Special Issue

निर्माण सारिका

A Newsletter of BMTPC

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World Habitat Day

2nd October, 2017

Housing Policies: Affordable Homes

World Habitat Day

bmtpc

निर्माण सामग्री एवं प्रौद्योगिकी संवर्द्धन परिषद्
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BUILDING MATERIALS & TECHNOLOGY PROMOTION COUNCIL
Ministry of Housing & Urban Affairs, Government of India

"Creating Enabling Environment for Affordable Housing for All"

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From the Desk of
Executive Director

BMTPC publishes special edition of its quarterly newsletter Nirman Sarika on the occasion of World Habitat Day every year on the theme chosen by UN-Habitat. This year's theme Housing Policies: Affordable Homes gets well with the Indian housing policy of affordable Housing for all. Right to shelter is the clarion call given by Prime Minister of India and through Pradhan Mantri Awas Yojna – Urban, the Govt. machinery is geared up to provide approximately 20 million houses specially to poorest of the poor in association with state governments, beneficiaries, public-private partnership including credit link subsidy. During its two years of implementation, about 24 lakh houses are already sanctioned and are at different stages of completion. More than hundred thousand houses have been completed and being occupied by the eligible beneficiaries. This kind of commitment towards housing sector especially affordable sector has never been seen before and it is bound to transform our cities. The private sector is also equal to the task and entering into the affordable housing sector in a big way.

Affordability is the key word here and is being defined in terms of financial capabilities of an individual, nevertheless, I toss a different set of questions here i.e. *Can we afford to build so many houses without vitiating the anatomy of mother earth and its resources; Can affordable housing precipitate improved economic and social fabric of the county*? Affordable homes mean the sustainable homes and therefore affordability is to be measured in terms of environmental sustainability, economic sustainability and social sustainability. Environmental sustainability is the ability to build safe houses (i) without depleting our precious natural resources, (ii) with least ecological imbalance, (iii) no air, land & river pollution, (iv) less fossil fuel usage (v) more use of renewable resources (vi) maintaining bio-diversity. Economic sustainability is economic growth (a) without damaging social fabric of the community or harming the environment (b) optimizing utilization of tangible and non-tangible assets. Social sustainability is creating places which promote equity, livability, well-being, healthiness, community development & resilience, cultural ties, human adaptation etc. These three pillars of sustainability need to be addressed in our policies so as to have affordable homes.

BMTPC, as building materials & technology promotion council is putting its best efforts to bring paradigm shift in the current construction practices by introducing new construction systems which are time tested and proven world over. These systems not only help in fast delivery of houses but also add to affordability and sustainability. Some State and Central Government departments have already started using these new construction systems. Ministry of Housing & Urban affairs is also working on creating a technical framework which help in smoother adoption of these systems in construction industry with the help of BIS, CPWD, Research & Academic Institutions and different chambers. Also, the technology providers around the globe are looking for opportunity to work with India so as to contribute in our mission of providing affordable housing to all.

(Dr. Shailesh Kr. Agrawal)

सत्यमेव जयते

HARDEEP S. PURI
Minister of State (Independent Charge)
Ministry of Housing and Urban Affairs
Government of India

MESSAGE

The first Monday of October is designated World Habitat Day and celebrated the world over by the United Nations and other Habitat related institutions. This provides an opportunity to address impending issues related to our habitat and basic rights for providing adequate shelter to all. This year's theme "Housing Policies: Affordable Homes" is intended to remind the world that we have both the power and the responsibility to shape the future of our cities and towns.

India is witnessing rapid urbanisation. The urban population is increasing every year as a result of migration from small towns and villages. Expanding urban population has thus made increasing the housing supply a vital and urgent necessity.

Government of India announced its first National Urban Housing and Habitat Policy in 2007. The country set the challenging goal of Affordable Housing for All. This policy intends to promote sustainable development of the habitat in the country with a view to ensuring equitable supply of land, shelter and services at affordable prices to all sections of society. Following this, many programmes specific to affordable housing have since been initiated. The Government through its various schemes has made concerted efforts to enhance the supply of affordable housing to the urban poor.

The Pradhan Mantri Awas Yojana (Urban) - Housing for All Mission of my Ministry lays emphasis on rehabilitation of Slum Dwellers with participation of private developers using land as a resource; Promotion of Affordable Housing for weaker section through credit linked subsidy; Affordable Housing in Partnership with Public & Private sectors; and Subsidy for beneficiary-led individual house construction/enhancement, for providing housing to all by 2022. A Technology Sub-Mission has also been set up to facilitate adoption of modern, innovative and green technologies and building material for faster and quality construction of houses.

Building Materials & Technology Promotion Council (BMTPC) has been entrusted the task of bringing new housing technologies and alternate materials which can help in creating quality, sustainable and safe housing stock. BMTPC has played a pro-active role in identifying emerging technologies for mass housing.

I welcome BMTPC's effort for bringing out a Special Issue of its Newsletter "Nirman Sarika" on the occasion of "World Habitat Day". I wish them success in their future endeavours.

(Hardeep S Puri)

New Delhi
25 September, 2017

सत्यमेव जयते

DURGA SHANKER MISHRA
Secretary
Ministry of Housing & Urban Affairs
Government of India

MESSAGE

Every year on first Monday of October, the world celebrates "World Habitat Day", to give attention to the issues related to human habitat. This year's theme "Housing Policies: Affordable Homes", declared by United Nation, reminds the world about the importance of proper policy framework by the respective Governments, of the country to make the basic need of housing affordable for all people, specially the poor and underprivileged one.

The definition for Affordable Housing, may spell out different criteria in different countries but largely it remains the same and addresses the housing needs of lower or middle income households. Housing is often the single biggest expenditure of low and middle income families and the house remains their greatest source of wealth. Increasing cost of land and building materials, however, makes it difficult for middle and low income group of people to convert their dream of owning a safe pucca house a reality in cities. People below poverty line have no option but to settle in slums, exposed to natural and manmade hazards. It requires a multipronged approach to deal with the subject.

Government of India, giving this basic need the topmost priority, has taken various measures to meet this challenge. Pradhan Mantri Awas Yojana (Urban) - Housing for All, provide a policy framework with involvement of all stakeholders, for construction of affordable houses in the country, so as to provide a safe Pucca House with water connection, toilet facility and 24x7 electricity to all the household by 2022 – the 75th year of Independence.

Building Materials & Technology Promotion Council (BMTPC) is one of the agencies, which is devoted to identification, evaluation and promotion of fast track sustainable construction technologies to bring quality, durability and speed in the construction at affordable cost under the Mission.

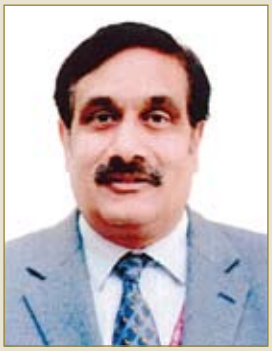
I congratulate BMTPC for bringing out the Special Issue of their Newsletter "Nirman Sarika" on the occasion of the World Habitat Day to address important burning issues related to Affordable Houses.

I wish BMTPC all the best in their future endevours.

(Durga Shanker Mishra)

सत्यमेव जयते

DR. SAMEER SHARMA
Additional Secretary
Ministry of Housing & Urban Affairs
Government of India



MESSAGE

This year's theme for the "World Habitat Day", declared by the United Nation is **"Housing Policies: Affordable Homes"**. It gives us an opportunity to focus on the policy issues associated with the dream Mission of the Hon'ble Prime Minister, to make a decent pucca house with facility of water, toilet and electricity available to every household at an affordable cost, by the 75th year of Independence i.e. by 2022.

