor GRIHA and Sh M.K.Sharma, Former ADG, CPWD
11.50 – 12.15	Technical Presentation on "Monolithic Concrete Construction System using Aluminium Formwork" by Dr Rajeev Goel, Former Dy CE, M/o Railways
12.15 – 12.40	Technical Presentation on "Flyovers- New Technologies in Indian Context" by Sh Dinesh Kumar, Former SDG, CPWD
12.40 – 13.05	Technical Presentation on "Bamboo: The Building Material for Future" by Smt Usha Batra, Former SDG, CPWD and Dr K.M.Soni, Former ADG, CPWD
13.05 – 13.10	Vote of Thanks by Sh N.K. Bansal, CE(T&R)-I, National CPWD Academy

शैलेंद्र शर्मा
महानिदेशक
Shailendra Sharma
Director General

सत्यमेव जयते

भारत सरकार
Government of India

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MESSAGE

As we celebrate the 'Azadi ka Amrit Mahotsav' in consonance with the Atmanirbhar Bharat Abhiyan recently announced by Hon'ble PM to commemorate 75 years of Independence of India, I am happy to know that National CPWD Academy is organizing an Online National level conference on "Indigenous Engineering Solutions in Construction for a Self-Reliant India" on 28th October 2021.

CPWD is already committed to keep pace with the technological advancement and adoption of indigenous, sustainable and clean technologies in our construction activities. We have adopted 46 new construction technologies and 14 E&M technologies which are both environment friendly and locally available.

CPWD has been playing a lead role in the country in dissemination of knowledge relating to practices in building industry profession by periodically releasing a vast number of technical publications for the engineering community in line with the vision of our Hon'ble PM for a 'Atmanirbhar Bharat' and 'Make in India mission'. This conference will give an opportunity to the participants in enriching their knowledge and moving towards the goal of making India Self-reliant in the field of construction.

I would like to congratulate Shri M K Mahobia, ADG(T&R), National CPWD Academy and his team for organizing this National Level Conference on 'Indigenous Engineering Solutions in Construction for a self-reliant India' and also releasing the proceedings in the form of a booklet to facilitate all stakeholders, as another step towards Atmanirbhar Bharat.

15/10/2021

(Shailendra Sharma)

मनोज कुमार महोबिया
अपरमहानिदेशक (प्रशि० एवं अनु०)
Manoj Kumar Mahobia
Additional Director General (T&R)

सत्यमेव जयते

भारत सरकार
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MESSAGE

India is fast moving ahead in its urbanization and industrialization. The construction industry which plays a pivotal role in development of any nation has to keep pace with the rapid changes in the construction environment with indigenous rapid construction and sustainable technologies with optimum use of local available materials and resources.

To boost India's "Atma Nirbhar Bharat" vision of self-reliance, the use of indigenous engineering technology in construction, manufacturing as well as "Make in Inida" aspect is very crucial. I am happy that to commemorate the Azadi Ka Amrut Mahotsava in tandem with Atma Nirbhar Bharat Mission and to celebrate the Rashtriya Ekta Diwas week, National CPWD Academy, as part of its knowledge sharing programme, is holding National level conference on **Indigenous Engineering Solutions in Construction of a Self-Reliant India on 28th October 2021.**

The conference will be attended by experts, officers from organizations other than CPWD and will give them an opportunity to deliberate and discuss this important topic. I hope that this conference will be an enriching and knowledge sharing experience for everyone and will help in achieving the goal of a self reliant India.

I thank Shri N.K.Bansal, CE, and his team Shri Santosh Kumar, SE(Trg.), Shri Satyendra Kumar, EE(Trg), Shri Shivani Kaushal, EE(Trg) and Shri B.K.Rana, AE(Trg) for their tiring efforts in organizing the conference and bringing out this publication.

Place: Ghaziabad
Date: 26-10-2021

Manoj Kumar Mahobia
Additional Director General (T&R)

Speaker No. 1.

Topic: Climate-appropriate and indigenous building techniques and technologies for Self-built housing: A knowledge repository

 Sh. Rajneesh Sareen Programme Director, CSE	Sh. Rajneesh Sareen Programme Director for Sustainable Habitat Programme in Centre for Science and Environment, New Delhi is an alumini of School of Planning and Architecture, New Delhi and an IEMA certified advanced environmental systems auditor. He has working experience of around 21 years with expertise on sustainability in the built environment. He is leading several research programmes on sustainable urbanization.

Abstract

The COVID-19 pandemic has pushed many migrant workers from cities back to their hometowns – mostly in the rural areas. Such unprecedented reverse migration has left many in search of livelihood as well as increased the need for housing due to the burden on infrastructure in the rural and peri-urban areas. Pradhan Mantri Awas Yojana (PMAY) was launched in 2015 with an aim to house every Indian in a *pucca* house by 2022. While self-construction dominates PMAY, there is a lack of guidance on how to build these houses to respond to the native climatic conditions. Climate-appropriate and indigenous housing can not only eliminate the direct impact on the operational cost of living in a newly built house but also bring India close to its target of reducing cooling energy demand by 20 to 25 per cent by year 2037-38 set by the India Cooling Action Plan (ICAP), 2019. There is tremendous opportunity to leverage government housing schemes for skilling and enabling thermal comfort in self-built housing sector for a comprehensive green recovery. This paper is based on an investigation on traditionally prevalent materials and skilling efforts in Odisha – a state that is home to a bulk of India's migrant workforce. With an overview on these two areas, this paper brings forth the opportunities attached with the self-built housing sector for climate-appropriate building technologies and generating livelihoods through related skill building.

Introduction

Housing sector plays a crucial role in this considering its forward and backward economic linkages. It accounts for 6.8 per cent of the employment in the country, according to a study by National Council of Applied Economic Research. The share of informal employment to total employment in residential construction alone is second highest among all sectors, next only to agriculture. Moreover, for every Rs 1 lakh investment in the residential construction sector, 4.06 new jobs are created.

The housing sector, especially the self-construction segment, is not only a great lever for economic stimulus but also plays a vital role in taking India towards its thermal comfort and cooling energy demand reduction goals. Pradhan Mantri Awas Yojana (PMAY) was launched in 2015 with an aim to house every Indian in a *pucca* house by 2022. Today, as much as 63 per cent of these new (11.2 million) houses are being built by the beneficiary in urban areas. The rural counterpart of the scheme – PMAY - Gramin (G) – registered about 20.8 million dwelling units, all to be built by the beneficiary. The Government of India recognises this and has internalised technical skilling of masons and knowledge support to the beneficiary in PMAY-G.[i]

The need for skilling and generating livelihoods as also recognised by PMAY-G has only elevated during the ongoing COVID-19 pandemic. The pandemic has pushed many migrant workers from the cities back to their hometowns – mostly in the rural areas. According to the World Bank, nearly 40 million migrant workers (inter- and intra-state) were affected by the lockdown in India.[ii] States such as Odisha, West Bengal, Uttar Pradesh, Bihar, Jharkhand among others have faced the major heft of this reverse migration as these states are home to a bulk of India's migrant workforce. For instance, only the Ganjam district of Odisha received 2 lakh workers back from Surat during the lockdown.[iii] Such unprecedented reverse migration has left many in search of livelihood as well as increased the need for housing due to the burden on infrastructure in the rural and peri-urban areas.

Technical skilling and associated livelihoods have great opportunity to enable green recovery in a post-COVID era to not only meet ICAP goals but to also improve quality of life through the vast self-built housing segment. National skilling and livelihood schemes such as Deen Dayal Upadhyaya Gram Kaushal Yojana, Pradhan Mantri Kaushal Vikas Yojana, Construction Industry Development Council and Construction Skill Development Council of India can be good levers for green jobs and green recovery in the housing sector.

Odisha has registered a housing demand of 1.8 million dwelling units under PMAY-G.[iv] Being home to substantial migrant workforce, Odisha was chosen as the first case study for this research. This research comprises a combination of primary and secondary investigation to understand the indigenous buildings techniques and technologies that are native to Odisha.

As part of secondary research, various research papers, reports published by the governmental and non-governmental organizations, governmental schemes and missions, and similar studies done by the organizations were reviewed to identify indigenous building techniques and technologies and skill building efforts in Odisha. Along with this, interviews were conducted with various practicing architects and academicians using Delphi technique as part of primary research to gather their perspective and build sense on the indigenous building techniques and technologies prevalent in Odisha as well as skill building.

This research has yielded opportunities lying with the self-built housing sector to achieve ICAP goals, economic growth and instill green recovery through indigenous building techniques and technologies.

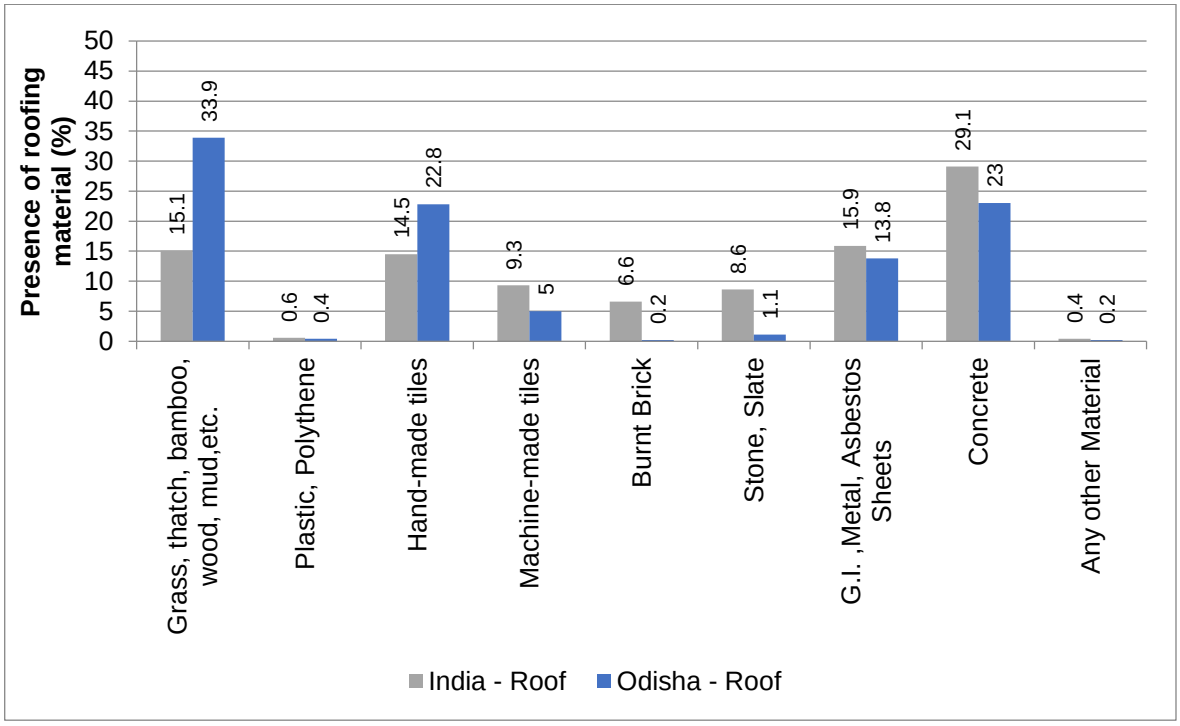
Mapping indigenous building techniques and technologies

To understand indigenous material prevalence in Odisha, three methods were adopted. First method involves data on indigenous materials as recorded in Census 2011. Second method focuses on materials and building techniques used in PMAY. Third method includes literature survey further validated and augmented by subject experts.

Material presence as per Census 2011

Census of India records the predominant material of roof and walls in states distribution of households. According to Census 2011, Odisha is dominant (33.9 per cent of total households) with use of grass, thatch bamboo, wood, mud, etc. (see Graph 1: Material usage in roof in Odisha as per Census 2011). It is followed by concrete (23 per cent) and hand-made tiles (22.8 per cent).

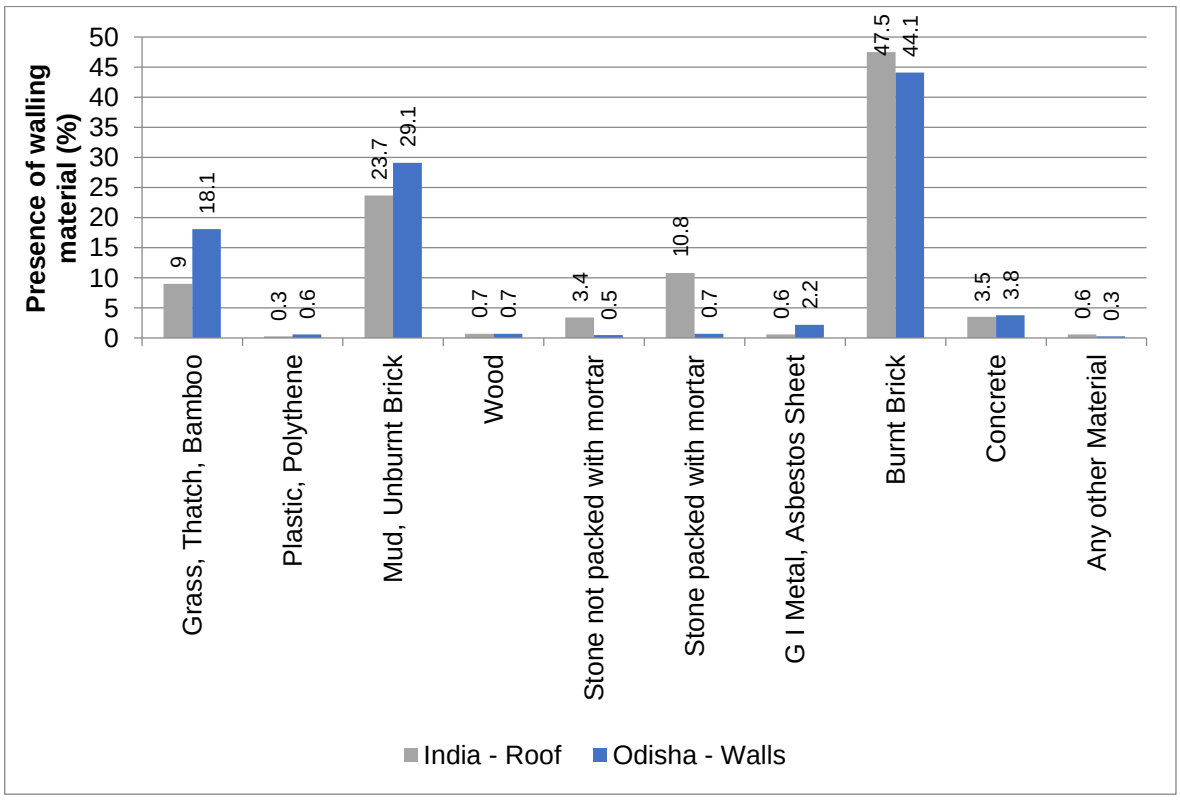
Graph 1: Material usage in roof in Odisha as per Census 2011



Source: Census 2011

In case of walls, Odisha is dominated with burnt brick (44.1 per cent) as the primary material which is followed by mud/unburnt brick (47 per cent) and grass, thatch, bamboo (18.1 per cent) (see Graph 2: Material usage in walls in Odisha as per Census 2011).