With 96 percentage of housing shortage falling under the category of Economically Weaker Section (EWS) and Lower Income Group (LIGs), fulfilling the housing need of the country is very challenging. It requires an integrated approach with proper policy instruments which not only help household to reach the needed financed benchmark but also to create a proper eco system with involvement of all stake holders, to fast track the construction with due attention to ecological, environmental and sustainability aspects at an affordable cost.

Building Materials & Technology Promotion Council (BMTPC) is playing an important role in the Housing for All Mission, by identifying, evaluating and promoting new emerging construction technologies, which fulfil the present need of speed, quality, durability, sustainability and affordability.

I am happy that Building Materials & Technology Promotion Council (BMTPC) like previous years, is coming out with a special issue of its Newsletter "Nirman Sarika" on the occasion of World Habitat Day. I sincerely hope the publication will provide better insight to the chosen theme of the World Habitat Day.

I extend my best wishes to BMTPC in their endeavours.

(Sameer Sharma)

सत्यमेव जयते

MANOJ KUMAR
Additional Secretary
Ministry of Housing & Urban Affairs
Government of India

MESSAGE

World Habitat day is celebrated worldwide on first Monday of October every year with an objective to remind us of the state of affairs relating to sustainable habitat and also to take forward the agenda of improving the basic right of adequate and affordable shelter to all.

The Government of India had brought out the National Urban Housing and Habitat Policy in 2007 which seeks to promote sustainable development of habitat in the country. The Policy promotes various types of public-private partnerships for realizing the goal of Affordable Housing for All. Housing being a State subject, State Governments formulate their own housing policies which normally amalgamate with the central schemes to give maximum benefits to the beneficiaries.

This year's theme of "Housing Policies: Affordable Homes" has great relevance in the current Indian scenario as Government of India is implementing Pradhan Mantri Awas Yojana (Urban) - Housing for All to address the housing requirements of urban poor, including slum dwellers. I hope that the theme will give further impetus to the current endeavors of Government of India in providing safe and affordable housing for all.

Building Materials & Technology Promotion Council (BMTPC) has been making concerted efforts to identify and evaluate emerging technologies for affordable housing. The Council should further intensify its efforts to ensure speedy dissemination of innovative concepts and technologies in the implementation of housing programmes.

I am happy to know that the BMTPC is bringing out a Special Issue of its Newsletter "Nirman Sarika" on the occasion of the World Habitat Day. I wish it all success.

(Manoj Kumar)

सत्यमेव जयते

JHANJA TRIPATHY
Joint Secretary & Financial Advisor
Ministry of Housing & Urban Affairs
Government of India

MESSAGE

As India becomes more urbanized, there is an increasing requirement of housing for the entire cross section of the society. Weaker sections, low-income and disadvantaged groups need special attention in the context of emerging challenges. Despite sustained economic growth in the last few years, India still faces challenges of addressing the issues of affordability, accessibility and availability that haunt a large segment of population. Climate change adds to the existing stresses on the sustainability of human settlements and society.

Recognising the seriousness and complexity of these issues the Government of India has taken several initiatives including implementation of Pradhan Mantri Awas Yojana (Urban) – Housing For All Mission, to promote sustainable development of habitat in the country for realizing the goal of Affordable Housing for All. The objectives of these initiatives are: achievement of social sector goals; community empowerment; creating sustainable support systems; employment generation and skill upgradation; environmental improvement and shelter upgradation.

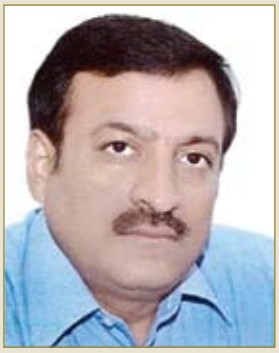
I am happy that the Building Materials & Technology Promotion Council under the aegis of this Ministry is bringing out the special issue of its Newsletter "Nirman Sarika" highlighting the theme of the World Habitat Day which is "Housing Policies: Affordable Homes".

I take this opportunity to wish BMTPC every success in its efforts.

(Jhanja Tripathy)

सत्यमेव जयते

AMRIT ABHIJAT
Joint Secretary & Mission Director (Housing for All)
Ministry of Housing & Urban Affairs
Government of India



MESSAGE

The Theme of World Habitat Day this year - "Housing Policies: Affordable Homes" is, an appropriate one. Affordable housing today is one of the challenges of the emerging economic across the world having resource constraints in terms of land, finances & fast depleting natural resources of building materials.

Government of India has taken several initiatives for making houses affordable to the vulnerable segment of its population. The Pradhan Mantri Awas Yojana (Urban), a flagship programme of the Government envisages facilitating the efforts of States/UTs in addressing the urban housing shortage. Across the four verticals of this Mission, the abiding theme is that by the year 2022, every household should have a pucca house. In order to achieve affordability and sustainability, States are being encouraged to make use of modern, innovative & green technologies.

BMTPC is playing an important role for making houses affordable through promotion of cost-effective, environment friendly and disaster-resistant building materials & technologies. Further as per the requirement of mass housing under PMAY(U), it has been identifying and evaluating new and emerging technologies to bring quality and speed in construction and make the houses affordable.

I am sure that the publication of special issue of Nirman Sarika of the Council brought out on the occasion of World Habitat Day 2017 would go a long way in highlighting important issues related to the theme.

I wish BMTPC all the success in their future endeavour.

(Amrit Abhijat)

Innovating the Affordable Housing Value Chain with Performance-oriented Regulations and Policies

Anil Sawhney*
PhD, FRICS, FHEA

It is not every day that one lives to witness a program or mission to build 20 million affordable housing units. When India launched the Housing for All (Urban) program in 2015, many saw this as a formidable task that was important for the future of the country and its citizens. Acknowledging the crucial role of technology the creators of the mission simultaneously embedded a Technology Sub-mission in the program with the aim of enriching the value-chain through technology-driven innovation. It was amply clear that business as usual or as many call it the 'sticks and bricks' approach would not work, at least not as the only path to accomplishing the mission's goal of building close to 3 million houses a year. So what is the lever that can be used to propel the affordable housing value chain to match the delivery targets? What kind of innovation is needed to make this shift?

In the first eighteen months of the program, the central government has approved the construction of 1.5 million affordable housing units as part of 3031 projects in the 3,888 participating cities spread over 34 States and Union Territories. These approvals amount to an investment of approximately USD 3.5 billion by the central government. Most approved projects are in their early stages of implementation with many still on the drawing board. The industry needs to start thinking about the delivery mechanism for these houses as the program moves forward. Successful delivery of the housing units under the first batch of approved projects will be crucial to the final success of the entire mission. Technology and innovation are crucial in this journey.

So, is there a dearth of available technologies for affordable housing? The answer to this question is resounding no. Recent advancements in construction technology, from traditional site-based 'sticks and bricks' methods to "more efficient combination of off-site and on-site methods", has brought upon us new possibilities for the construction of affordable mass housing. This paradigm is now spread across the globe encompassing a greater use of prefabricated systems and innovations for designing and constructing affordable and sustainable housing. These emerging methods and technologies are superior to traditional technologies in terms of delivery time, cost, sustainability, safety, quality and overall performance. Paradoxically though, adoption of emerging housing technologies in the Indian housing sector remains low. While there is no dearth of available technologies, selection of the most appropriate one among the emerging technologies remains a complex process that depends upon a plethora of factors. Mainstreaming of these superior technologies is challenging as the Indian housing value chain is complex. Most technologies are rejected by superficial analysis of first-cost and perceived implementation difficulties. Other hurdles and challenges remain, including the controversial issue of regulations and policies.

The discussion on regulatory issues begins and ends with approval delays and single-window clearance. Do we have adequate

* Professor of Project Management, Liverpool John Moores University, Liverpool, UK; E-mail: A.Sawhney@ljmu.ac.uk

capacity to follow through with a regulatory framework that supports and encourages the use of emerging technologies and products safely and securely? Is quality of construction using traditional methods of construction monitored adequately by local building authorities? A significant effort is needed to upgrade and modernise our codes, bylaws and ensuring capacity to implement them. We need to reach a stage that building regulations and policies become a mechanism to promote innovation in the affordable housing value chain.

Historically regulations and policies have been seen as a mechanism to maintain business as usual and stifle innovation. This worldview has to be disrupted if the path to accomplishing the targets of the affordable housing mission have to be made real. The needed shift will take place if we move away from prescriptive housing policies and regulations towards performance-oriented policies and regulations. The regulations and policies surrounding the affordable housing ecosystem must be deployed as a portfolio of tools aimed at improving the performance of the housing stock and meeting the needs of the end-user. Such a deployment will likely stimulate system innovation up and down the value change. It can provide the affordable housing value chain with the business environment, market incentive and institutional frameworks that are conducive to innovation. Our policies and regulations must proactively seek to encourage innovation in housing products and materials, and process improvement including new product development and systems integration.

The idea of performance-based regulation is not new. The aviation, health and safety, and nuclear sectors have used this approach for several decades. The idea for affordable housing can be very simple. Build affordable houses with superior technologies that meet the performance criteria pertaining to factors like cost and time certainty, energy efficiency, thermal comfort, sustainable use of materials, design flexibility, future maintenance requirements and performance throughout the housing life-cycle, customer satisfaction and acceptance, and compliance with building regulation. The Performance Appraisal Certification Scheme (PACS) designed by BMTPC can play a significant role in attaining performance-oriented regulations and policies for affordable housing in India. If the technology successfully adheres to all the parameters and criteria, then the technology can be further evaluated for implementation and promotion to suit end-users' performance requirements.

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Affordable Housing Scheme in Nigeria
Source: https://constructionreviewonline.com/2017/07/stakeholders-in-nigeria-advocate-value-chain-financing-for-affordable-housing/

Government's Initiatives towards Housing Policies: Affordable Homes

*Dr. Shailesh Kr. Agrawal**
*& Dalip Kumar***

India is committed towards affordable housing for its citizens specially at the bottom of the pyramid. It can be clearly seen in the housing policies & flagship programmes of the successive governments since its independence. Urban areas in India are fast growing and being seen as engines of growth, however faulty planning, poor programme implementation and unplanned growth has given rise to proliferation of slums and as a projection, India's slum population may surge to around 9%. This means urban planners will face escalating challenges as these slums will mostly thrive in sleepy towns and in semi-rural areas, a consequence of an accelerating rural to urban shift across the nation.

The bigger states like Maharashtra, Uttar Pradesh, Andhra Pradesh and Madhya Pradesh will host the largest share of India's slum population. A projection of the slum population on the basis of the Pranab Sen Committee Report in 2011 was 93 million, or 7% of a total population of 1.21 billion. The census of 2011 recorded 1.3 crore urban slum households. So, if a household is estimated at five members, the urban slum population is around 65 million.

The 2011 census also shows the problem is growing as it indicates the percentage of people living in slums in smaller cities with a population of less than a million is rising. While 62% people in these cities are slum dwellers, it is 38% in all million-plus cities that include mega metros like Delhi and Mumbai.

In absolute numbers while million-plus cities have 52 lakh slum households, the count is 85 lakhs in the sub-million cities. Census data further shows how a large section of the urban population lives in slums in the four metropolitan cities -- as high as 41.3% in Greater Mumbai, 29.6% in Kolkata, 28% in Chennai and about 15% in Delhi. There are indications that as urbanization grows, and the projected share of urban households rises in the next two decades from the current 28% to 50% of India's population, the slums are only likely to grow exponentially.

The socio-economic implications of a large slum population which includes the cost of civic services, housing and health care, and increased crime and social tensions saw the previous governments frame the JNNURM & Rajiv Awas Yojna as a policy response. The scheme intended to provide affordable housing to the poor and make urban areas slum free but these efforts could register little progress.

However, the present Govt. launched a comprehensive Housing for all scheme both for urban & rural areas to provide pucca house to each household by the 75th year of Independence i.e. 2022. The progress is also unprecedented so far with sanction of 23,92,061 houses. Out of which, the houses grounded for construction are 9,93,278 whereas houses completed are 1,57,106 and occupied are 1,27,398 as on 31st July 2017. The overall investment till date is of the order of Rs. 1,27,480.16 Crore with the central assistance of Rs. 37,270.84 Crore.

The extracts of some of the policy level interventions and flag-

* Executive Director, Building Materials & Technology Promotion Council, New Delhi
** Sr.Field Officer (DC&E), Building Materials & Technology Promotion Council, New Delhi

ship programmes operationalized by Govt. of India from time to time are given in this paper to reconfirm Government of India's resolve towards affordable housing & slum eradication.

National Urban Housing & Habitat Policy (2007)

The erstwhile Ministry of Housing & Urban Poverty Alleviation (MoHUPA) now Ministry of Housing & Urban Affair (MoHUA) is responsible to bring national housing policy and also handholds states to bring their own housing policy to address the urban issues. Affordable housing has always been the highlight of Govt. of India housing policy. The National Urban Housing and Habitat Policy (2007) aims at

i) Accelerating the pace of development of housing and related infrastructure.

ii) Creating adequate housing stock both on rental and ownership basis with special emphasis on improving the affordability of the vulnerable and economically weaker sections of society through appropriate capital or interest subsidies.

iii) Using technology for modernizing the housing sector for enhancing energy and cost efficiency, productivity and quality. Technology would be harnessed to meet the housing needs of the poor. The concept of 'green' and 'intelligent' buildings would be put in place on the ground. Technological advances would be disseminated for preventing and mitigating the effects of natural disasters on buildings, e.g., in case of earthquakes, floods, cyclones, etc.

Model State Affordable Housing Policy for Urban Areas : Draft 2014

To tackle urbanisation and related issues, Ministry came up with the National Housing and Habitat Policy (NUHHP), 2007 with "Affordable Housing to All" as its mandate. The NUHHP, 2007 had envisaged that the States should prepare a State Urban Housing and Habitat Policy and also a State Urban Housing & Habitat Action Plan. The draft model state policy empowers the States to include passing of specific Acts by the States to achieve the housing policy objectives through institutional, legal & regulatory reforms, fiscal concessions, financial sector reforms and innovations in the area of resource mobilization for housing and related infrastructure development including promotion of cost effective building materials and technologies at the State level. The policy should also include an action plan and a pragmatic road map to achieve the objectives of the policy.

The aim of the policy, therefore, is to create an enabling environment for providing "affordable housing for all" with special emphasis on EWS and LIG and other vulnerable sections of society such as Scheduled castes/Scheduled Tribes, Backward Classes, Minorities and senior citizens, physically challenged persons in the State and to ensure that no individual is left shelter less. The Policy further aimed to promote Public Private People Participation (PPPP) for addressing the shortage of adequate and affordable housing. However, the policy is still in draft stage and to be finalised.

Jawaharlal Nehru National Urban Renewal Mission (JNNURM)

(2005-2012)

In order to check growth of slums around Indian cities and to look at urban renewal in holistic manner, a comprehensive ambitious scheme of JNNURM was launched. It was a welcome step as it overcame the distinct demerits of earlier VAMBAY & slum development scheme. The MoHUPA operationalized two sub-missions of JNNURM namely **Basic Services to the Urban Poor (BSUP)** and **Integrated Housing & Slum Development Programme (IHSDP)**, which are being discussed now.