Graph 2: Material usage in walls in Odisha as per Census 2011

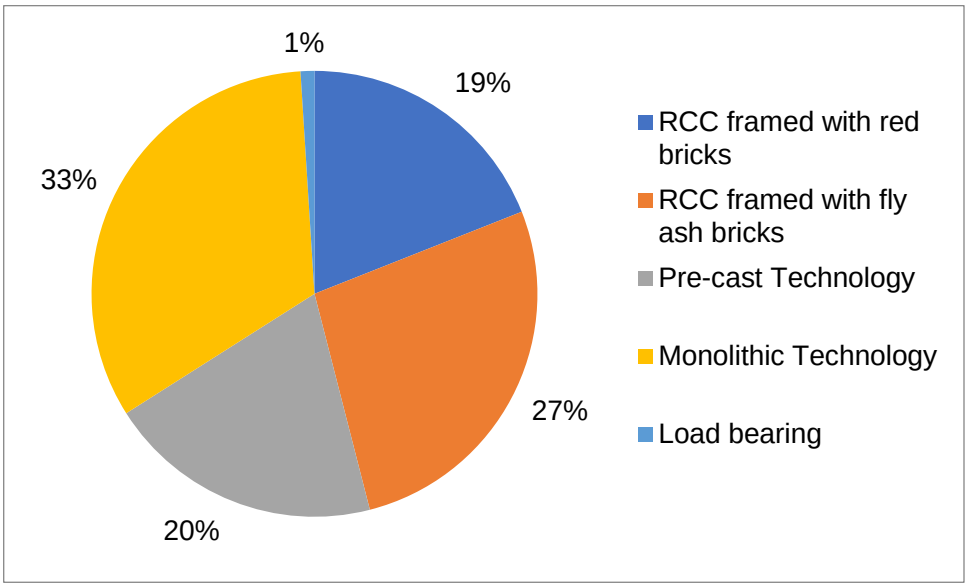


Source: Census 2011

Material and building technologies in PMAY

As per the data submitted by different States and Union territories to the Central Sanctioning and Monitoring Committee (CSMC) under PMAY, about 128 projects were studied for their materials and building technologies. Under the affordable housing in partnership (AHP) vertical of PMAY-U, monolithic technology (33 per cent) dominates the walling techniques within the sample (see Graph 3: Construction materials and technologies used in PMAY-U (AHP)). Reinforced concrete cement (RCC) frame structure with fly-ash bricks (27 per cent) form the secondary presence of materials followed by RCC frame structures with red bricks (20 per cent) and pre-cast technology (19 per cent).

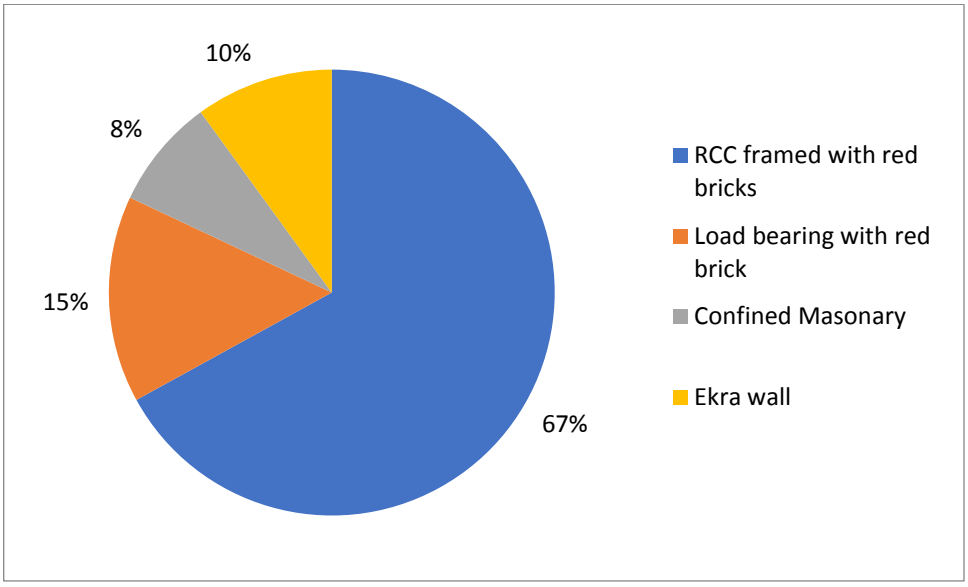
Graph 3: Construction materials and technologies used in PMAY-U (AHP)



Source: MoHUA

Speaking of the beneficiary-led construction (BLC) vertical of the PMAY-U, RCC frame structures with red bricks form the majority with 67 per cent of the units using it in a sample size of 115 projects (see Graph 4: Construction materials and technologies used in PMAY-U (BLC)). Load bearing structure with red bricks (15 per cent), Ekra wall (10 per cent) and confined masonry (8 per cent).

Graph 4: Construction materials and technologies used in PMAY-U (BLC)



Source: MoHUA

For PMAY-G, data on materials is available for nine states and 69 projects in a series known as *Gaon Vikas ki Ore* on the PMAY-G website. Majority of the units were load bearing structures (55 per cent) followed by RCC frame structures (39 per cent) and Ekra wall (6 per cent). The materials in these load bearing structures can be further broken down into five categories. About 55 per cent of the walling comprises red brick, 19 per cent fly ash bricks, 16 per cent sandstone and 5 per cent each laterite blocks and flyash brick-red brick combination.

Literature review and Expert interaction

Based on the literature survey, expert interactions, and experts' perception survey, the regional material and technology presence was established and mapped with a focus on the self-built housing sector. This review has revealed nine types of roofs and seven types of walling material in Odisha (see Table 1: Roofing material in Odisha; Table 2: Walling material in Odisha).

Table 1: Roofing material in Odisha

Sl. No.	Name of Construction Technology	Typology	Description	Image
1.	**Brick Arched Roof**	Traditional	The brick arches are made with burnt bricks and held together with the help of mortar. Sometimes metal frame is also used for support. It saves cost and improves insulation.	

2.	**Country Tiled Roof**	Traditional	These tiles are made from soil which is locally available and typically the potters in the village make them. These tiles are mounted on either wood or timber understructure. The technology is cost effective and labour intensive.	
3.	**Double roof**	Traditional	It is a simple mud roof topped by thatch roof with understructure made with timber/wood which is locally available. This technique provides space for the storage of granaries and also provides better insulation from heat.	
4.	**Kadi baraga roof**	Traditional	Kadi means the timber beams and baraga means the timber rafter. This technique of roof construction is mostly seen in the rural areas and in the wealthy households. This is typically a form of a flat roof made with locally available wood/timber.	
5.	**Thatch roof**	Traditional	Dry long straws of grass, large leaves, hay, etc. is heaped on the top of a timber/wood rafter. This roof provides better insulation from the heat.	

6.	**Ferrocement roofing channels**	Neo-Sustainable	These are precast shells made with ferrocement using wire mesh with the definite shape – usually curved. They help in reducing the quantum of steel and cement used in roof construction. The technology is being promoted mainly due to its structural ability to withstand cyclones.	
7.	**Funicular shells**	Neo-Sustainable	The bricks and the stone waste is laid in the funicular profile topped with cement-sand mortar and concrete screed. This technique not on helps in saving the virgin material but also looks aesthetically pleasing.	
8.	**Plank and Joist roofing**	Neo-Sustainable	Precast RCC planks and precast RCC joists are laid on concrete girders making the plank and joist roofs.	
9.	**Filler Slab**	Neo-Sustainable	Slabs made with lightweight filler materials such as the inverted pots, clay tiles, etc. replacing unnecessary use of concrete in tension zones. These slabs look aesthetically pleasing while they save on virgin material.	

Source: Author's compilation

Table 2: Walling material in Odisha

Sl. No.	Name of Construction Technology	Typology	Description	Image
1.	**Wattle & Daub**	Traditional	It has interwoven rods of twigs/bamboo splits, plastered with mud or clay. One of the oldest forms of techniques while using bamboo and mud together. It has good heat insulating properties.	
2.	**Cob Based Wall**	Traditional	A wall constructed using the mixture of subsoil, clay, lime and straw. Mostly found in villages and is very durable and earthquake resistant as well.	
3.	**Laterite Blocks Wall**	Traditional	Laterite blocks are readily available in most of the parts of Odisha. These blocks are cut and put to use with the help of mud/lime/cement mortar. They are resistant to fire and water and are very durable and have good heat insulating properties.	
4.	**Bamboo/Timber Attu**	Traditional	When the bamboo/ timber is easily available, its poles may or may not be split but are stuck close to each other and plastered with earth.	

5.	**Khondolite Blocks Wall**	Traditional	Khondolite blocks are readily available in most of the parts of Odisha. These blocks are cut and put to use with the help of mud/lime/cement mortar. They have been used mostly in the construction of ancient temples.	
6.	**Compressed Stabilised Earth Blocks (CSEBs)**	Neo-Sustainable	These blocks are made of stabilized soil and are compressed with steel press which is manual or motorised press. This technique is labour intensive, cost effective and energy efficient.	
7.	**Hydraform masonry blocks (cast in-situ)**	Alternate Technology	These blocks are used to build load bearing walls using mortar in the super structure. These blocks have a special feature of interlocking with each other and thus they are sometimes dry-stacked on each other.	

Source: Author's compilation

Skills mapping

The perception survey conducted with experts from Odisha involved academicians, practicing architects and social workers from the state who have on-ground experience or expertise in this subject. These experts not only validated the finding of the literature but also provided information on skills associated with indigenous building materials and techniques. The questions sought information on skills associated with each of the materials and techniques identified, ways of acquiring skills, demonstration centres (if any) among others.

The survey revealed that the skills to construct walls using traditional construction materials/techniques are acquired mainly from the ancestral knowledge (73 per cent of the respondents) (see Graph 5: Experts' perception on ways of acquiring skills). The intricacies associated with wall constructions using

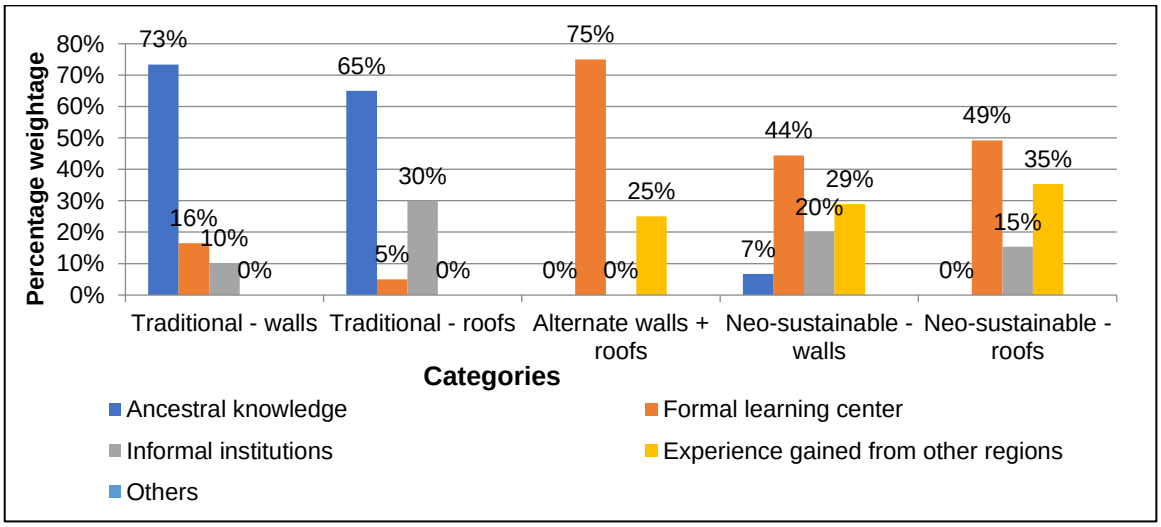
traditional materials/techniques such as the mathematical calculations, vertical alignment of the wall, the ideal height up to which the wall can be raised on each day of construction, mix proportion and its composition, etc. are mostly passed on from one generation to another.

The formal learning centers such as Industrial Training Institution (ITI), local NGOs, building/demonstration centers, etc. provide formal training related to various construction techniques. Around 16 per cent weightage has been given to these formal institutions for skilling people to learn construction of walls using traditional materials/techniques.

In case of construction of roof using traditional or indigenous materials/techniques, 65 per cent of the experts suggested that it is acquired from predominantly from ancestors. Around 30 per cent of the experts stated that for construction of traditional roofs can be learned by the informal ways – such as associating with a senior mason at work. This is because roof construction mainly depends on understanding the installation techniques for the rafters and purlins. Once this is learned, placing of thatch, tiles, or any other roofing material is a fairly simple process.

While alternate materials and building techniques are modern/new age materials/techniques mostly factory made and known to boost the pace of construction and are being promoted by organizations such as the Building Material Technology Promotion Council (BMTPC), Neo-sustainable technologies involve any type of construction material with improved/innovative application which makes it sustainable. Examples of alternate materials are monolithic concrete construction, sandwich panels, etc., whereas, neo-sustainable materials and techniques include filler slab, rat rap bond, etc. In case of these materials and technologies, the formal learning centers play a crucial role followed by the experience gained from exposure to other regions. This is because these materials and techniques have evolved over a period of time and thus need to be taught about.

Graph 5: Experts' perception on ways of acquiring skills



Source: Authors' survey

Way forward

Great opportunity for skilling on climate appropriate materials: This scoping has revealed that there is a dearth of formal training on climate appropriate materials and building techniques. With a number of national and state schemes for skilling and livelihood, there is opportunity to instil green recovery in the

housing sector. To enable this, the formal institutions for capacity building will have to recognize and internalize traditional knowledge and their potential for climate responsive development.

Plenty of knowledge resource on climate appropriate materials, needs to be tapped: This investigation has resulted in nationwide presence of traditional materials and building techniques, mapping of technology demonstration centres and related research conducted by institutions and experts. All these are invaluable knowledge resource that need to be approached and understood for their potential of thermal performance, disaster resilience, overall liveability, availability, cost among other factors. High performing materials need to be brought to the forefront of the construction industry especially for the self-construction segment that largely remains unguided.

Fast switch towards modern materials, need to regulate: An assessment of materials used in PMAY revealed that modern materials are quickly penetrating in the construction industry not only in the urban areas but also the rural areas. Seeking durability, rural households are moving towards RCC framed structures, load bearing structures and red bricks – largely uninformed, while traditional materials take a back seat. These households need to be guided as part of the housing scheme to use climate appropriate materials and delay the cross-over to thermally inefficient materials. Traditional knowledge and the informal sector become crucial to enable this and need to be internalised in skilling programmes.

Enormous knowledge with the informal sector, need to mobilize: This investigation has revealed that there are mason clusters that are regionally prevalent in rural areas of Odisha. These clusters are equipped with knowledge on traditional materials and building techniques. These clusters have great potential for demonstration-based learning and skilling. To enable this, local institutional frameworks need to be created to facilitate networking between trainees and trainers, formalisation of courses on traditional materials and building techniques and subsequent roll out under skilling and livelihood programmes.