The main thrust of the Sub-Mission on Basic Services to the Urban Poor (BSUP) was on integrated development of slums through projects for providing shelter, basic services and other related civic amenities with a view to provide utilities to the urban poor.

The Sub-Mission on Basic Services to the Urban Poor covered the following:

i. Integrated development of slums, i.e., housing and development of infrastructure projects in the slums in the identified cities.

ii. Projects involving development/improvement/maintenance of basic services to the urban poor.

iii. Slum improvement and rehabilitation projects.

iv. Projects on water supply/sewerage/drainage, community toilets/baths, etc.

v. Houses at affordable costs for slum dwellers/ urban poor/ EWS/LIG categories.

Occupied Dwelling Units built under JnNURM (BSUP) in Mysore, Karnataka

vi. Construction and improvements of drains/storm water drains.

vii. Environmental improvement of slums and solid waste management.

viii. Street lighting.

ix. Civic amenities, like, community halls, child care centers, etc.

x. Operation and maintenance of assets created under this component.

xi. Convergence of health, education and social security schemes for the urban poor.

Integrated Housing & Slum Development Programme (IHSDP) for small cities aimed at combining the existing schemes of VAMBAY and NSDP under the new IHSDP Scheme for having an integrated approach in ameliorating the conditions of the urban slum dwellers who do not possess adequate shelter and reside in dilapidated conditions.

The components for assistance under the IHSDP included all slum improvement/ upgradation/relocation projects including upgradation/new construction of houses and infrastructural facilities, like, water supply and sewerage. The admissible Components under the scheme were:

i) Provision of shelter including upgradation & construction of new houses.

ii) Provision of community toilets.

iii) Provision of physical amenities like water supply, storm water drains, community bath, widening and paving of existing lanes, sewers, community latrines, street lights, etc.

iv) Community Infrastructure like provision of community centres to be used for pre-school education, non-formal education, adult education, recreational activities, etc.

v) Community Primary Health Care Centre Buildings can be provided.

vi) Social Amenities like pre-school education, non-formal education, adult education, maternity, child health and Primary health care including immunization, etc.

vii) Provision of Model Demonstration Projects.

viii) Sites and Services/houses at affordable costs for EWS & LIG categories.

ix) Slum improvement and rehabilitation projects.

x) Land acquisition cost will not be financed except for acquisition of private land for schemes/ projects in the North Eastern States & hilly States, viz., Himachal Pradesh, Uttaranchal and Jammu & Kashmir.

Houses built under JnNURM (IHSDP) in Bilaspur, Chattisgarh

Rajiv Awas Yojana (RAY) (2013-2015)

In pursuance of Slum Free India vision, after JNNURM and with active participation of States, the JNNURM was recast with more freedom, powers to states and Rajiv Awas Yojana (RAY) was launched in June 2011 in two phases; the preparatory phase for a period of two years which ended in June 2013 and implementation phase. Central Government has approved the implementation phase for the period of 2013-2022.

RAY envisaged two-step implementation strategy i.e. preparation of Slum free City Plan of Action (SFCPoA) and preparation of projects for selected slum. The two step implementation strategy i.e. preparation of Slum-free City Plans of Action (SFCPoAs) on 'whole city' basis and Detailed Project Reports (DPRs) on 'whole slum' basis for selected slums comprised of following main elements:

Preparation of Slum-free City Plans of Action (SFCPoA):

1. The SFCPoA will be an overall action plan of the ULB with investment requirements projected and prioritized for improving/ developing the existing slums and providing houses including basic civic infrastructure and social amenities for the urban poor for the next 10-15 years.
2. Selected cities will draw up their SFCPoA in accordance with the detailed guidelines on the subject, with the overall goal of tackling the problem of slums in a systematic and time bound manner.
3. SFCPoAs would be for a city as a whole, but within a city the implementation of slum up-gradation/redevelopment may require to be phased out and paced as per the financial and resource capacity of the implementing agencies.
4. The strategy to tackle slums would need to be in two parts – a) Curative Strategy for slum redevelopment of all existing slums; and b) Preventive Strategy for containment of growth of future slums.
5. As described in the SFCPoA guidelines, under the curative strategy, the main steps are identification of all slums, slum mapping, profiling, tenability analysis, prioritisation based on assessment of housing and infrastructure deficiency in each slum, formulation of development options for each slum. Under the preventive strategy, the main steps would involve assessment of housing shortage for the urban poor, framing supply options for the urban poor and enabling policy reforms for supply of urban poor housing.
6. As preparation of SFCPoAs would take some time, States/ UTs may submit projects of specific slums for consideration and sanction, pending the preparation of SFCPoAs in the first year of the scheme. Slums taken up for intervention under RAY should be part of prioritised slums in SFCPoAs. Projects approved in RAY pilot phase would be integrated in the RAY implementation phase and funding and release pattern as in implementation phase will be applicable for DPRs approved in pilot phase.
7. States would also require to develop mechanisms to implement all mandatory reforms under RAY, mechanisms and structures for community mobilisation, private sector participation and institutional and human resource capacity.
8. Each completed SFCPoAs will be submitted for technical review of the subcommittee under Central Sanctioning & Monitoring Committee (CSMC) and after incorporation of comments, it would be placed before the CSMC for consideration and acceptance.

Preparation of Detailed Project Reports for the Selected Slums

1. On the basis of prioritization of slums in SFCPoAs, cities

AHP houses in Rajnandangoan, Chhattisgarh

AHP houses in Gujarat

would be required to prepare Detailed Project Reports (DPRs) following a 'whole slum' approach. In each selected slum, an integrated approach would be adopted with the provision of housing, basic civic infrastructure and social amenities. DPRs should include details of arrangements for convergence of inputs of health, education, social security, livelihoods and connectivity to city civic infrastructure from existing schemes and programmes of State/ULB/ Centre.

2. Infrastructure components would include all basic civic infrastructure and social amenities like water supply, sewerage, drainage, solid waste management, approach and internal road, street lighting etc. and community facilities such as pre-schools, child care centres, health centres/sub-centres, livelihoods centres etc.

3. The detailed DPR preparation guidelines must be referred while preparing the DPRs. The DPRs will have the financial and revenue model including commitment of State/ULB share required to complete the projects. DPRs submitted to the Ministry for consideration shall contain duly authenticated detailed cost estimates, relevant drawings, prescribed undertaking by States/UTs and implementing agencies, list of beneficiaries, copy of necessary approvals etc.

4. In-situ development of selected slum would be preferred to ensure that development does not lead to loss of livelihood linkages or additional commuting hours leading to loss of income. Interventions in selected slums can be on the following lines:

   Redevelopment: Development of entire slum by providing adequate housing and infrastructure (civic and social) to the slum dwellers after demolition of the existing built structures.

   Upgradation: Development of the entire slum by filling gaps in housing and infrastructure (civic and social) to the slum dwellers without complete demolition of the existing structures.

5. If temporary transit housing is required to accommodate the displaced slum dwellers of intervened slums, then it may also be proposed as part of the project DPR.

6. Slum relocation should preferably be selected as a method of slum-redevelopment for untenable slums and in such case, emphasis should be laid on providing mobility and recreating livelihood linkages. Such interventions would include adequate connected infrastructure (civic and social) on alternate site selected for such slum relocation.

7. Type of housing to be considered for slum upgradation/ redevelopment/ relocation, hereinafter referred to as slum intervention strategy, may include the following:

   New housing: Slum dwellers without pucca houses should be provided with new dwelling unit (Single storey or Multi-storied building) of carpet area between 21-27 sqm. with two rooms, kitchen, bathroom, water sealed toilet and individual potable water connection facility.

   Incremental housing: During the assessment of housing needs, it may be determined that the existing dwelling units built by the slum dwellers may need improvement i.e. if the dwelling unit is a pucca construction but having less than the desired minimum floor space or rooms, additional provision of rooms, toilets etc. should be considered to meet the minimum criteria so as to facilitate housing unit up-gradation. In case land is not available for expansion, vertical development may be considered. Provision of individual water supply, sanitation etc. should also be considered, where so required. As specified in the para above, for incremental housing also the central support shall be

limited to the carpet area of 21-27 sqm.

Rental Housing: Rental housing may be the preferred choice to accommodate tenants of slums, labourers, floating population and urban homeless. Recognising that managing such rental premises is challenging, States/UTs will be required to clearly enunciate mechanisms for managing such premises including fixation of rent, operation and maintenance, vacancy norms etc. The size of rental DUs is expected to be between 16-20 sqm. with shared civic infrastructure. However, rental DUs with size 21-27 sqm. can also be proposed in exceptional cases.

8. With regard to housing, full flexibility of approach is available for the manner of construction and arrangement of funds. Following models for execution may be adopted:

   Beneficiary-led Execution: Beneficiaries may be involved for construction of DUs which would result in better monitoring and implementation. Implementing agencies should ensure timely availability of funds required for the smooth progress and completion of projects. Funds to beneficiary should be released in not more than four instalments, the first of which can be before commencement of construction (10%), second once construction is upto plinth level (30%), third after construction is upto roof level (40%) and final instalment on completion of construction (20%). The exact quantum may be varied by implementing agencies as per local conditions.

   Executing Agencies: Execution of housing projects may be taken up by ULBs or parastatal agencies like Housing Boards, Development Authorities etc.

9. It would be expected that the implementing agencies will take into account the provisions of the City Development Plan, City Sanitation Plan etc while planning its interventions under RAY so as to achieve synergy with ongoing schemes/ programmes. Each DPR would be submitted through the State Nodal Agency (SLNA) with approval of the SLSMC and would be considered for approval by Central Sanctioning and Monitoring Committee (CSMC). Each project would need to be in conformity with the SFCPoA except as mentioned in para 7.1.6.

10. Community should be involved at every stage, from planning through implementation and post-project sustenance, necessitating that the designing of slum development is done with people's participation, which will lead to community ownership and sustainability of the scheme. To have better coordination and participation in project formulation, implementation and post construction O&M, it is recommended that each slum should form cooperatives/ associations of the resident slum dwellers or any other such structure. These can act as the representative body for giving ownership/ lease rights, rent management, operation and maintenance e.g. paying of electricity, water bills, day-to-day maintenance of the premises etc.

Pradhan Mantri Awas Yojana (PMAY) – Housing for All (Urban)

(2015-2022)

Hon'ble Prime Minister envisioned Housing for All by 2022 when the Nation completes 75 years of its Independence. In order to achieve this objective, Central Government has launched a comprehensive mission "Pradhan Mantri Awas Yojana – Housing for All (Urban)". RAY has been subsumed in this scheme.

The mission seeks to address the housing requirement of urban poor including slum dwellers through following programme verticals:

- Slum rehabilitation of Slum Dwellers with participation of private developers using land as a resource
- Promotion of Affordable Housing for weaker section through credit linked subsidy
- Affordable Housing in Partnership with Public & Private sectors
- Subsidy for beneficiary-led individual house construction / enhancement.

This is so far the most thought and comprehensive scheme being run under four verticals as enumerated above. Also, to augment affordable housing supply, the credit link subsidy scheme was reframed so as to bring Middle income group under its ambit. The scheme is showing quite healthy result and is being explained here.

Credit Linked Subsidy Scheme for EWS/LIG

Pradhan Mantri Awas Yojana (Urban) - Housing For All Mission,

Completed House under BLC-PMAY(U), Tamil Nadu (Geo-tagged)

Completed House under BLC-PMAY(U), Jharkhand (Geo-tagged)

PMAY(U) Houses built with Waffle Crete Technology in Gujarat

PMAY(U) Houses built with Precast Concrete Technology in Chhattisgarh

in order to expand institutional credit flow to the housing needs of urban poor is implementing credit linked subsidy component as a demand side intervention. It has following features:

- Beneficiaries of Economically Weaker Section (EWS) and Low Income Group (LIG) seeking housing loans from Banks, Housing Finance Companies and other such institutions would be eligible for an interest subsidy at the rate of 6.5 % for a tenure of 20 years or during tenure of loan whichever is lower.
- The credit linked subsidy will be available only for loan amounts upto Rs 6 lakhs and additional loans beyond Rs. 6 lakhs, if any, will be at nonsubsidized rate.
- Interest subsidy will be credited upfront to the loan account of beneficiaries through Primary Lending Institutions (PLI), resulting in reduced effective housing loan and Equated Monthly Installment (EMI).
- The Net Present Value (NPV) of the interest subsidy will be calculated at a discount rate of 9 %.

Area which can be constructed

- Carpet area of house being constructed or enhanced under this component of the Mission should be upto 30 square meters for EWS category and upto 60 square meters for LIG category.
- Beneficiary, at his/her discretion, can build a house of larger area but interest subsidy would be limited to first Rs.6 lakh only.
- For incremental housing/extension, the area limit will be 30 sq.mt. and 60 sq.mt. of carpet area for EWS and LIG category respectively.

Credit Linked Subsidy Scheme for Middle Income Group

This Scheme will support acquisition/construction of houses (including re-purchase) of 90 sq. mts. (for MIG I) and 110 sq.mt. (for MIG II) carpet area as per income eligibility with basic civic infrastructure like water, toilet, sanitation, sewerage, road, electricity, etc. Beneficiaries of MIG will be eligible for an interest subsidy with following features:

Particulars	MIG I	MIG II
Household Income (Rs. p.a.)	6,00,001 -12,00,000	12,00,001 - 18,00,000
Interest Subsidy (% p.a.)	4.00%	3.00%
Maximum loan tenure (in years)	20	20
Eligible housing loan amount for interest subsidy (Rs.)	9,00,000	12,00,000
Dwelling Unit carpet area	90 sq. mts.	110 sq. mts.
Discount rate for Net Present Value (NPV) calculation of interest subsidy (%)	9.00%	9.00%

Closure

The above article is to bring Ministry of Housing & Urban Affairs, Govt. of India's strides towards World Habitat Day 2017 theme "Housing Policies: Affordable Homes" for last two decades and the material presented here is collation of various guidelines, reports and publication of ministry available on its website. It is evident that urbanisation and associated issues particularly housing for poor has always been priority area in any of urban scheme of Government and with perseverance, India would be able to tackle and prevent further proliferation of slums in urban centres. The authors sincerely acknowledge all the Secretaries of MoHUA who provided opportunity to BMTPC to be part of these Schemes/Programmes.

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India's Building Materials Sector

*Dr. A.K.Minocha** *Soumitra Maiti***

The construction industry is a major contributor towards India's GDP, both directly and indirectly. It employs 33 million people, and any improvements in the construction sector affect a number of associated industries such as cement, steel, technology, skill-enhancement, etc. This is the only sector which has shown substantial growth in the last three years when our economy has been growing at a slow pace. Simultaneously, the construction sector is reeling under a severe shortage of skilled workforce, and in many areas of the country, shortage of construction sand, raw materials, and political disturbances are also acting as growth deterrents. The pace in the Indian construction sector on the ground, however, does not reflect what lies in store for the future. For example, technological advancements will soon begin increasing the pace and potential of this sector, and act as a growth catalyst. Among its many positive influences, the arrival of new construction technology and the entry of international infrastructure players into India is generating employment across a vast array of different skill sets.