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[1] http://www.iay.nic.in/netiay/Uploaded/Guidelines-English_Book_Final.pdf

[2]https://openknowledge.worldbank.org/bitstream/handle/10986/33634/COVID-19-Crisis-Through-a-Migration-Lens.pdf?sequence=5&isAllowed=y

[3] https://thewire.in/labour/odish-migrant-workers-gujarat-surat

[4] https://rhreporting.nic.in/netiay/homereports/HomeCumulativeDataReport.aspx?type=2

Speaker No. 2

Topic: Disasters Paradigm and Damage Assessment

 Dr. Chandan Ghosh NIDM, MHA	Dr. Chandan Ghosh is a Civil Engineering graduate (1985) of Bengal Engineering College (now IIEST). He completed his masters in Civil Engg. (1987) from Jadavpur University and PhD from IIT Kanpur (1992) and Dr. Engg. (2004) from Ibaraki University, Japan. He served as faculty of Civil Engg. at IIT-BHU and IIT Jammu. He has received various accolades and awards for his contribution in his field. Presently he is serving with NIDM, MHA, GOI as Professor & Head, Resilient Infrastructure Division

Abstract

Earthquakes in Bhuj-Kashmir-Sichuan-Haiti-Turkey-Taiwan, Bomb blasts in Bali-London-Mumbai, Floods in Bihar-Pakistan-China-Thailand, Cloud bursts in Leh-Uttarkashi-Kedarnath, hurricanes/cyclone in Florida-Myanmar-Bangladesh-Odisha-West Bengal, Guatemalan mud slides, India Ocean Tsunami, droughts in China-India, famine in Africa underscored the need to adopt a multi-dimensional endeavor involving diverse scientific, engineering, financial and social processes. There is a need to adopt multi-disciplinary and multi-sectoral approach and incorporation of risk reduction in the developmental plans and strategies. It's not just climate change, geology and bad governance that cause disasters: their causes can be technological, scientific or biological too. Refinery fires, factory explosions, train/air crashes, HIV Aids, and perhaps even a mutating corora, avian or swine flu virus have also become highly disastrous, sometimes with trans-boundary and worldwide impact. Therefore, disaster management is a strategy to avoid, reduce, manage and overcome any type of catastrophic event that threatens human lives. It is usually done by identifying potential disasters, man-made or natural, and by creating contingency plans and procedures to be initiated when disaster erupts. The effective functioning of government during any emergency lies in collaborating with other departments, stake holders and agencies, and lifeline facility managers to enhance the resiliency against all impending hazards. India, while stepping up public investment in infrastructure, has been actively engaged in involving private sector to meet the growing demand. This paper highlights some of the emergent approaches required in the management of disasters, keeping in view the Indian context.

1.0 Introduction

During the past decade, incidents of natural disasters that meet EMDAT criteria have increased six fold compared to the 1960s and the increase is mainly due to small and medium scale disasters [1]. Of the total, almost 90% are hydro-meteorological events such as droughts, storms and floods and scientific evidence suggests that global climate change will only increase the number of extreme events, creating more frequent and intensified environmental emergencies [2,3,4].

There is general consensus about the key role of risk reduction in mitigating the vulnerability of human settlements to natural hazards, although there is a lively debate regarding the distinctions between risk and vulnerability. Sarewitz *et al* (2003) [5] have summarized six central assertions that differentiate between drivers of public policies for risk reduction and those for vulnerability reduction. The authors

argue that covering costs of risk do not depend on reducing vulnerability and that accurate prediction of incidence of events is unlikely to improve understanding of vulnerability and finally that while reduction of vulnerability is a human rights issue, risk reduction, which is essentially cost based, is not. At this time, these distinctions which are the basis of public policy still remain under discussion. Notwithstanding the debate around risk and vulnerability, the importance of reducing both risk and vulnerability is widely acknowledged. Yet funding patterns and indisputable indicator of real priorities, show that it is disaster relief and not reduction that grabs the largest share of disaster funding [6,7].

2.0 Emergence of Disaster Management

While dealing with disaster management, core intervention areas include relief management, assessment of losses/needs, psycho-social intervention, training and capacity-building, demonstration of participatory processes, advocacy, policy formulation, mobilization of human resources, popularizing appropriate technology, NGO coordination, publications and documentation, and peace initiatives in the context of communal tensions.

Disaster management is a rapidly emerging subject and professionals with academic qualifications and practical experience have key roles in lessening the impact of human and ecological catastrophe. Disaster or emergency management is about dealing with a disaster but also looking for and implementing strategies that could prevent or at least minimize the chance of them happening again or minimizing their impact. It is a continuous process, not just a reaction to a specific event. The management of disasters is not an exact process. It is dependent on local economic factors, conditions, the weather, the number of people involved and the whether the emergency has been caused by nature or human beings.

The growth of GIS, and usage of other technologies such as LIDAR (Light Detection And Ranging) help scientists to utilise probabilistic risk analyses to predict impacts and assess cost-benefits of various management strategies. However, there is limited knowledge of the probabilities/magnitudes of many events. This is often coupled with poor regional building codes along with scant Legislature and/or Institutional implementation of mitigation measures; the existence of communication gaps between local vested interests and pure science based researchers who treat hazard assessments in a language that often defying social needs.

3. Losses from Natural disasters

The magnitude of the Sikkim earthquake has restricted the overall damage, but natural disasters like earthquakes, tsunamis, hurricanes, floods can wipe out years of progress in a flash. The Japanese earthquake and tsunami that occurred earlier in 2011 is expected to result in a loss of as much as $235 billion, or about 4.1 percent of the Japanese GDP. Japan's economy might well contract this year as it copes with the losses of the natural disaster. While the latest Japanese earthquake is reportedly the most expensive ever, other natural disasters in the recent past have caused substantial damage to life and property too. For instance, the 1995 Kobe earthquake is estimated to have cost as much as $235 billion, or 1.9 percent of Japanese GDP. In the US, the hurricane prone zone, losses on account of Hurricane Katrina in 2005 cost the US 1 percent of its GDP, while Hurricane Ike in the US and the Caribbean (2008) cost about 0.3 percent of GDP. The Yangtze River floods of China in 1998 cost the country as much as 3 percent of its GDP, and the Great Floods in the US in 1993 cost 0.3 percent of its GDP.

4. Damage Assessment Methodologies

Governments and agencies involved in housing and community reconstruction should be familiar with some of the common or especially useful assessment methodologies. The following section presents a brief description of some common assessment types, including multi-sectoral assessment (DaLA and

community-led assessment), housing sector assessment, and community-specific assessment (LENSS and housing damage assessment).

Good practice in conducing assessments is universal, regardless of the type of assessment. This includes the need to compose assessment teams so that they incorporate the appropriate expertise and representation, including representation of the affected community, and the importance of properly training assessors in the use of the assessment instrument, the definitions of assessment terms, and the peculiarities of the assessment environment, so that the results are consistent.

Table 1: Damage assessment methodology [8]

Methodology	Considerations
Multi-Sectoral assessment	
Damage and loss assessment Rapid, joint, multi-sectoral – **1st month**	The principal multi-sectoral preliminary assessment methodology used in recent years by IFIs, such as the World Bank, is the DaLA methodology developed by ECLAC. The assessment process is sometimes referred to as a "joint rapid assessment." This is generally conducted as soon as possible after the initial disaster response is over. A DaLA is a detailed assessment methodology that estimates the direct economic impact (lost wealth), indirect economic impact (effect on gross domestic product), and secondary effects (fiscal impacts) of a major natural disaster. The methodology provides guidelines for social sectors, including housing, infrastructure, economic sectors, and damage assessment. Numerous examples of completed DaLAs are available from the World Bank. A DaLA is a detailed yet rapid assessment that is conducted as early as possible after a disaster. It is not a substitute for either detailed, sector-specific assessments or a detailed, door-to-door housing condition assessment, both of which come later. DaLA results are often used by donors to establish initial financial commitments for housing and community reconstruction.
Community-led assessments Detailed, multi-sectoral – **1st quarter**	After any disaster, affected communities are the primary responders. Yet once organized relief operations get under way, communities may not be consulted on important aspects of the relief and recovery. Complementing traditional agency-led assessments with community-led assessments (CLAs) provides a more complete view of the needs and capacities of the affected population. CLAs will help capture the social and psychological impacts on a community, including livelihoods, and the resources available to survivors. Because these factors affect reconstruction, they should not be overlooked; reconstruction can only begin once the household is stabilized. The CLA team must include representation of all community groups in the assessment area and be coordinated by an entity trusted them all (e.g., local government, or local or international NGO). The Community Damage Assessment and Demand Analysis (CDADA), developed by the All India Disaster Mitigation Institute, is a very good CLA methodology. It is a detailed multidisciplinary, multi-

Methodology	Considerations
	sectoral, multicultural assessment that is adaptable to every disaster type, and can produce sector-specific outputs. The CDADA applies the Sphere Project principles and the IFRC Code of Conduct and emphasizes the role of affected communities, local governments, and community organizations.
Housing Sector Assessment	
Housing sector assessment Detailed, sector-specific – **1st quarter**	A housing sector assessment can be very useful after a disaster to analyze the capacity of an affected region's institutional framework for land tenure and housing and community development, its housing production and finance system, and the impact of the disaster on this system. If it is conducted early (within the first few weeks of the disaster) in parallel with other assessments, the results of the housing sector assessment can be used in the formulation of the overall reconstruction policy and in defining the housing assistance strategy. If reconstruction has already begun and stakeholders are not satisfied with the results, a housing sector assessment will diagnose what is going wrong. The importance of a housing sector and land tenure analysis may not be recognized early on. People may assume that recovery will not conform to "normal" procedures anyway, but will instead be done using "special" arrangements. However, this may not be the most sustainable reconstruction approach. Outside agency support to post-disaster reconstruction rarely runs long enough, or provides sufficient resources, for full recovery. Local development, housing, and land tenure issues that emerge after a disaster are often not new, but the disaster may exacerbate any weaknesses in the system. Reconstruction challenges—widespread poverty, extensive informality in the housing system, or a large number of housing units that need to be reconstructed—will just make the problems more visible. A housing sector assessment can also help government and agencies involved in reconstruction identify longer-term housing sector reform initiatives.
Other Detailed Sector Assessments	
Detailed, sector-specific – **1st quarter**	Detailed sector assessments are likely to be carried out in other sectors as inputs to housing and community reconstruction planning. These assessments can include, among others, environmental assessments, communications-based assessments, cultural heritage assessments, social assessments, and corruption risk assessments.
Local Housing Assessment	
Local Estimate of Needs for Shelter and Settlement Rapid, sector-specific – **1st month**	The LENSS methodology is designed for rapid shelter and settlement needs assessment in the immediate aftermath of a disaster and before the recovery phase. It provides a systematic assessment methodology and a series of extremely clear formats for collecting and organizing shelter data for a specific locality, which may be collected directly or extracted from other sources. The tool kit is intended to be used to conduct a needs assessment of and

Methodology	Considerations
	by a locality, in whatever way the population is able to organize itself after the disaster, so that it is prepared to deal with agencies that offer to assist, but it could also be used by an agency itself. One innovation in the LENSS methodology is the use of a storytelling approach to explaining the shelter situation in the community.
Housing damage (or condition) assessment Detailed, sector-specific –**1st to 2nd month**	A housing damage assessment is the necessary first step that will eventually permit the re-occupancy of residential buildings. It provides the evidence needed to support decisions about providing housing assistance, training, and technical assistance for reconstruction. The assessment process is made up of a predictable set of activities, and procedures for a number of them can be established ahead of the disaster to speed up the initiation of the post-disaster housing damage assessment process. Beside demonstrating to citizens that recovery is beginning, housing assessments serve other purposes: (1) public safety: identify whether houses can be occupied during reconstruction (a housing safety inspection process may be required); (2) planning: to quantify the funds, time, and other resources required for recovery; (3) technical: provide information of the types of damage and the technical skills required in reconstruction; and (4) economic and social: to provide data on the impacts of the disaster at the household level.

5. India Road Map in DM policy

The new approach proceeds from the conviction that development cannot be sustainable unless disaster mitigation is built into the development process. Another corner stone of the approach is that mitigation has to be multi-disciplinary spanning across all sectors of development. The new policy [9] also emanates from the belief that investments in mitigation are much more cost effective than expenditure on relief and rehabilitation. Disaster management occupies an important place in this country's policy framework as it is the poor and the under-privileged who are worst affected on account of calamities/disasters. The steps being taken by the Government emanate from the approach outlined above. The approach has been translated into a National Disaster Framework [a roadmap] covering institutional mechanisms, disaster prevention strategy, early warning system, disaster mitigation, preparedness and response and human resource development. The expected inputs, areas of intervention and agencies to be involved at the National, State and district levels have been identified and listed in the roadmap. This roadmap has been shared with all the State Governments and Union Territory Administrations. Ministries and Departments of Government of India, and the State Governments/UT Administrations have been advised to develop their respective roadmaps taking the national roadmap as a broad guideline.

The broad features of the draft national policy of India on disaster management are enunciated below:-

a. A holistic and pro-active approach for prevention, mitigation and preparedness will be adopted for disaster management.
b. Each Ministry/Department of the Central/State Government will set apart an appropriate quantum of funds under the Plan for specific schemes/projects addressing vulnerability reduction and preparedness.

c. Where there is a shelf of projects, projects addressing mitigation will be given priority. Mitigation measures shall be built into the on-going schemes/programmes.
d. Each project in a hazard prone area will have mitigation as an essential term of reference. The project report will include a statement as to how the project addresses vulnerability reduction.
e. Community involvement and awareness generation, particularly that of the vulnerable segments of population and women has been emphasized as necessary for sustainable disaster risk reduction. This is a critical component of the policy since communities are the first responders to disasters and, therefore, unless they are empowered and made capable of managing disasters, any amount of external support cannot lead to optimal results.
f. There will be close interaction with the corporate sector, nongovernmental organisations and the media in the national efforts for disaster prevention/vulnerability reduction.
g. Institutional structures/appropriate chain of command will be built up and appropriate training imparted to disaster managers at various levels to ensure coordinated and quick response at all levels; and development of inter-State arrangements for sharing of resources during emergencies.
h. A culture of planning and preparedness is to be inculcated at all levels for capacity building measures.
i. Standard operating procedures and disaster management plans at state and district levels as well as by relevant central government departments for handling specific disasters will be laid down.
j. Construction designs must correspond to the requirements as laid down in relevant Indian Standards.
k. All lifeline buildings in seismic zones III, IV & V – hospitals, railway stations, airports/airport control towers, fire station buildings, bus stands major administrative centres will need to be evaluated and, if necessary, retrofitted.
l. The existing relief codes in the States will be revised to develop them into disaster management codes/manuals for institutionalizing the planning process with particular attention to mitigation and preparedness.

6. Institutional Arrangements

Some of the areas where improvement is urgently needed are:

a) Integrated planning for disasters, including the integration of relevant Armed Forces formations into disaster management planning at all levels from District to State and Central Government.
b) Setting up of a modern, permanent national command centre or operations room, with redundant communications and data links to all State capitals. The national command centre or operations room needs to be manned on a 24-hour basis by professionals to cater for instant integrated response. There needs to be a properly equipped operations room at the State level as well.
c) Establishment of a national stand by, quick reaction team composed of experienced professionals, both military and civilian, drawn from Central and State Government staff to respond immediately by flying in a matter of hours an experienced response team to the locations when a disaster strikes. This team can be organized and run professionally on the same lines as the United Nations Disaster Assessment and Coordination (UNDAC) teams.
d) Creation of urban search and rescue capacity at all levels, by establishing a fully equipped Search and Rescue unit, as part of the fire service in all State capitals, with trained staff and modern equipment such as thermal imagers, acoustic detection devices etc. This is of immediate relevance since a major weakness exposed in the Gujarat earthquake was a lack of specialised urban search and rescue capability in India.

e) Media policy geared to handling the growing phenomenon of real time television reporting, which generates enormous political pressures on a government to respond rapidly and efficiently. This needs attention since the effect is going to increase, not decrease in future.
f) Closer interface with and better understanding of the international system for disaster response, and putting in place, systems for dealing with international assistance once it comes in e.g., customs, immigration, foreign policy implications etc. A greater appreciation is needed of the speed and automation of modern international response to a natural disaster. Closer interaction is required between of the Ministry of External Affairs and the relevant inter-national agencies concerned with disaster response.
g) Standard procedures for dealing with domestic humanitarian and relief assistance from non-government sources. Procedures and systems need to be set out to avoid confusion and ensure best utilisation of the assistance being offered, just as in the case of systems for international assistance.