Apart from the Smart Cities project, the Government's **'Housing for All by 2022'** will be a major game changer for the industry. Increased impetus to the creation of affordable housing mission, along with quicker approvals and other supportive policy changes will soon result in an increase in construction activity. Likewise, the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) will bring in increased activity in infrastructure and related sectors. Township housing and infrastructure will also become major drivers for the construction sector in the immediate future. In most cases, the development of townships and their associated infrastructure happens in new corridors of our cities, and the Government is extending a lot of support for developing untapped areas

The engineers, architects, specifiers, builders, contractor etc. who are charged with the responsibility of selecting materials of construction for specific applications are always concerned with the engineering properties, cost and availability of selected materials. The professionals, who were keen to select the best option out of the various available ones, depended on the scientific evaluation of the claims made about a material, on the basis of its composition, and structure which normally help in predicting the properties and performance for the intended use. With the rapid advances in science of materials also involve the knowledge of several aspects of the materials under consideration, such as the process technology, the associated health hazard, impact on environment and embodied energy that has gone into its production. Additionally, how a material or component is going to behave in an environment and conditions of use likely to confront the selected material, and how long it is going to withstand these conditions without losing its structural stability and performance are also considered(Table 1).

The selection of building materials is a predictive effort to ensure its future performance or durability.

* Chief Scientist, Environment Science and Technology Group, CSIR-Central Building Research Institute, Roorkee 247667
** Scientist, Environment Science and Technology Group, CSIR-Central Building Research Institute, Roorkee 247667

Table 1: Service life of materials (years)

Material	Severe exposure	Moderate exposure	Mild exposure	Very mild exposure
Strong natural rocks	100-1,000	1,000-10,000	0.1 million	> 1million
Natural rocks	10-100	100-1,000	10,000	> 100,00
Ceramic materials	1-100	100-1,000	10,000	> 100,000
High strength concrete	10-100	100-1,000	10,000	> 100,000
Mortar	1-10	10-100	2,000	> 10,000
Wood	1-10	10-100	1,000	> 10,000
Plastic	1-10	10-100	100	> 1,000
Paint	-	2-20	500	> 2,000
Gypsum	-	1-10	500	> 2,000
	Frost, snow, erosion, dissolution, strong sun light, pollution	Average variation of outdoor conditions	Moderate temperature, dry, slight changes	Dry, very slight ventilation, no sunlight, low temperature

Brick

Brick is one of the oldest building materials. Archeological excavations at Dhaulavira, Harappa, Lothal, Nalanda and other places establish that the art of brick making was well known in ancient India. While it is not clearly known whether five millennia ago brick making existed as an industry or not, surviving brick structures leave no doubt that the hard baked clay brick was a basic building material in the ancient period. In colonial India, brick making was largely a cottage industry. A modest output of bricks from small clamps was sufficient to meet the requirements of small towns and urban centres. The construction of railways by the British provided an opportunity for reviving the manufacture of brick. The introduction of the Bull's trench kiln allowed for continuous production. Railway engineers, J Bull and H Bull designed a kiln on the lines of the H German arch less Hoffmann kiln with two modifications: (a) the kiln was sunk in a trench, and (b) a portable chimney was installed. Prior to this clay bricks and tiles were burnt in clamps.

CSIR-CBRI Efforts

A group of researchers at the CSIR-CBRI, Roorkee devoted themselves exclusively to the study of clay and clay products. (Table 2)

In 1947, the Indian Standard Institute (ISI) set up a Clay products building Sectional Committee (CDC 30) to formulate standards for all types of clay products used in buildings and codes of practice for the methods of production. In July 1990, the Building Materials and Technology Promotion Council (BMPTC) were established under the aegis of the Ministry of Urban Affairs and Employment with the objectives of promoting modern technology in the building materials Industry.

Extensive R&D work has been carried out for over five decades at CSIR-CBRI which may be classified as:

- Study of soils including inferior soils as key raw material
- Standardization
- Bricks from agro-industrial wastes
- Process improvement
- Product range expansion and upgrading
- Environmental concerns

Knowledge of the mineralogical composition of soil is essential for the selection and blending of various clays and non-clayey materials in order to produce good quality brick. Major soils in India may be classified as: (a) alluvial, (b) peat, (c) black cotton, (d) red (ferruginous), (e) laterite, (f) desert, (g) terai and forest. Scientist carried out a thorough investigation of

Table 2: Types of soils and their mineral compositions

Soil type	Major clay mineral	Clay content	Clay +silt	LL	PI
Alluvial	Kaolinite and illite	20-30	40-65	25-40	7-16
Black	Montmorillonite	30-50	50-70	> 40	15-30
Red	Kaolinite and montmorillonite	10-30	30-40	20-25	5-15
Marine	Kaolinite and illite	40-60	60-75	40-50	20-30
Sandy	Kaolinite and Attapulgie	4-6	10-20	5-15	5-6

the physico-chemical composition of soils generally used for brick making viz., alluvial, red and black as well as marine and sandy soils. The mechanical properties of major clays in the five main soil types used for brick making and general physico-Chemical characteristics of the clay minerals are given in Tables 3 and 4 respectively. Table 5 also gives the results of differential thermal analysis (DTA) and the maximum firing temperature at which the main strength contributing minerals are formed, if brick making soil predominately consists of a particular clay mineral.

Process improvement

The batch type country kiln

These kilns are either rectangular or conical in shape, and are constructed with brick or stone, in mud or lime mortar. A portion of the kiln is kept underground in order to reduce construction cost as well as heat losses during production. There is a door at floor level on the broader side and a number of fire-holes on the two longer sides depending upon the size of the kiln. The air-holes opposite each other are connected. Before firing, a mixture of mud and cow dung is applied as a linking to the inside wall. This lining helps to plug any faults or holes. The kiln is operated batchwise. For setting, firewood is spread over the flues at the bottom of the kiln, followed by a layer of limestone, then firewood or coal, in alternate layers. There is no control over the size of coal which varies from powder to large pieces and causes uneven burning that leaves under-burnt or over-burnt lime. The firing schedule takes up to 20 days and a few days are allowed the lime at the topthe lime lumps; powder and unburnt limestone are

Table 3: Physico-chemical characteristics of clay minerals

Characteristics	Kaolinite	Illite	Montmori-llonite	Chlorite	Attapulgite/ sepiolite
Chemical analysis Molar S_iO_2 Al_2O_3 % K_2O % MgO % Organic matter	 2.0-3.0 Trace Trace Trace Trace	 2.0-3.5 1.0-2.5 0.5-1.2 0.5 Trace	 5.0-6.5 0.5-0.8 0.5-0.8 0.5-2.0 0.5-1.0		
Cation exchange capacity (Me/100g)	3-15	10-40	75-150	15-45	20-30
Particle size% 2 to 1 µ 1 to 0.1 µ 0.1 µ	 20 50 30	 15 40 45	 30 20 50	 20 55 25	 20 30 50
X-ray diffraction Clay mineral % Quartz % Iron compounds	 5 Nil	 1 Trace	 2-5 1.5-4.5	 1-2 1.5-2.5	
DTA analysis % water below 100^0 C % water 500 to 600^0 C Exothermic temp. ^{0}C Phase upto 1200^0 C	 1.5-6 0.5-0.8 6-10 1000 Crystobalite Mullite	 2-5 0.5-1.0 6-8 900 Mullite spinel	 5-10 2-5 8-15 850	 2-4 3-8 5-6 900 Mullite B-quartz	 1-2 3-2 5-6 950 Mullite spinel