Table 1: Category of disaster management paradigm [10]

HAZARD	A source of danger that may cause damage.
MITIGATION	To soften, mollify, make less harsh.
HAZARD MITIGATION	Cost-effective measures to reduce the potential for damage from hazards.
HAZARD MITIGATION ACTIONS	a) Acts upon the hazard – e.g. fire fighting. b) Keeps the hazard away – e.g. flood control. c) May interact with a hazard – e.g. hurricane shutters. d) Keeps people away i.e. relocate – e.g. relocation. With respect to tsunamis, b) and d) are the main actions.
LONG TERM HAZARD MITIGATION	a) Strengthening building codes. b) Strict zoning regulations. c) Responsive development. d) Education/Awareness.
WHEN TO MITIGATE	a) During the design phase of new buildings. b) During the restoration effort pose a disaster. c) At any time as a retrofit. d) During the daily practice of a profession/job. e) When planning for development or re-development of a community.
VULNERABILITY ANALYSIS	a) Sets the foundation for effective mitigation. b) Commences with hazard assessment. c) Documents time, space and frequency components of the hazard. d) Reviews the physical, social and economic aspects.
ACTIONS	a) Macro (Regional) mitigation b) Micro (Site specific) mitigation. c) Damage function (benchmark) d) Cost-benefit analysis. e) Environmental issues.

7.0 Conclusions

Disaster response in India has been constrained by several factors ranging from weak government policies to fragmented disaster management strategies. Having contributed systematically to disaster response in India, our experience suggested the need to develop qualified, skilled and committed professionals in the field of disaster management - people who could think critically and also act creatively. It is of paramount importance that people understand the vulnerability of the natural and human systems, together with the measures that must be taken to reduce the potential for damage. Public Disaster plans have to be developed which must have the support of all stakeholders. Hazard mitigation relates to any cost-effective measure undertaken to reduce the potential for damage from a hazard, but the limits of cost/benefit analyses are well known.

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Speaker No. 3

TOPIC: Indigenous Engineering Solutions in Construction, Green Buildings and Sustainability

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Introduction

Our rapid indigenous technological strides

Indigenous technologies culture has already flowered in India, the full stack trinity of Jandhan, Aadhar and Mobile (JAM) has revolutionized and has successfully integrated the bottom of the pyramid in our developmental process. Strategic leveraging and extending such innovations in other sectors is thought to benefit all sectors[v].

Our space programme has cost effectively created new world records, successfully launching 104 satellites in a single mission—in one go—without collision. ISRO's journey has been a saga in successful Project and Programme management[vi].

About construction sector

Why such spectacular successes (barring exceptions such as DMRC) did not happen in construction can be traced back to the historical perspectives as to how the industry has evolved and its stakeholders. Lessons learnt then can be contextualized.

Unlike the post-independence inception of space and IT sectors which were shaped by scientific research and the urban work culture and unlike the Metro Railways, which was systematized by an act of Parliament in 2002, the construction industry initially grew organically constrained only by local materials and technologies. Often it served the purpose of providing employment during the famine that were created and experienced during colonial period[vii].

One important differentiation of this sector is its massive impact on Sustainability aspects.

Sustainability and Construction sector

Overview

An important aspect of controlling global warming and sustainability requires humanity to limit the global warming to 1.5 degrees Celsius above pre-industrial systems. Our urban systems require transformation[viii].

Countries put forward mitigation commitments in the form of Nationally Determined Contributions (NDCs). The India Third Biennial Update Report[ix] to the United Nations Framework Convention on Climate Change, states that the emission intensity of India's Gross Domestic Product (GDP) has reduced by 25% over the period of 2005 – 2016. Building energy policies are an important aspect of India's mitigation strategy[x]

The construction is a key part in humanity's efforts on sustainability. [xi] Fei, Wenmei., et al. in their article *"The Critical Role of the Construction Industry in Achieving the Sustainable Development Goals (SDGs): Delivering Projects for the Common Good"* has explored and highlighted the role of Construction Industry in achieving the 2030 Sustainable Development Goals (SDGs). Though the construction industry has a critical role in achieving all the 17 SDGs , its role in 10 key SDGs, namely: sustainable cities and communities (SDG 11); climate action (SDG 13); clean water and sanitation (SDG 6); responsible consumption and production (SDG 12); industry, innovation and infrastructure (SDG 9); life on land (Biodiversity) (SDG 15); gender equality (SDG 5); good health and well-being (SDG 3); affordable and clean energy (SDG 7); decent work and economic growth (SDG 8) has been identified as most important.

The MEP sub-sector has already very actively engaged with the Sustainability shift and Green building certification[xii].

Green Buildings certification in India is driven by the big trade associations [xiii],[xiv] and an NGO[xv] and are based on energy efficient matrix of Energy Conservation Building Code (ECBC) and the broad green norms as included and emphasized in our national building code (NBC). Even those run by NGOs follow the model of approving their own favored products[xvi]. It often results in promoting the business as usual and more. Yes, all the rating systems promote efficient usages of energy, water and other resources but with reference to their own baselines. Examples of ECBC compliances for decreasing the U values by increasing the RCC thicknesses make habitat less sustainable and not more as intended. A categorical remark of NBC on usage of glass[xvii] *"Glass is a high embodied energy mineral material…… if not chosen and positioned in a building properly, may lead to lot of heat ingress/egress"* loses its meaning when we see more and more usage in the certified buildings.
How would our construction-sector transform into the successes as demonstrated above for the IT and space sectors? How the present policy framework can be helped in this transform? Would this push support our nationally Determined Commitments (NDCs) and Sustainable Development Goals missions? The new green rating certification launched by the CPWD must respond to this need.

The solution lies in leveraging the construction industry with inputs from other industries, utilizing the extensive research done at national research laboratories, academic institutions and the BMTPC—breaking silo boundaries and using the true intents of our National Building Code.

Construction industry is known for its inefficiencies[xviii] and is constrained by labor market [xix]. Efficient Construction is not just important for our growth, it is even more important for achieving SDGs and fulfilling international commitments by overachieving on the NDCs.

The consumer market, largely uninterested in the technicalities of building, needs to be further convinced of the advantages of prefabrication and other innovations. Further research to inform targeted marketing is required into how prefabrication and other new innovations meets consumer demands for flexibility and alignment with traditional build requests. This future research should additionally take into account consumers' state of residence, rurality and whether their purchase is a first or subsequent home. Drivers identified included reduced onsite work, less coordination of multiple trades, reduced waste, and improved building quality, performance and sustainability. No drivers related to the regulatory environment, industry culture or supply chain factors were identified, although

some barriers were briefly identified, such as unclear legislative requirements, negative perceptions of prefabrication from clients and finance institutions, and the lack of demand[xx].

Indigenous Engineering Solutions

The mission Atma Nirbhar Bharat has been equipped to fight the economic downfall caused by the pandemic. The central and state governments are pushing aggressive reforms[xxi]. Infrastructure is one of the five pillars of this mission[xxii]. Readily available perks to local construction Industry stakeholders were disallowing of global tenders for government procurements up 200 Crores and consideration for an extension in contractual obligations up to the six months on account of the lockdown. It would surely provide some support to already stressed-out construction project managers and contractors sitting across the table. We need to use and utilize the present policy framework into construction sustainability.

Report by Save the Children a non-profit NGO[xxiii] predicts a very grim scenario of the younger generations who are likely to face the increasing frequency and intensity of extreme climatic events. International Institute for Environment and Development (IIED) and Anti-Slavery International's pre-COP26 (United Nations conference of Parties) report[xxiv] points weather extremes to put women, children and weaker sections of the society at risk of modern slavery and human trafficking. A resilient and climate proof Human habitat can mitigate human sufferings to a great extent—herein lies the critical role of indigenous research.

Default prevails

The construction industry is not only complex but has tremendous inertia. Succeeding and bring indigenous innovations into practice requires us to not only to understand its massive inertial but also to break the vested interests. [xxv].

All over the world, influential people in government and the private sector are becoming increasingly aware of the power of default rules[xxvi], which can and should be taken as an opportunity for transformative policy changes. The phenomenon manifests in construction practice as whatever is included in our widely acceptable specifications, schedule of rate and routine practice is repeated ad nauseum.

Demos are demos after all

The default does not seem to apply for the best sustainable buildings. The often quoted best green rated and sustainable habitats use alternate means for thermal comfort such as earth tunnelling and demonstrate electrical grid free sustainability. These also use the best passive techniques and recycle wastes and wastewater using nature-based solutions. However, taking a big picture look at green building examples reveal that most of the building made today are fully or partly airconditioned using commercial mechanical systems. The Covid-19 has shown the enclosed spaces (which commercially available air-conditioning systems entail) were at the high risk. Indoor spread of infectious diseases may be assisted by the conditions of the HVAC systems, and we are yet struggling at controlling it through reinventing air recirculation[xxvii]. Use of 100% fresh air in the systems has been shown as protective against Covid[xxviii].

Most transmission has occurred inside closed indoor environments[xxix] which airconditioned buildings present. The expert recommendation for protection is to keep the windows open[xxx]. Should we prefer passive measures and nature based solutions over Air-conditioning is a no brainer. But present trends of air conditioning using only commercial solutions is not encouraging. We need to pause and rethink as to what would be our best options for achieving acceptable thermal comfort in our habitat. A norm for enclosed buildings that have crept into practice may not be desirable.

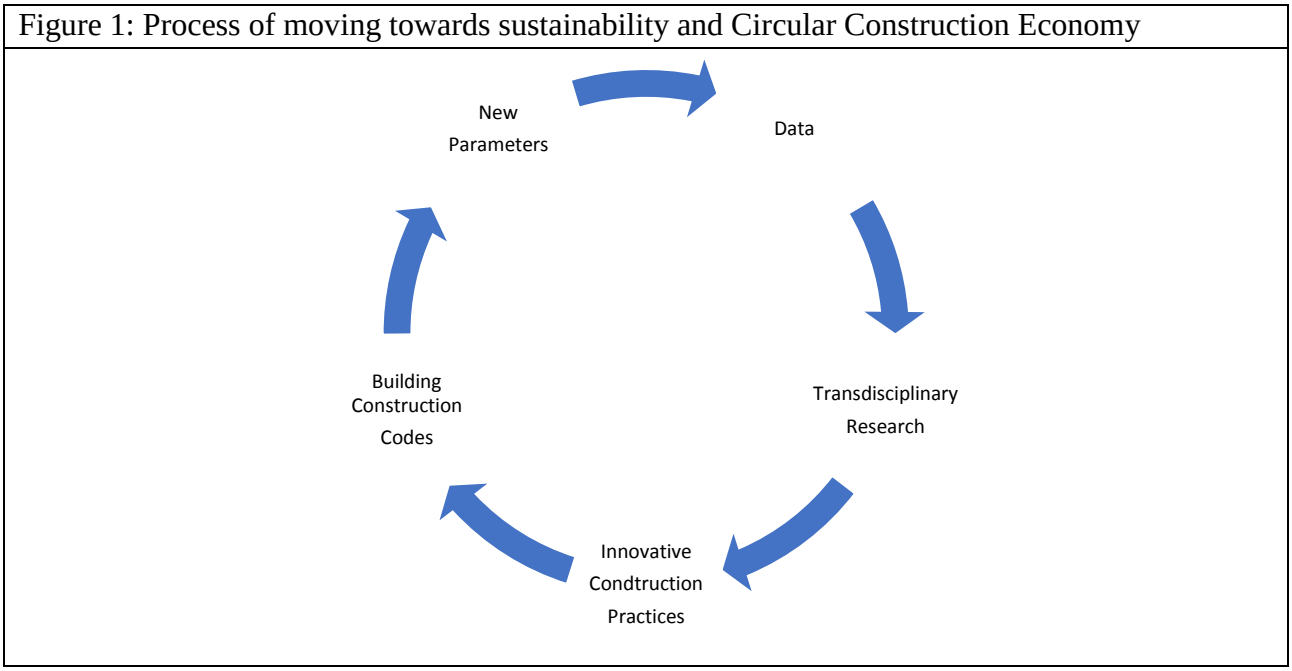
Government as a policy driver

Historically the Governments have been driving the construction industry. The government department's national wide experience and data availability is unique. The authors have been involved in the inception training of Architects and Engineers. Professionals were taken to various research laboratories. One stark difference in research culture is confronted at Dehradun's FRI where field professionals are intensively involved and Central Building Research Institute (CBRI) and Roorkee University (Now IIT Roorkee) where field professionals were conspicuous by their absence. Considering the vibrant research culture in our forestry sector and lack of popular acceptability of building research, it is hypothesized that involving the construction field professional in the building innovations and research process would propel research and innovations into our construction practice.

Like mutations most technological innovations are duds and deserve to be eliminated yet overcoming the built-in resistance is the key to the progress[xxxi]. It is therefore recommended that the documentation of all sustainability aspects and user feedback of the new promotional technologies[xxxii] is documented as the first step.

The next step of transdisciplinary research would weed out undesirables and fine tune what is a good construction practice. The inclusion of best practices into our building construction codes would result in generating more data that through analysis and research would feed to the innovations.

Figure 1: Process of moving towards sustainability and Circular Construction Economy



A thriving research culture enabled through involvement and active push by the field professionals would make it happen. The cultural change would also bring the voluminous research and innovations done by our academic and research institutions into construction practice.

An important yet less researched area with immediate sustainability implications relates to "Pucca Ghars". Our policy makers seem to be obsessed with Pukka houses. Even the PM Affordable Housing Mission (Rural) talks about Pucca "सबके लए पक्का घर" Houses[xxxiii]. Pucca in common parlance is known as made of bricks or stone or concrete. Though the Mission Document's Pucca Ghar definition *"an all weather dwelling unit" can be interpreted in many ways, the damage in terms of sustainability specially the vulnerability to probable heat waves are severe. Climate crisis demands that all weather long life traditional houses are improved through research into all-weather long life buildings using renewable materials.*

Lack of access to safe water in rural areas and uninterrupted water supply in most cities make life in hot summers unbearable with no possibility of relief. Estimates of Heat wave induced deaths in north India are astounding[xxxiv]*. Accelerating towards net zero is most important long-term health intervention*[xxxv]*. Green buildings may be the most important in the short term.*

There are success stories, and we need to replicate them on a very large scale. The mission mode approach for promoting the fly ash usage[xxxvi] that resulted in the exponential growth and added enormously to our sustainability is a good starter on lessons learnt. It began with its inclusion in the **CPWD** specifications and Schedule of rates in the late 1990 and by 2005 the usage was a practice norm.

Now is the time that our field professionals get actively involved in transdisciplinary research as the prime tool and add to the incremental and essentially circular path to sustainability.

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Speaker No. 4

TOPIC: Indigenous Aluminum form work system for Monolithic RCC Construction of High-Rise Buildings

 Dr. Rajiv Goel Former Dy. CE, IRSE	Dr. Rajiv Goel is a civil engineering graduate from Institution of Engineers (AMIE). He completed his masters in Structural Engineering & PhD in Civil Engineering from Delhi College of Engineering. He joined Indian Railway (IRSE) in Dec-2000. and resigned as Deputy Chief Engineer in 2012 to start a new career as an Entrepreneur. He has successfully completed many high rise buildings using indigenous formworks in construction and is presently involved in developing and constructing integrated township projects.

History of Aluminium Formwork

The Aluminium Formwork System was developed by W. J. Malone, a Canadian Engineer in the late 1970s as a system for constructing low–cost housing unit in developing countries. The units were to be of cast-in-place concrete, with load bearing walls using a formwork of aluminium panels. To be erected by the hundreds, of a repetitive design, the system ensured a fast and economical method of construction.

The in-situ construction of all walls and partitions reduces the requirement for follow- on wet trades. The concrete surface finish produced with the aluminium forms allows achievement of a high quality wall finish without the need for extensive plastering.

INTRODUCTION

- This is one of the systems identified to be very much suitable for Indian conditions for mass construction, where quality and speed can be achieved at high level.
- The speed of construction by this system will surpass speed of most of the other construction methods/technologies.
- The labour handles this method effectively to speed up the construction, to assure quality control and durability. Adoption of this system reduces overall cost of the structure.

TECHNOLOGY

- Aluminium Formwork System is highly suited to load bearing wall construction whereas traditional formwork consisting of plywood and timber is not suitable to the high pressures of fresh concrete on the wall.
- **COST**: Use of this formwork in load bearing design gives an average of 15 per cent cost saving in the structure of the building and increased usable floor space of 8 per cent over RCC design.
- **TIME**: For 100 per cent work, construction through slab beam wall construction takes X time and through Aluminium Formwork technology the time required is 1/6th of the X time.
- **ENVIRONMENT FRIENDLY**: The technology is environment friendly as there is no use of timber. The formwork gives the box or cellular design resulting in the walls giving support to the super structure in two directions. As a result, the structures are more resistant to earthquakes than the traditional RCC column and beam designs.
- **LIFTING**: As the Aluminium Formwork is lightweight, no tower cranes are required for the same unlike in tunnel framework.

- **LABOURS**: Due to simplicity of the assembly, only unskilled labours are required with minimal supervision.
- **REPETITIONS**: The Aluminium Formwork System is removable and can be reused hundreds of times with little maintenance.
- **SCRAP VALUE**: Moreover, the requirement of steel is also reduced in this technology as aluminium has a higher scrap value.

ASSEMBLY

- The simplicity of Aluminium Formwork and the repetitive nature of the assembly process make it possible to accurately programme construction sequences and thus cycle times well in advance.
- In addition, this enables the unskilled labour to work with the formwork, therefore reducing the burden on skilled labour when this is in short supply.
- On leaving the factory, all panels are clearly labelled to ensure that they are easily identifiable on site and can be smoothly fitted together using the formwork modulation drawings.

SIMPLE ASSEMBLY SYSTEMS

- **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.

- **QUICK STRIP PROP HEAD**

  - One of the principal technical features which enables this speed to be attained using a single set of formwork panels is the unique V shaped prop head which allows the 'quick strip' to take place whilst leaving the propping undisturbed. The deck panels can therefore be reused immediately.

- **SPEED**

  - The in-situ construction of all walls and partitions reduces the requirement for follow-on wet trades.
  - The concrete surface finish produced with the aluminium forms allows achievement of a high quality wall finish without the need for extensive plastering.
  - Doors and windows are formed in position, with this high degree of precision items such as door and window frames can be directly installed on site with minimal re-sizing required.

- **QUALITY**

  - High quality Aluminium Formwork panels ensure consistency of dimensions.
  - On the removal of the Formwork mould, a high quality concrete finish is produced to accurate tolerances and verticality.
  - The high tolerance of the finish means that no further plastering is required.
  - Typically a 3mm to 4mm skim coat is applied internally prior to finishing and a 6 mm build up coat prior to laying tiles.

Necessity of the Aluminium Form work System

- Rapid urbanization has resulted in a geometric increase in the housing demand, which cannot be fulfilled using conventional materials and methods of construction.
- The traditional or conventional method of construction for mass housing & high rise buildings is comparatively, a slow process and has limited quality control, particularly when a large size project is involved.
- It is therefore obligatory to work out a method or a scheme where the speed and quality of construction are controlled automatically by a systematic approach.
- Therefore Aluminium Formwork System (AFS) identified to be suitable for Indian conditions for mass housing construction where quality and speed can be maintained at a reasonably high level.

Aluminium Formwork System

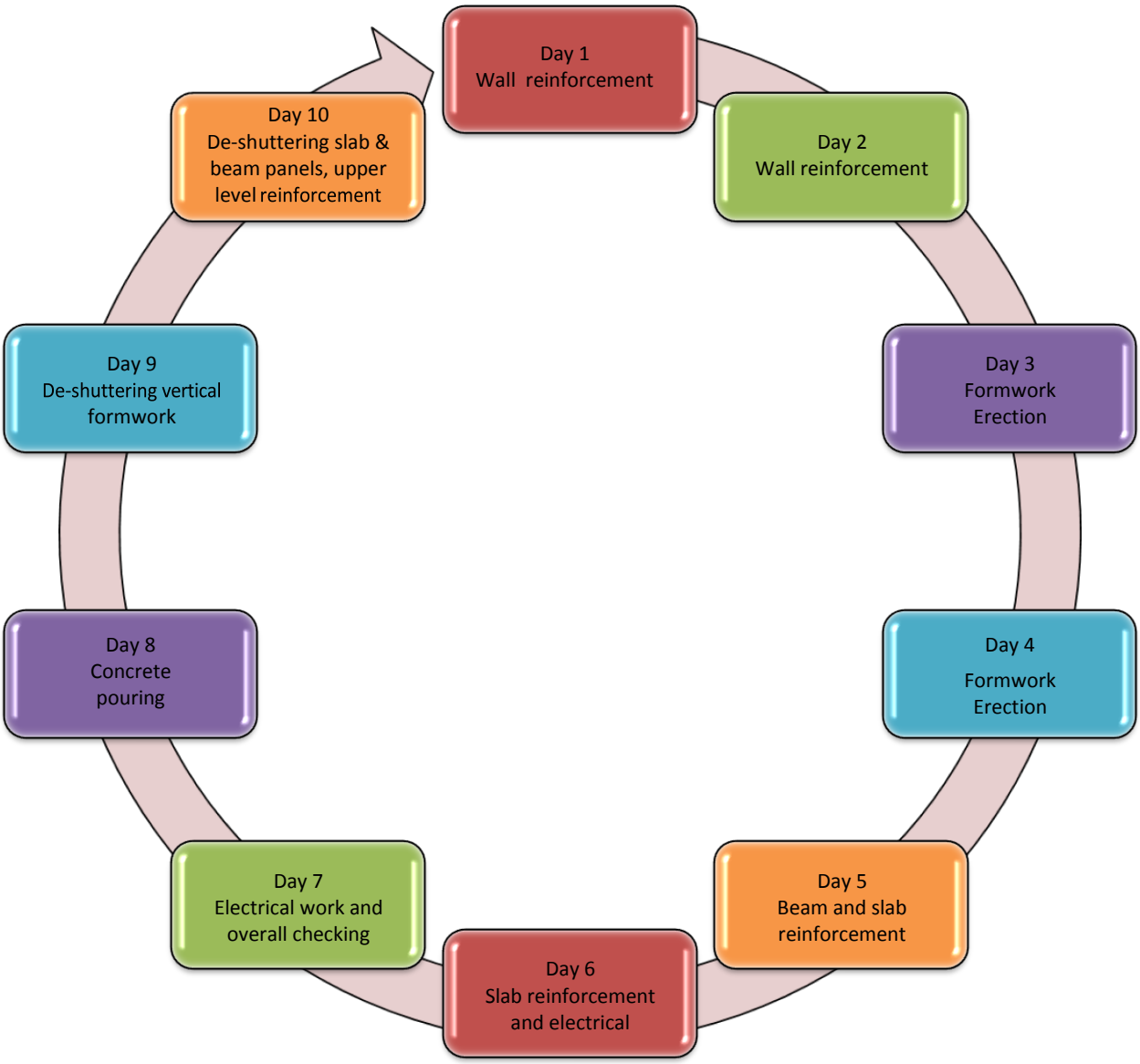
Aluminium Formwork System is a construction system for forming cast in place concrete structure of a building. It is also a system for scheduling and controlling the work of other construction trades such as steel reinforcement, concrete placement and mechanical and electrical conduits.

The System is fast, simple, adaptable and very cost effective. It is unique because it forms all of the concrete in a building including walls, floor slabs, columns, beams, stairs, window hoods, balconies and various decorative features in exact accordance with the architects' design. The dimensional accuracy of the concreted work also results in consistent fittings of doors and windows. The smooth–off form finish of the concrete eliminates the need for costly plastering.

Aluminium Formwork System provides Aluminium Formwork for RCC load bearing or RCC framed multi-storied buildings and enables the walls and slabs to be poured in the same operation. These increases efficiency and also produces an extraordinarily strong structure with excellent concrete finish. Due to the fine tolerance achieved in the machined metal formwork components, consistent concrete shapes and finishes are obtained floor after floor. This allows plumbing and electrical fittings to be prefabricated with the certain knowledge that there will be an exact fit when assembled.

Unlike other construction systems, Formwork Systems of aluminium forms can be erected by unskilled labour and without the need for hoisting cranes. The largest panel weighs not more than 25 kgs which means it can be handled by a single worker.

Aluminium Formwork - Project cycle



Aluminium formwork System Advantages

Advantages

- NO Plastering required.
- Savings on overhead expenses due to speedy construction (4 days per floor).
- Monolithic crack free structures.
- Doesn't require timber or plywood for construction activities.
- Casting of walls and slabs possible simultaneously.
- Doesn't require skilled labour.
- Floor slab forms removed without moving props.
- Earthquake resistance of resulting structures increases manifold.
- The Formwork is specifically designed to allow rapid construction on all types of architectural layouts.
- Total system forms the complete concrete structure.
- Custom-designed to suit project requirements.
- Unsurpassed construction speed .
- High quality finish.
- Eliminates plastering, saves almost 50 percent construction time.
- The system becomes cost effective where there is considerable repetition of floor layouts on a project such as in the case of low cost mass housing.
- Panels can be re used up to 280 times.
- Erected using unskilled labour.
- Requires no cranes or heavy lifting equipment.
- Suitable for low as well as high rise buildings.
- No need to use any timber or plywood.
- The resulting structures are highly durable and this ensures that the expenditure on maintenance is kept to a minimum.
- After the 25 cycles of reusing of our formwork system we will reach the breakeven point of the conventional formwork cost.
- Aluminium formwork supplied by other companies will consist of two panels. i.e. standard panel up to the door level and special panels above the door level. Since there is a joint in the door level, the panels will easily bulge which affects the plumb of the wall/column. But our panels are designed for the full height of the structure which will eliminate the above problem.
- The major problem in Aluminium formwork is mismatching of holes. To avoid this we do a moke- up in the factory itself so that all the problems will be eliminated while dispatching the materials.
- Sheet panels are generally used in the Aluminium formwork system. Since the sheet panels are made by welding the rails on four sides the joints will easily get damaged. To avoid this problem we use 450mm wide panels which are being made by welding two 'L' shaped extrusions. So the corners will be stronger than the sheet panels.

Disadvantages

- Initial high investment.
- Compares very poorly on modifications, against brick work constructions.
- Fear of theft of valuable Aluminium Extrusions & sheets & hence kit not being complete at critical stages of construction.
- Mass Housing projects are not as high for investing in large number of Aluminium Formwork.

Relative Comparison of In–Situ AluminiumForm SystemWithConventional Construction

S. No	FACTOR	CONVENTIONAL	IN – SITU ALUMINIUM FORM SYSTEM	REMARKS
1	Quality	Normal	Superior. In – Situ casting of whole structure and transverse walls done in a continuous operation, using controlled concrete mixers obtained from central batching, mixing plants and mechanically placed through concrete buckets using crane and compacted in leak proof moulds using high frequency vibrators	Superior quality in "System housing"
2	Speed of construction.	The pace of construction is slow due to step – by – step completion of different stages of activity the masonry is required to be laid brick by brick. Erection of formwork, concreting and de-shuttering forms is a two week cycle. The plastering and other finishing activities can commence only thereafter.	In this system, the walls and floors are cast together in one continuous operation in matter of few hours and in built accelerated curing overnight enable removal and re-use of forms on daily cycle basis.	System construction is much faster.

3	Aesthetics.	In the case of RCC structural framework of column and beams with partition brick walls is used for construction, the columns and beams showunsightly projections in room interiors.	The Room – Sized wall panels and the ceiling elements cast against steel plates have smooth finishing and the interiors have neat and clean lines without unsightly projections in various corners. The walls and ceilings also have smooth even surfaces, which only need colour/white wash	
4	External Finishes.	Cement plastered brickwork, painted with cement – based paint. Finishing needs painting every in three years.	Textured / pattern coloured concrete facia can be provided. This will need no frequent repainting.	Permanent facia finishes feasible with minor extra initial cost
	Consumption of basic raw materials			
5	Cement. Reinforcing Steel	Normal Reinforcing steel required is less as compared to the in situ construction as RCC framework uses brick wall as alternative	Consumption somewhat more than that used in conventional structures. It may, however will be slightly more than corresponding load – bearing brick wall construction for which, requirements of IS 456 have to be followed for system housing.	Although greater consumption strength and durability is also more. Steel requirement is more, as it is required for the shear wall construction. But shear wall construction increases safety against earthquake.

6	Maintenance	In maintenance cost, the major expenditure is involved due to : • Repairs and maintenance of plaster of walls / ceiling etc. • Painting of outer and inner walls. Leakages due to plumbing and sanitation installation.	The walls and ceiling being smooth and high quality concrete repairs for plastering and leakage's are not at all required frequently.	It can be concluded that maintenance cost is negligible.

Speaker No. 5

TOPIC: New Technologies in Bridges & Flyovers

 Sh. Dinesh Kumar Former SDG, CPWD	Sh Dinesh Kumar did his B.E in Civil Engineering from University of Roorkee (now IIT Roorkee) in 1977. He joined CPWD through Central Engineering Services (Group A) in 1978 and superannuated as SDG in January 2015. He is presently, Chairman, Institution of Engineers India, Delhi State Centre & Arbitrator in most of the Govt organizations.

Bridges are constructed since ancient age when to cross rivers wooden structures/floating structures were constructed to cross rivers. As the technology advances since 19th Century the concrete & masonry arch bridges were constructed. Well foundation was constructed in big rivers & otherwise solid open foundation. Pile foundation has also started in 19th century only but commonly used in 20th century. Since, the heavy construction machinery is available now, piles are preferred over the well foundation. Now a days in most of the cases only pile foundation is used as heavy rig pile machinery is available. Well foundation is used only in exception where piling is not possible.

For superstructure only cement concrete is used except in cases where not possible due to certain reasons.

Mainly the following are the main features in the superstructure ofbridges/flyovers:

- Thin and higher structures.
- Single pillar bridges/flyovers.
- Spinal beam structures.
- Pile foundation instead of well foundation.
- Extra doze bridges instead of suspension cantilevers bridges.