Table-4: Properties of fired bricks (22.80 cmx 11.40 cmx 7.60 cm) utilizing siliceous waste materials

Additive Location	Soil Location	Addi-tive (w/w) %	Characteristics of bricks fired at temperatures					
			950^{0}C			1020^0 C		
			C.S. (MPa)	W.A. (%)	B.D. (g/c)	C.S. (MPa)	W.A. (%)	B.D. (g/c)
Flyash								
Delhi	Roorkee	15	10-12	15-17	1.65-1.70	15.2-17.1	12-15	1.75-1.80
Kanpur	Kanpur	20	11-13.5	14-17	1.63-1.72	15.5-18.2	11-14	1.75-1.85
Titagarh	Calcutta	25	12-13	18-20	1.62-1.65	16.4-17.5	15-17	1.74-1.80
Korba	Korba	35	8-9.2	17-19	1.55-1.60	13.0-14.6	16-18	1.61-1.65
Nagda	Nagda	30	7.2-8.5	16-19	1.52-1.56	11.8-13.4	15-18	1.60-1.67
Vijaywada	vijayawada	40	-	-	-	14.8-17.8	16-18	1.42-1.51
Cinder/Coal Ash								
Indore	Indore	20	5.1-6.2	17-20	1.40-1.45	6.6-7.1	17-19	1.50-1.52
bhopal	Bhopal	20	5.5-6.0	18-20	1.42-1.46	6.5-7.6	16-19	1.50-1.53
Coal shale								
Kargali	Roorkee	25	8.0-9.2	13-15	1.60-1.65	17.7-20.5	7-10	1.70-1.75
Kargali	Kargali	25	8.6-10	12-14	1.62-1.70	22.2-25.0	6-9	1.71-1.77
Rice-husk ash								
Vizag	Vizag	15	7.5-8.2	20-22	1.32-1.35	12.0-12.5	18-20	1.60-1.68
Rama-gundam	Rama-gundam	15	5.2-6.3	23-24	1.30-1.35	8.2-8.7	18-21	1.61-1.66
Stone dust								
Guna	Guna	40	7.8-9.2	12-18	1.65-1.80	10.0-12.8	11-14	1.75
Khandwa	khandwa	40	9.6-10.2	12-15	1.67-1.79	11.6-13.4	11-15	1.74-1.82

Table 5: Soil characteristics of some brick making soils

S.No	Source of soil sample	State	Soil group	Plastic index	Organic Matter (%)	$CaCO_3$	Clay minerals identified
1	Roorkee	UP	Alluvial	18.5	0.12	Nil	Illite, kaol
2	Roorkee	UP	Alluvial	23.4	0.24	1.2	Illite, kaol
3	Indore	MP	Black	30.8	0.43	9.5	Mont., kaol
4	Indore	MP	Black	18.8	0.22	2.5	Mont., kaol
5	Ujjain	MP	Black	24.4	0.46	2.5	Mont.
6	Ahmedabad	Gujarat	Black	19	0.28	Nil	mont., Kaol
7	Ramagundam	AP	Black	34.3	0.92	4.5	Mont.
8	Cuttack	Orissa	Red	34.5	0.16	1.5	Kaol,
9	Phulbani	Orissa	Red	21.5	0.27	Nil	Kaol, mica
10	Nagpur	Mahar-ashtra	Red	19.3	0.22	0.5	Mont., kaol

Table 6: Types of kilns and thermal efficiency

S. No.	Type of kiln	Capacity of production	Heat requirement	Thermal efficiency
1	Vertical shaft (Twin shaft)	50-100	850	> 85
2	Vertical shaft (single shaft)	10-20	1,100-1,200	60-65
3	Open top large	30-50	1,800-2,000	40-45
4	Small intermittent	2-10	1,600-2,000	40-45

separated manually. The burning of limestone in these kilns gets easily affected by the speed and direction of the wind and rain, causing enormous deviations in the operational pattern. (Table 6)

Improved kiln design

The all India Khadi and village Industries Commission (KVIC).

Cement

Cement is one of the most important building materials today. The term 'Cement' is generic that can be applied for many inorganic and organic materials. However, the most widely used and versatile variety is Portland cement can be traced back to only about 150 years, when Joseph Joseph Asdin invented and patented it in 1824. Over time, Portland cement has come to be most accepted form all over the world replacing the old cementitious materials that were first made by the Romans using a mixture of calcined clay and lime.

The growth and development of cement industry in India dates back to 1914 when the first cement plant had been commissioned. Since then the industry has witnessed spectacular growth and developments, particularly after 1977, when the policy of partial decontrol was adopted by the Government this progress has been possible through modernization of cement production technology, development of infrastructure, energy efficiency and the R&D work carried out by the research institutions established in the post-independence period. At present, the Indian cement industry ranks fourth among the major cement producing countries of the world

Cement industry is a crore sector industry and forms the backbone of infrastructure development of the country. Industry has shown steady and consistent growth in the last three plan periods. The easing of controls which was initiated in 1982 culminating in total decontrol in 1989 and the implementation of policies of liberalization put the dormant cement industry on a vibrant growth path. The industry grew 3 times both in terms of capacity and production. The capacity and production which were 29 MT and 21 MT in 1981-82 shot up to 97 MT and 69 MT respectively in 1995-96. The industry is presently growing at the rate of 8% - 10% per annum. The major achievements of the industry since 1947 are summarized in Table 7. The industry appears to have successfully dealt with technological challenges arising out of energy crises and problem relating to limestone deposits. It is now technologically at par with leading industrialized countries.

Grades of cement

Ordinary Portland cement is manufactured in three grades-Grades 33, 43 and 53. Other types of cement are not graded and are produced for one specific minimum value of characteristics compressive strength of 33 to 35 MPa at 28 –day. The 3-day and 7-day strengths of cements other than OPC vary and are lower than those specified for OPC except in the case of rapid hardening cement.

Additional requirements

The British code for cement BS 12 covers four grades classified on the basis of strength: classes 32.5, 42.5, 52.5 and 62.5. Due to the differences in testing methods, the strength of Indian cements is relatively lower. Cements corresponding to 52.5 and 62.5 grades are not available in India.

Initial and final setting times

The British Standard specifies a minimum initial setting time of 60 minutes. Considering the hot weather conditions in India, a

Table 7: Cement production (in million tonnes)

Country	Cement production	
	1995	1996
China	400.70	430.00
Japan	90.30	97.00
USA	76.00	77.00
India	65.90	73.00
Russia	36.40	37.00
Italy	34.80	34.40
Other countries	695.90	708.60
world	**1,400.00**	**1,457.00**

lower initial setting time than the stipulated 60 minutes is appropriate. The IS code specifies the final setting time as not more than 600 minutes. The British Standard code no longer specifies a limit for final setting time.

Functional requirement

According to BS 12 Cement shall, when appropriately batched and mixed with aggregate and water, be capable of producing mortar or concrete which retains workability for a sufficient time and shall, after defined periods attain specified strength levels and also possess long term volume ability. This also applies for Indian cements.

Chemical properties

As per the British Standard, chloride content is limited to 0.10 percent. This is a very important requirement affecting the durability of concrete. In the Indian Standard, the specification regarding chloride content in cement appears as a footnote to IS 269:1989 and has not been incorporated in the main table. The requirement specifies that the "total chloride content in cement shall not exceed 0.05 percent by mass, for the cement used in prestressed concrete structures and long span structures'.