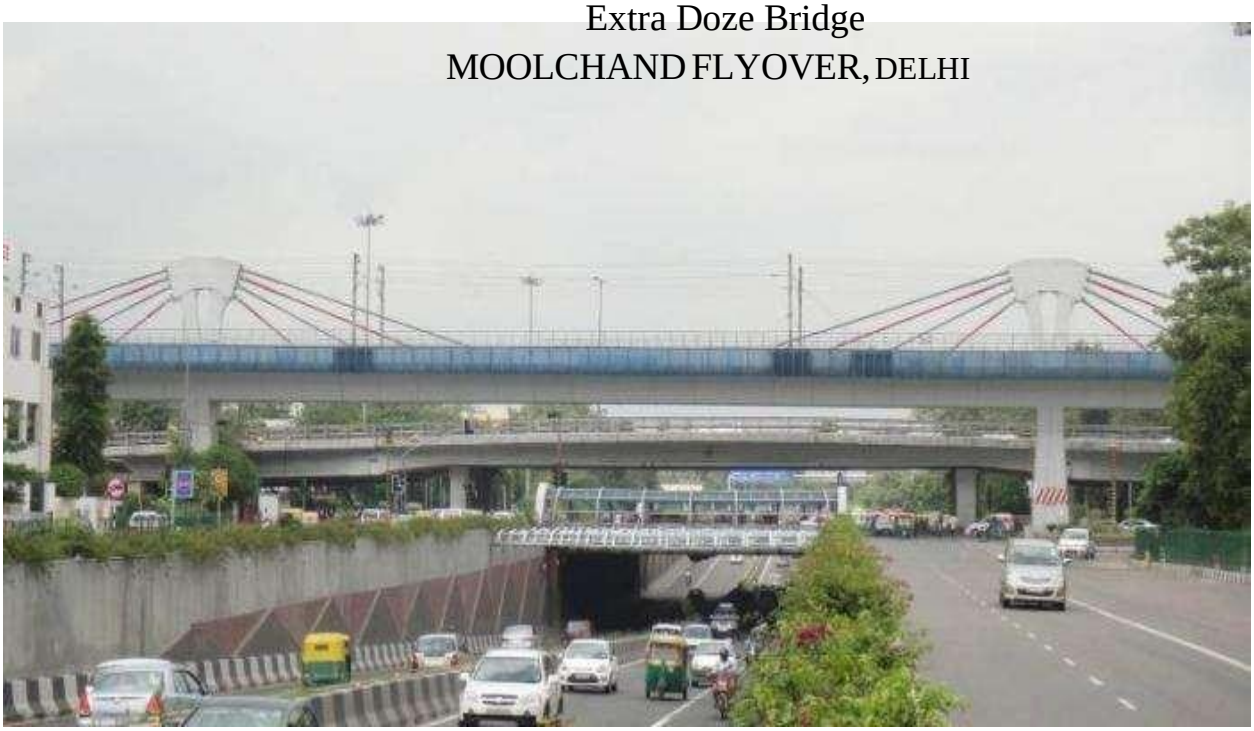
Photos of some bridges/flyovers as given below.

Suspension Bridge

Suspension Cantilever Bridge

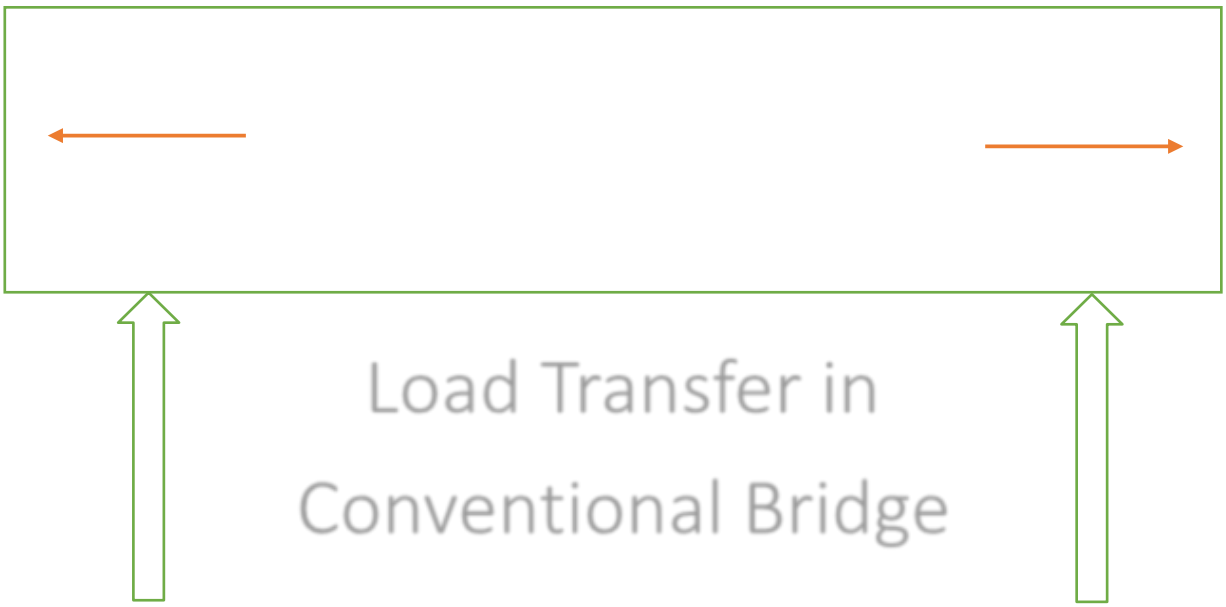
Single Pillar Bridges/Flyovers

Extra Doze Bridge
MOOLCHAND FLYOVER, DELHI

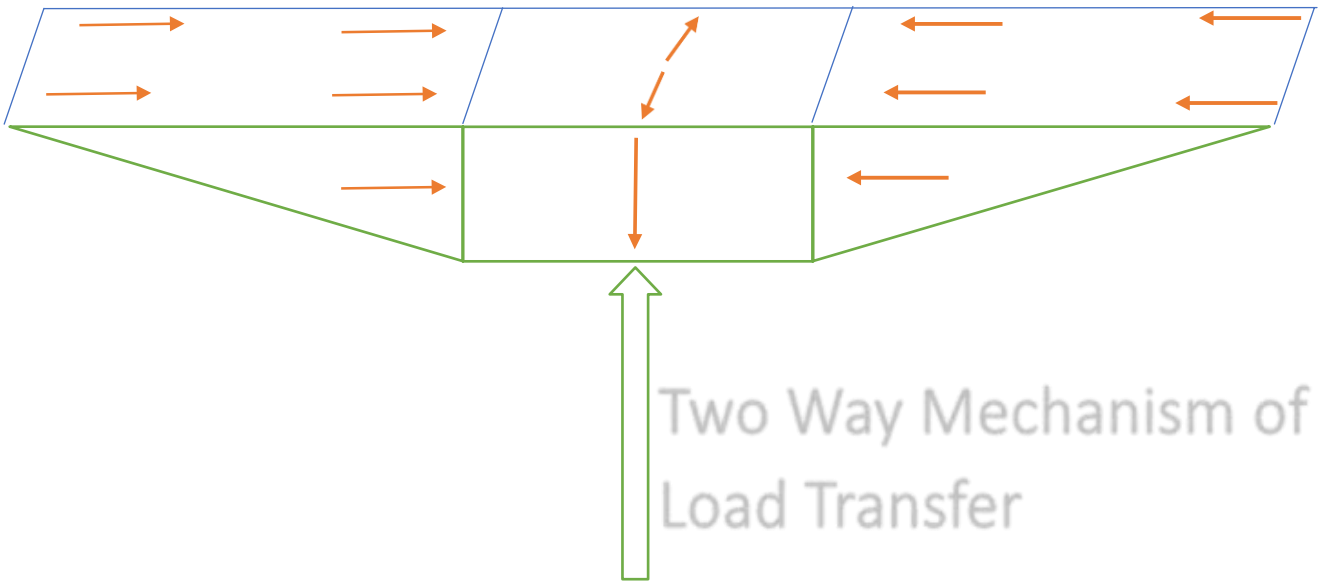


Spinal beam structure

Normally in case of flyovers/bridges, the load is transferred from the center of the bridge to the pier & thus the load is transfer only one way. Thus, the deck or beam of the flyover transferred load to pier or abutmentonly. In this case the width of pier or abutment is almost the same as the width of deck or road way as shown below.



If a spinal beam is placed in the center (longitudinal) of the bridge/flyover, the load can be transferred from edges of the bridge toward the center of the bridge (Railing side) as shown below:



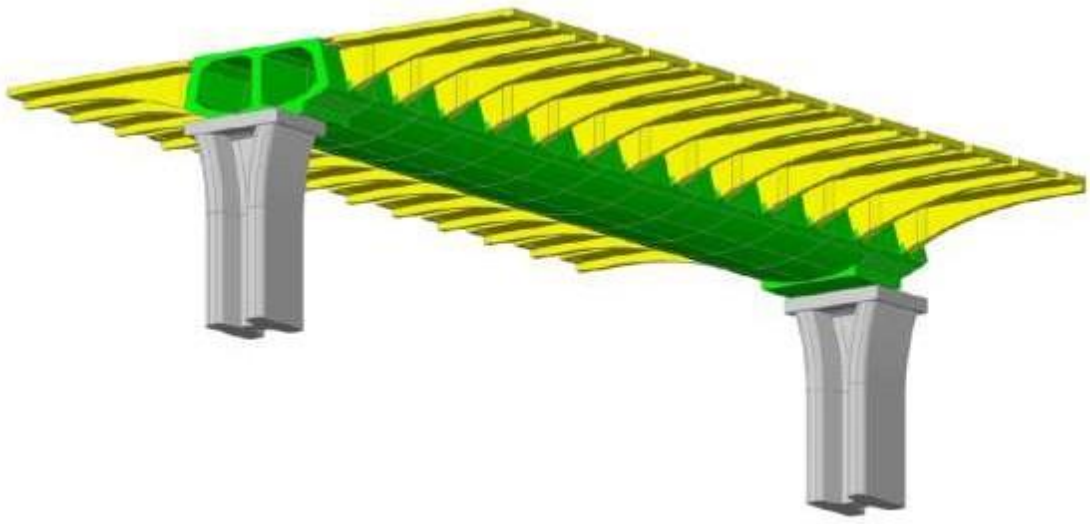
By the spinal longitudinal beam, the load can be transferred to the piers/abutment. By inserting a spinal longitudinal beam, the load from the deck of the bridge is transferred in two ways i.e., from the edges towardscenter & center to the piers.

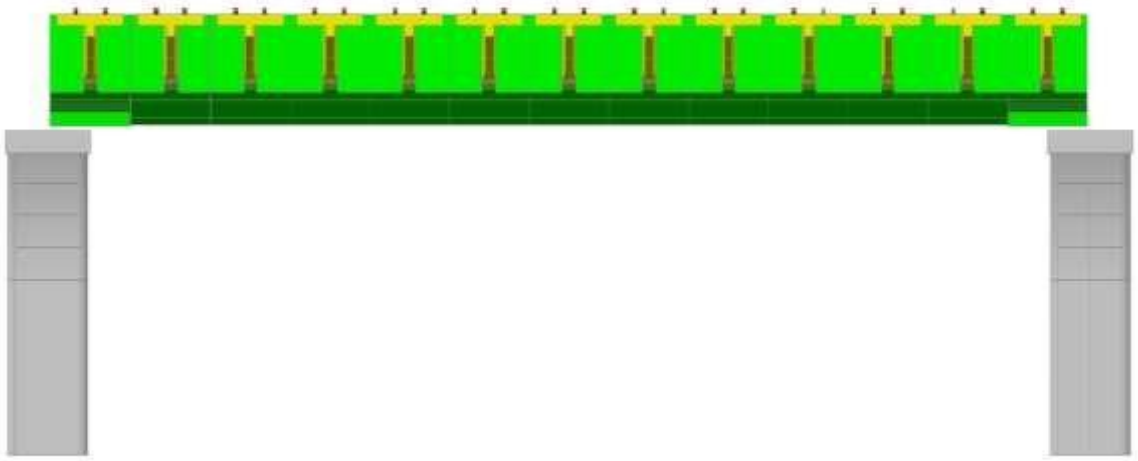
As the theory of structure itself suggest that the depth of two-way slab is lesser than the depth of one-way slab. The depth of the slab from the edges to center beam is reduced & thus the dead load of the bridges deck/beams is reduced even about 25%. As the D.L is reduced the thickness of substructure/piers is also reduced & even the length of piles are also reduced. This all reduced the quantity of concrete & thus the cost of the bridges/flyovers is also reduced. In Delhi flyovers/elevated roads the overall cost has been reduced to about 15%.

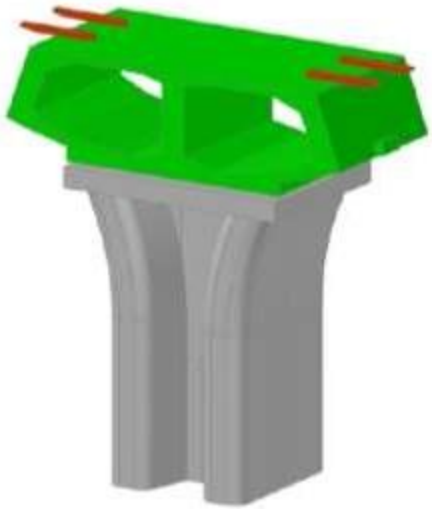
In substructure only single pier is capable to take the entire load of the flyover width of carriage way of about 24m. The shape of the piers isalso designed in such a way that about 3 m. central verge is sufficient forthe space of piers. Thus, the width of about 21m is also available below the flyover/elevated road for traffic use. The cost of land at ground level is big saving.

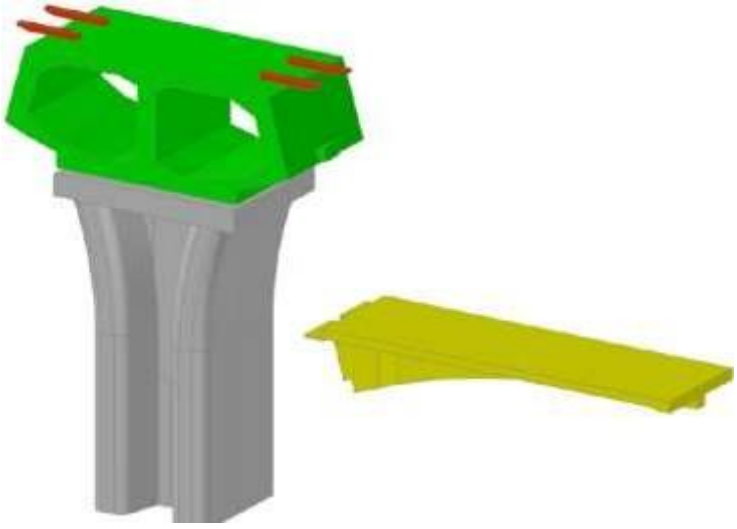
The construction of spinal beams, wings & erection of the same is avery specialized job which require lot of precautions. In big projects only the spinal beams are recommended. It is economical if length of flyover is more than 500m.

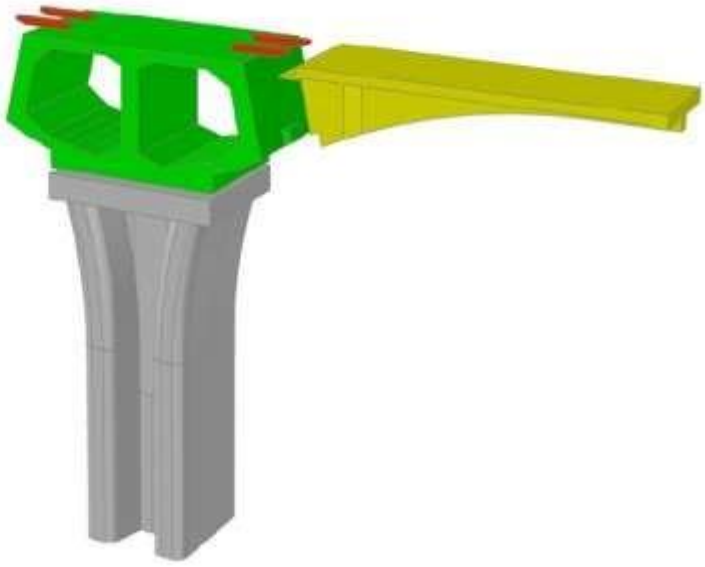
The erection methodology is shown below in pictures.

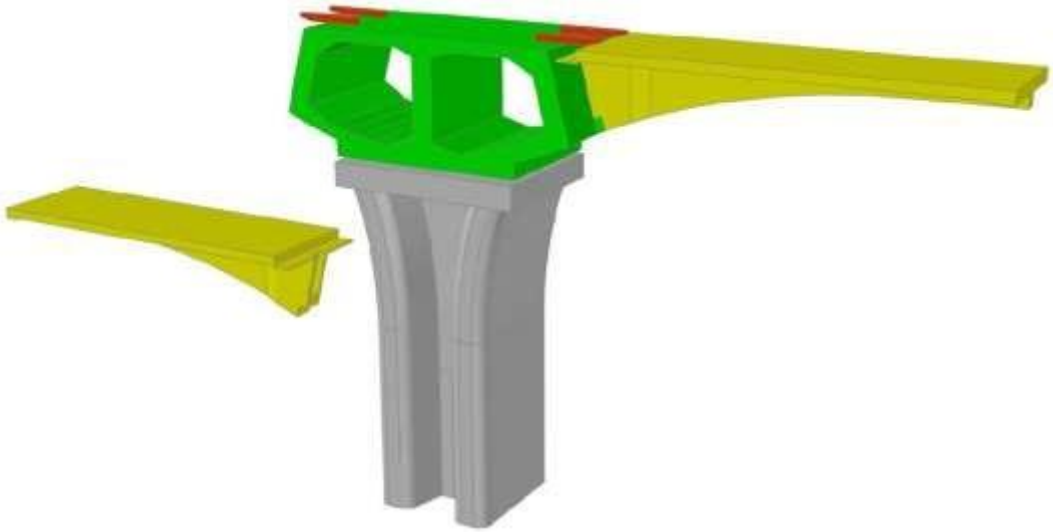












Finally, while erection the balance of cantilever potions is to be maintained as shown above. The wings are erected as per designedmethodology, normally two wings are erected in one side & then two wings on other side to maintain the balance. Finally, the in-situ stiches arecasted to keep the deck surface even & smooth. The edge facia is also casted on each side by maintaining the balance.

Before opening the traffic, the load testing is advised. In overall the spinal beam bridges/flyovers are economical & being segmental construction, the construction is also faster.

In bigger projects & elevated roads this technology is most suitable & being followed in India.

Speaker No. 6

TOPIC: BAMBOO: THE BUILDING MATERIAL OF FUTURE

 Smt Usha Batra Former SDG, CPWD	Smt Usha Batra graduated in B.Arch from Chandigarh College of Architecture in 1981. She joined CPWD in August 1985 and superannuated as Special Director General, CPWD in March 2020. She was recipient of many awards for her valuable services and outstanding contribution in the Building Profession and has authored many important publications.
 Dr K M Soni Former ADG, CPWD	Dr K M Soni is a civil engineering graduate of 1980 batch and Post graduate from MANIT Bhopal . He completed his PhD from IIT Delhi in Geotechnical Engineering. He joined CPWD through Central Engineering Services (Group A) in 1983 and worked in various capacities and superannuated as Addl DG, CPWD in July 2019.. Dr Soni is recipient of many awards and medals for his contribution in construction and research work. He was member of many professional bodies including Member of Leadership Excellence of Harvard Square, Senior Professional Engineer of ECI, Fellow of the IE(India), Member of IGS etc.

Abstract

Bamboo has been widely used in construction of low cost, temporary houses but its use for permanent structures has not been researched to a large extent probably due to availability of RCC and steel worldwide. RCC structures have shown distress due to corrosion at many places and steel structures are not preferred for sustainable development. Hence, there appears to be great prospects of bamboo being a green and sustainable material which can be used as a reinforcement and also as structural members in bunches.

To make bamboo durable, proper treatment is essential. Treated bamboo was also used in India Pavilion, Shanghai during World Expo 2010 which proved that treated bamboo can be successfully used in structural members. The case study also provided solutions of joining the bamboos themselves and joining them with RCC and steel members. These aspects are discussed in the paper.

A comprehensive research is required on bamboo for the use as a building material. Maharashtra PWD has also included it in its Schedule of Rates 2020-21.

Introduction

Bamboo is one of the fastest-growing plants in the world and grows in many parts of India particularly in north eastern part of the country. It is renewable and extremely versatile resource for construction activities as it has high compressive strength and low weight. It can

be used in many applications in the structural members of buildings, bridges and roads, architectural, and interior works including scaffolding.

Bamboo is also referred as an alternative to steel in RCC, but it is also quite fragile, as it is made of fiber and can succumb to cracking along its core hence it requires treatment and protection from insects and natural circumstances such as humidity, moisture, heat and sunlight. Actually, all nutrients for the bamboo travel through the fiber, heavily saturating the plant with sugar attracting microorganisms liable to rotting if not harvested and treated properly.

It is said that the first shooting of the bamboo plant is often weak, next stronger, and the next one even further stronger and so on and best to harvest in four to six years as it is too flexible before reaching to the threshold value and weaken again. The bottom part of the stem of bamboo has larger diameter, closer nodes and stronger hence suitable for construction, and scaffolding. Also, bamboo is not uprooted from the ground rather cut close to its base, generally above the second visible node. Nowadays, it is often treated with solution of borax and boric acid. Properly selected, sorted, dried, shaped and treated bamboo can be a better replacement of steel reinforcement bars as it is not prone to corrosion.

Durability of Bamboo

Bamboo is often described as very durable however not so much without proper treatment and maintenance. With proper use, treatment, maintenance and care, even 200 years old bamboo structure exists depicting its excellent durability.

Bamboo does not possess toxic deposits that can help it against biodegradation therefore its natural durability of untreated bamboo poles is low. Further, large amounts of starch present in bamboo makes it highly attractive to mold and fungi, termites and powder post beetles causing much damage during drying, storage, and subsequent use. Therefore, bamboo needs to be treated against potential insect contamination immediately after harvest. Once all the natural sugars in the bamboo fibers are replaced with salts, they get protected from insects. Treated bamboos have a service life of 50 years or more, assuming that they are kept away from direct contact with sun, rain and soil. Additional maintenance and care is required to be taken when used for outdoor applications.

It might have been observed that a bamboo cracks under different temperature or humidity changes. Bamboo being an anisotropic material has entirely different properties in longitudinal and transverse directions, being strong and stiff in the longitudinal direction due to cellulose fibers and brittle and soft in the transverse direction mainly due to lignin therefore, having relatively little tangential capacity. Because of the differences in anatomical structure and density, there is a large variation in tangential shrinkage from the inner to the outer part of the Culm wall leading to cracking.

Bamboo being hygroscopic material absorbs or expels moisture from or to its surroundings until equilibrium reaches thereby its moisture content vary according to the properties of the surrounding air. Water is held in it in two ways as free water retained in the cell cavities, and bound water retained in the cell walls themselves. During drying bamboo loses free water and

becomes liable to shrink if all the water is driven out, but it can swell again after drying if moisture ingresses into it from the surrounding air. Splits and cracks may then occur due to stress caused by sudden drying and direct exposure to the sun. Therefore, bamboo needs to be protected against weathering and cracking also. Before protecting bamboo against weathering and cracking, few precautions are taken as given in the following;

i. Avoid direct contact with soil to prevent the bamboo from rotting. Bamboos should not be used under the ground without protection like bitumen coating or other preservatives.

ii. Do not use nails to join bamboos which may lead to splitting. Hooks or bolts can be used if required holes are pre-drilled in the bamboos.

iii. Do not drop bamboos from a height and use hammer as these may cause cracks and splits.

Methods of Working on Bamboo

Selection of bamboo

Matured bamboo poles are selected for the construction. Normally, bamboos get matured and are ready to be harvested in 4 to 6 years. The matured bamboos of about 100 mm dia and 4-6m long are selected for construction depending upon species.

Preservation of bamboo

As already mentioned, bamboo is susceptible to insects like termites, borers, the powder post beetle, and even fungi and if not treated properly, the structures will only last a few years before they are eaten by the insects. A thorough treatment of bamboo is required to protect it against insects and rot before it is put into use, particularly from inside. Generally, a mixture of Borax and Boric acid is used for this purpose. In this method, a pre-mixed powder blend of boric acid and borax, available in a 1:1.5 ratio, known as *disodium octaborate tetrahydrate* is used. It has low toxicity and is odorless, white colour and non flammable and is simply dissolved in water and applied to the bamboo with a brush, or spray, or by submerging the bamboos in the chemical solution. Further, other patented and toxic chemicals are also available to cure bamboos though may not be environmental friendly like Copper Chrome Arsenic, Copper Chrome Boron, Copper Chrome Acetic, and Zinc Chrome, **Creosote** etc. Another procedure generally employed is to boil cut bamboo to remove the starches that draw insects. A low technological treatment option has also been developed known as the Vertical Soak Diffusion (VSD) for small projects in which all the bamboo nodes **except the last one** is punctured with a long iron rod with a spearhead in which the preservative of borax and

boric acid is poured inside. Such preservatives known as non fixing preservatives are non toxic or less toxic compared to fixing preservatives like zinc chrome and copper chrome arsenic though more permanent.

Before the treatment, bamboo has to be processed. This includes sorting, drying, and shaping. Green bamboo is not to be used for building purposes as it is more attractive to pests, insects, mold and fungus.

Air drying of bamboos is quite popular in which the bamboos are dried in the open air through good ventilation. Though air circulation is critical, the bamboos are also required to be covered, and protected from the rain and direct sunlight. Air drying will normally take about two to three months, depending on the climate and the size of the bamboos.

If the bamboos are stacked too high, they could crack under their own weight and pressure. To avoid undesired bending and curving, the bamboos can be rotated frequently. While trying to maintain a good air flow, dramatic changes in temperature or humidity are also to be avoided.

Heat treatment is another method to treat bamboos. After heating, a protective coating can also be applied. Heating is also resorted to for shaping of bamboos in curve shape or as per the requirements. Sometimes bamboos are soaked in salt water making them less appealing to pests. Afterwards, these are dried in the sun for two to three months.

To reduce cracking, bamboos are also sealed at the ends with beeswax, paint or similar material to avoid rapid moisture loss, where they are most likely to crack. Another technique to prevent culms from cracking is to drill small holes. This helps in removal of air of the hollow internode space and prevents the pressure building up in case the bamboo gets too hot, either in storage or in transit. Also, similar arrangement is used for the treatment of bamboo from the inside through chemicals for which holes are drilled in opposite direction so that extra chemical can be removed after treatment. The small holes do not affect the bamboo's structural strength.

Shaping of bamboo

Bamboos can be bent or shaped as per the requirements while they are freshly cut by heating normally above the temperature of 150°C. They retain the shape even after cooling and drying off.

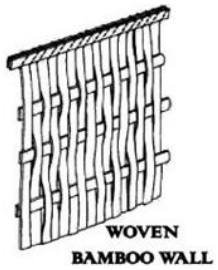
Bamboo as Building Material

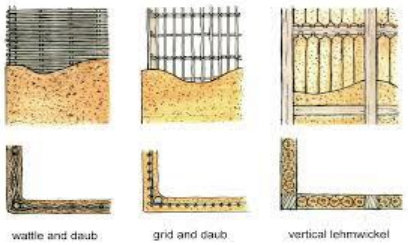
The most popular bamboos for building construction have more height and the thick culms. ***Phyllostachys edulis***, or Moso bamboo, is widely used in China, **Guadua** in Central and South America, **Chusquea** in Latin America and Bambusa Balcooa, Bambusa Nutans and Bambusa Polymorpha in India. Maharashtra PWD has included Bambusa bamboo construction in their Schedule of Rates.

Bamboo can be used at locations except where it may come in contact with moisture. In case, moisture is expected, it should be treated properly using appropriate chemicals, particularly in foundations that are expected to have moisture. Bamboos are used in various shapes and forms in the foundation like **(**a) Flattened bamboo acquired by splitting freshly cut bamboo

stalks and then rolling and flattening them (b) Woven bamboo mats applied with phenolic resins and (c) Bamboo plastic composites, plastic being the core material.

Bamboo has been traditionally used for construction of walls. In North-Eastern India, Ekra walling also known as Assam walling for semi permanent structures was used for a long time and even prevailing today. The bamboo mats were provided between vertical posts and horizontal beams i.e. members of a structural frame made of wooden members. Being light, they also behaved well during earthquakes. Both sides of walls were plastered as per availability of the material. Drawback of such infill bamboo mats was that they were not chemically treated hence had limited life.





It is felt that treated bamboo can also be used for monolithic construction in construction of reinforced bamboo concrete walls. Treated bamboo mats or woven bamboos can be used as reinforcement in cement concrete suiting to design requirements hence a research is required in this field.

Bamboos have also been used traditionally in various applications like purlins, and rafters being light and durable. However, its use in beams and slabs has been made in a limited way rather on experimental basis. Research has been carried out for using bamboo as reinforcement like in RCC. Therefore, bamboo reinforcement concrete is being researched exactly like steel reinforcement concrete. Such reinforcement has been tried in columns, beams and slabs in the split form. It is felt that concept of bamboo structure should also be researched similar to steel columns and beams where bamboos can be used in bundles/bunch according to the design requirement.

Maharashtra PWD has included bamboo items in its Schedule of Rates 2020-21 (Item Nos. 2045-2056). Some of the items included in the Schedule of Rates are given in the following;

i. Providing and fixing after cutting in proper size and shape bamboo pole of bambusa balcooa / bambusa bamboos or equivalent with minimum wall thickness of 10mm & distinctive internodes of 300 mm max Size 100mm (+/- 10mm) dia. (i.e., 100mm dia. in bottom & top dia. should not be less than 75mm & average dia. should not be less than 85 mm, taper length should not be more than 2.5mm per Running metre), well seasoned by freshly cut canes including treatment with preservative inside the bamboo pole, & dosing with CCB (Chromium Copper Bromate) using pressure vacuum treatment plant with retention level minimum 8 % and in accordance with IS 9096. The framing is connected by articulated joints preferred with bamboo wedging without filling, including bending, bunching of bamboos as per design with bamboo pegs in inclined 45 degree manner, SS bolt (304 Grade), studs (304 grade), GI plates coated with epoxy coating, including transportation and cost of material, anti abrasive fire retardant coating (Two coats before bunching and final coat after complete installation as directed by Engineer in Charge), necessary scaffolding with all lead, lift, machinery & equipment charges, etc. complete, as directed by the Engineer in charge. Bamboo pole for main structure like Beam, Column etc. or as per design.

ii. Providing and fixing after cutting in proper size and shape bamboo pole of bambusa balcooa / bambusa bamboos or equivalent with minimum wall thickness of 10mm & distinctive internodes (300mm max) Size 75mm (+/- 8mm) (i.e., 75mm dia. in bottom & top dia. should not be less than 50mm & average dia. should be 60mm & taper length should not be more than 2.5mm per Running metre), dia well seasoned by freshly cut canes including treatment with preservative inside the bamboo pole,& dosing with CCB (Chromium Copper Bromate) using pressure vacuum treatment plant with retention level minimum 8 % and in accordance with IS 9096. The framing is connected by articulated joints preferred with bamboo wedging without filling, including bending, bunching of bamboos as per design with bamboo pegs in inclined 45 degree manner, SS bolt (304 Grade), studs (304 grade) of bamboos as per design GI plates coated with epoxy coating, including transportation and cost of material, anti abrasive fire retardant coating (Two coats before bunching and final coat after complete installation as directed by Engineer in Charge), necessary scaffolding with all lead, lift, machinery & equipment charges, etc. complete, as directed by the Engineer in charge. Bamboo pole for Main structure like Beams, columns etc as per design and drawing

iii. Providing and fixing after cutting in proper size and shape bamboo pole of dendrocalamus stocksii or equivalent with minimum wall thickness of 10mm & distinctive internodes (300mm max) Size 50mm (+/- 5mm) (i.e., 50mm dia. in bottom & top dia. should not be less than 35mm & average dia. should be 40mm dia. & taper length should not be more than 2.5mm per Running metre) which is well seasoned by freshly cut canes including treatment with preservative inside the

bamboo pole, & dosing with CCB (Chromium Copper Bromate) using pressure vacuum treatment plant with retention level minimum 8 % and in accordance with IS 9096. The framing is connected by articulated joints preferred with bamboo wedging without filling, including bending of bamboos as per design or SS bolt, studs (304 grade), GI plates coated with epoxy coating, including transportation and cost of material, anti abrasive fire retardant coating (Two coats before bunching and final coat after complete installation as directed by Engineer in Charge), necessary scaffolding with all lead, lift, machinery & equipment charges, etc. complete, as directed by the Engineer in charge. Bamboo pole for Purlins, Ties, Facia, Gap Filling etc.

iv. Providing and fixing Bamboo Shingle roofing with top layer of Bamboo shingles, made of flattened CCB pressure treated bamboo of 50-100mm dia and in size of 450mm x150mm and 3 to 5 mm thick laid over bamboo battens of minimum 25mm thickness, perpendicular to rafter/Beam at spacing of 150mm c/c including laying of bituminous sheet 3 mm thick and minimum overlap of 300 mm placed over sub-purling which is laid parallel to main rafter /beam consisting of 50mm dia not less than 3m length at spacing of 300mm c/c on treated Bamboo woven matt of approved design made out of thin Bamboo strips, supported by CCB treated Bamboo purlins of min dia 50mm not less than 3m length at spacing of 300mm c/c and WPC sheet 6 mm thick, junction details as per drawing and design including all Bamboo accessories like CCB treated Shingles, anti abrasive fire retardant coating (top and bottom surfaces of roofing system as directed by Engineer in Charge), Bamboo, bamboo mats, SS clamps, nails, Screws, including required scaffolding and cost of labour material with all lead & lifts and machinery & equipment charges, etc complete. Ground Floor.

v. Providing and fixing in position Phenol bonded Bamboo wood flooring with planks of sizes 14mm thick, 1800 mm length (minimum) and 130 mm wide (minimum), in approved colour, texture and finish, having Performance Appraisal certified (PAC) issued by Building Materials & Technology Promotion Council (BMTPC). The flooring shall be fixed with tongue and groove interlocking system, with underlayment of 4mm thick expanded poly ethylene foam sheets having density 40Kilogram/One Cubic metre, over prepared surface with necessary quarter round planks of size 1900mm x 18mm and door reducer of size 1900mm x 44mm, wherever required. The bamboo wood planks shall have minimum density of 1000 Kilogram/One Cubic metre & minimum Hardness 1000 Kilogramf with eco friendly UV coating, all complete as per direction of Engineer in -charge. Ground floor

vi. Providing & fixing in position Phenol bonded Bamboo wood partition 60mm thick at all height with planks of size 10mm thick, 1800mm length (minimum) and 130mm (minimum), in approved colour, texture and finish, on both side having Performance Appraisal Certificate (PAC) issued by Building Material & Technology Promotion Council (BMTPC), with necessary profiled edges fixed with

40 mm SS screws 5nos in each tile to frame made of second class teak wood of size 40 x 40 mm in center of each tiles and bottom / top of work height. The bamboo wood planks shall have minimum density of 1000Kilogram / cum & minimum Hardness 1000Kilogramf with Eco friendly UV coating, all complete as per direction of the Engineer in -charge.

vii. Providing & fixing after cutting in proper size & shape bamboo pole of Dentrocalamus stocksii with minimum wall thickness of 10 mm of size 50 mm(+/- 5 mm) diameter (i.e., 50mm dia. in bottom & top dia. should be 35mm & average dia. should not be less than 40mm & taper length should not more than 2.5mm per Running metre), which is well seasoned by freshly cut canes including treatment with preservative inside the bamboo pole &dosing with CCB (Chromium Copper Bromate) using pressure vacuum treatment plant with retention level of minimum 8% and in accordance with IS 9096. These bamboos are used for making beams & columns including bending of bamboos, joining, bunching of bamboos, assembly and its installation as per design using bamboo pegs (45 degree), SS Studs fixed with nuts & bolts (304 grade), GI plates coated with epoxy coating, including transportation & cost of material, anti abrasive fire retardant coating before bunching of bamboos(Two coats before bunching and final coat after complete installation as directed by Engineer in Charge) , necessary scaffolding with all lead, lift, machinery & equipment charges, etc. complete, as directed by the Engineer in charge.

viii. Providing and fixing in roof system after cutting in proper size and shape Griha Certified WPP sheet made of wood polymer composite - WPC) of thickness 6mm, density more than 550 Kilogram/cum, having proper screw holding capacity. This board shall not be pasted with treated bamboo mats and fixed over bamboo purlins with SS Nails/SS Screws. The bamboo mat design visible from below may be haphazard. The rates shall be including transportation, cost of WPC Board and all fixtures and fastenings with necessary scaffolding with all lead and lift, machinery and equipment charges etc. complete as directed by Engineer in charge.

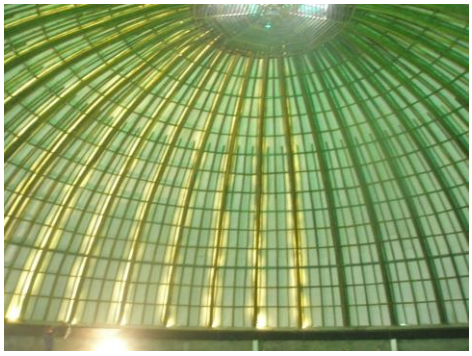
Bamboo in India Pavilion, Shanghai

As already mentioned earlier, bamboos can be used in bunching for beams behaving similar to steel beams. Such beams were used in India Pavilion, Shanghai (Soni, 2017). Though not used in columns, it appears that the same concept can also be used for columns by bunching bamboos in a composite concrete section like steel composite section in which core can be of bamboos. The bamboos were also used to support RCC slab and other dead and live loads in India Pavilion, Shanghai Expo.

The 34 m diameter bamboo dome was constructed as a part of the India Pavilion, designed to take dead and live loads and in which the dome was supported entirely on bamboos. Joining of bamboos was done in a well designed manner so as to take loads without using the concept of reinforced bamboo cement concrete. Treated *Moso* bamboos *(Phyllostachys edulis)* were used as structural members for taking the

dead load of entire dome and live loads expected over the dome. Large numbers of ornamental plants were planted over the dome, also accounting for their dead load.

Bamboos for the structural members also used in the vault. These were treated in a solution of boric acid and borax. Over the bamboo assembly in the dome, wire mesh was used to support reinforced ferro-cement layer. Membrane waterproofing was then provided over the ferro-cement layer. A PVC board was fixed over the waterproofing membrane on which three geotextile layers were provided for irrigation assembly and live plants. Copper pipes having nozzles were inserted inside upper two geotextile layers to irrigate the plants. *Tree of Life* was then made on the top of the dome from copper sheet and in the remaining portion ornamental plants were planted except in the area where solar panels were installed. To showcase energy efficiency, few solar panels were installed on the roof and a small wind mill provided in the central portion.



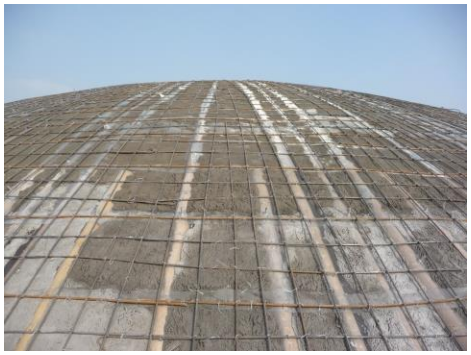
Moso bamboos used in the pavilion were of average 100 mm diameter and 6 m length. Since design methodology and jointing procedure for use of the bamboos in structural members was not available in the codes, a mock up structure was prepared to understand the method for their fixing with steel and concrete members.

The bamboo was required to be bent according to the shape of the dome and thus shaping of bamboo was done through heating process. Before fixing the bamboos, process of selection, drying, treatment and shaping of bamboos was followed. For the same, mature round bamboos were first sorted out having sufficient length of required diameter without any splits. The sorted bamboos were stored for drying and treatment. For the treatment, two holes were drilled internode in each bamboo i.e. between the nodes in opposite direction so that solution of Borax and Boric acid could enter the inner hollow space and remained filled up for adequate time.

After drilling the holes, the bamboos were immersed in the hot water tank filled with boric acid and borax mixture in the ratio 1:1.5. After treatment, the bamboos were taken out and air dried on horizontal supports prepared for the specific purpose. Bamboos requiring shaping as per the curvature of the structure, were clamped in the specifically prepared arrangement of steel jig having clamps. The heated bamboo was placed and kept clamped for a certain period to obtain the desired shape/curvature and prevent it to return into its original shape.

Since the diameter of the dome was about 34 m, the bamboos were required to be jointed. For this purpose, a reinforcement bar was inserted inside both the bamboos to be joined. Thereafter through the holes made in both the bamboos, micro concrete was inserted making it as RCC joint inside. The bamboos were also joined together in a bunch as per the requirements of the beams. Main beams had six bamboos. These bamboos were joined together by the galvanized iron bolts. Three bamboos were on upper layer, two below and one in the lowermost. To join the beam of these six bamboos with the steel ring beam on which cement concrete was laid, six reinforcing dowel bars were grouted in the concrete. The bamboos were inserted directly first in

reinforcing bars in the mock up exercise. Micro concrete was then inserted through the holes so that RCC provided inside the bamboo gets connected with the ring beam. This procedure was followed in the mock up structure, but realizing that the bamboo may split, stainless steel covering plate/socket was inserted into each reinforcing bar and thereafter bamboos seated in the covering plate. With this arrangement, bamboos got housed adequately. The stainless steel covering plates were used to avoid corrosion.

Other aspects of the assembly were designed like rafters and purlins. The assembly included bamboos in both cross and transverse directions of the dome. Some bamboos were terminated in the middle and due to shape of dome as less number of bamboos were required towards top portion of the dome. Finally, bamboos were painted from inside to enhance the durability and aesthetics. Bamboos were used in the similar way for the vault portal.


Over the bamboo assembly, a layer of wire mesh was laid to hold mortar. Ferro-cement layer was then provided with nominal reinforcement on the bamboo assembly. To avoid leakage and seepage, water proofing membrane treatment was provided on ferro-cement layer. Over the water proofing membrane, the plantation system was laid.

Thus, it is absolutely clear that the bamboo beams were loaded for same loading as done in case of RCC structures and worked very well.

Advantages of Bamboo as a Building Material

The various advantages of bamboo are higher tensile strength than even steel, higher capability of bamboo to resist fire, earthquake resistant material due to its elastic features, light weight, cost effective, non toxic, and a green material.

Conclusions

- Bamboo is one of the fastest-growing plants in the world. Being a green material, it is the construction material for future.
- Treated bamboos have a service life of 50 years or even more. It is an alternative to reinforcement steel in RCC construction and not prone to corrosion.
- Bamboos can be bent or shaped as per the requirements and being light, they also behave well during earthquakes.
- Bamboo is cost effective, has high tensile strength, and fire and earthquake resistant.
- Some bamboo items have been included in Maharashtra PWD Schedule of Rates 2020-21 and as such can be used as a building material for public works.

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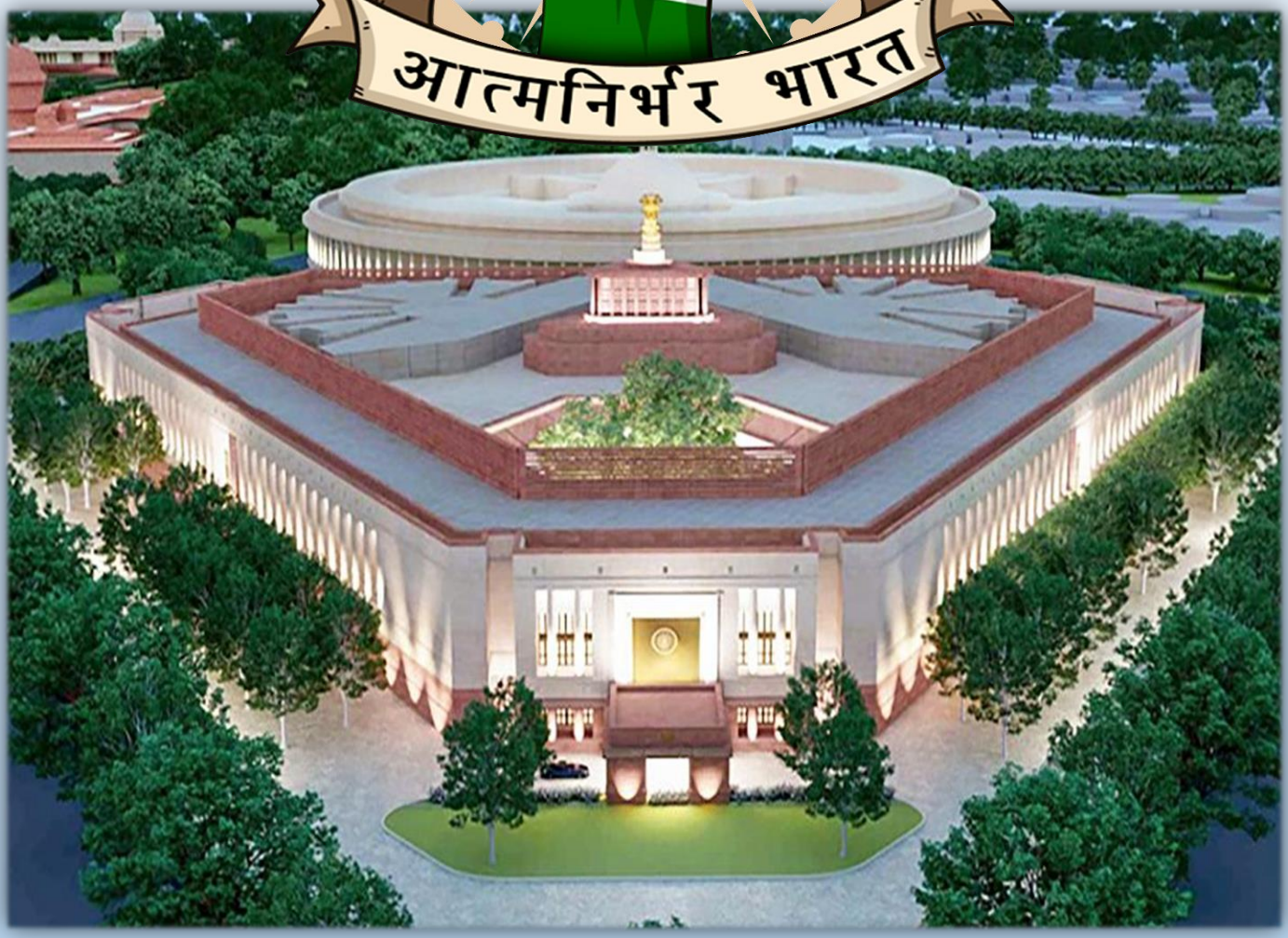

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