The total sulphar content when measured as the amount of SO_3 present in cement is limited to 3.5 percent in the British code. The Indian Standard specifies it as 'not more than 2.5 and 3 percent when C_3A percentage by mass is 5 or less, and greater than 5 respectively'.

Fineness of cement

The British standard does not specify any values, but provides that the user may specify the required fineness. Fineness influences the strength of concrete. A few manufactures in India produce cement of greater fineness to improve the compressive strength of cement. This has not always been desirable. Hence the BS 12 specification of controlled fineness is more appropriate for concrete in hot weather conditions.

Ordinary Portland cement (OPC)

Ordinary Portland cement (OPC) is available in various grades such as OPC:33, OPC:43 and OPC:53. The IS specifications for these grades are based on desired strength (IS 269:1989,IS 18112:1989 and IS 12269:1987). While OPC 33 is used for general construction work, plastering and finishing which does not require cement of high compressive strength, OPC 43 is preferred for higher grade M15, M20 concrete and precast items. OPC 53 is used for precast, prestressed concrete in bridges and tall structures.

The concept of cement has undergone further modification. Now the production and use of cement is governed by physical and mechanical composition. This changing concept of cement and the urge to make the best use f waste material form the basis of the thinking behind new classes of cements such as blended cements. (Table 8/9)

Table 8: Chemical requirements of cements

Class	MgO	SO_3	IR (Insoluble residue)	LOI (Loss on ignition)	Add. other than gypsum
OPC 33	6.00	2.5, 3.0+	4.00	5.00	1.0*
OPC 43	6.00	2.5, 3.0+	2.00	5.00	1.0*
OPC 53	6.00	2.5, 3.0+	2.00	4.00	-
RHC	6.00	2.5, 3.0+	4.00	5.00	1.0*
LHC @	6.00	2.5, 3.0+	4.00	5.00	1.0*
SRC#	6.00	2.50	4.00	5.00	1.0*

Maximum percentage

Class	Slag or pozzolana content	MgO	SO_3	IR	LOI	Sulphar	Additive other than gypsum
PSC	25-65	8.00	3.00	4.00	5.00	1.50	1.0*
PPC	10-25	6.00	3.00	@	5.00	-	1.0*

Table 9: Physical requirements of cements

Class	Fineness	Setting time		Soundness		Compressive strength		
	M^2/kg	Initial min. (min.)	Final max. (hrs.)	Le Chatelier max. (%)	Autoclave max. (mm)	3-day (MPa)	7-day (MPa)	28-day (MPa)
OPC 33	225	30	10	10,5*	0.8, 0.6*	16	22	33
OPC 43	225	30	10	10,5*	0.8, 0.6*	22	33	43
OPC 53	225	30	10	10,5*	0.8, 0.6*	27	37	53
RHC	325	30	10	10,5*	0.8, 0.6*	27	-	-
LHC	320	60	10	10,5*	0.8, 0.6*	10	16	35
SRC	225	30	10	10,5*	0.8, 0.6*	16	16	33
PSC	225	30	10	10,5*	0.8, 0.6*	16	22	33
PPC	300	30	10	10,5*	0.8, 0.6*	16	22	33

Blended cement

Blended cement is the result of intergrinding OPC with an admixture such as flyash, blast furnance slag, rice husk ash or silica fumes or any other reactive siliceous or calcareous material. There have been several notable developments in Europe regarding the production of blended cements and as such OPC need not be an essential constituent. The principal physical properties of these cements are similar to that of OPC. PPC, PBFSC and other masonry cements are principal types of blended cements are principal types of blended cements commercially manufactured in India.

Portland blast furnance slag cement (PSC)

Portland blast furnace slag cement (PSC) is obtained by intergrinding Portland cement clinker, granulated blast furnace slag and a stipulated quantity of gypsum. The slag content in PSC varies from 25 to 65 percent.

Generally slag does not react with water. However, in the presence of calcium hydroxide obtained on hydration of Portland cement, the minerals present in the slag undergo hydration products. The early strength obtained with slag cement is comparable to OPC (IS 269) at various ages, where sometimes the strength obtained is even higher. Also, due to a reduction of the lime content in the concrete made with PSC, the sulphate resistance of the concrete improves greatly. For this reason PSC is also categorized as cement for special conditions. Such cements are used for construction of bridges, seaports, and structures in chemically aggressive environments.

Cements for various environments and climatic conditions

This class of cement is intended for use in those constructions which have to withstand high and low ambient temperature and humidity, exposure to different soil and ground water conditions, and sea water. In addition, certain types of cement are to be used in industrial constructions like heavy chemicals, fertilizers and pharmaceutical industries, where there are possibilities of exposure to volatile and corrosive materials, acids, alkalies and enzymes. No single cement can be designed to suit all the requirements of the various application areas simultaneously, and as such, a variety of cements is prescribed for such purposes.

Sulphate resisting cement (SRC)

Concrete constructions using ordinary Portland cement deteriorate in strength on prolonged contact with soil and water rich in sulphates. Cements conforming to type V ASTM, slag cement and even PPC and HAC are considered to be sulphate resisting. This is due to the reduced tricalcium aluminate (C_3A) and lime content in these cements. Detailed studies have been conducted to establish the cause of such deterioration, and it has been concluded that cement with more than 5 percent C_3A is prone to deterioration under a high sulphate environment. Thus, a Portland cement with less than 5 percent C_3A is highly resistant to sulphatic action and is, therefore, known as sulphate resisting cement. Some of the cement plants in India manufacture SRC for specialized use such as in marine structures, underground constructions, chemical plants and effluent treatment plants.

High alumina cement (HAC)

High alumina cement is non-Portland type chemical resisting cement. It consisting essentially of monocalcium aluminate (CA) and $C_{12}A_7$. This cement is manufactured by the fusion of limestone and bauxite in a reverberatory furnace and cooling the fused mass to obtain clinker. This clinker is ground to obtain high alumina cement.

The chemical resistance of high alumina cement is attributed to the presence of monocalcium aluminate hydrate in the hydration products. However, this monocalcium aluminate hydrate is only meta-stable and is liable to transform into C_3AH_6 and alumina gel when exposed to high ambient temperature and humidity, such as the tropical climate of India. The rate of transformation to C_3AH_6 is very high. Therefore, this cement has not become popular in India for in use structural concrete, although the Indian Standard specifications cover this product. An additional feature of HAC is its high early strength, which is approximately twice that of OPC. Therefore, this cement can be used for emergency repairs. This cement is mainly used for furnace lining, as at high temperature it turns into a refractory material.

Super sulphated cement (SSC)

Super sulphated cement (SSC) is hydraulic cement. It is produced by intergrinding, or intimately blending a mixture of granulated blast furnace slag (80 to 85 percent), gypsum anhydride (10 to 15 percent) and a small quantity of Portland cement clinker (2 to 5 percent) or any other source of lime. SSC may compare well with OPC in strength and other physical proper-

ties. However, its heat of hydration will always be much lower; 60 cals/g at 7 days and 70 cals/g at 28 days. This cement is characterized by its chemical resistance to many aggressive conditions, particularly to attack by sulphates. The strength characteristics of SSC in India are marginally lower than those of OPC. However, the main limitation to the use of SSC in India is that it is not supposed to be used at servicing temperatures higher than 37^0 C, since the stability of ettringite (calcium sulpho-aluminate), the main strength giving hydration product in this cement, is questionable above this temperature.

Hydrophobic cement

There are certain valid apprehensions regarding deterioration of OPC when stored under conditions of high humidity. In order to increase the storage life of cement or to transport cement during the rainy season, some water repellent additives like oleic acid, stearic acid or palmitic acid (0.05 to 0.1 percent) must be used. This cement is known as hydrophobic cement and behaves like OPC as the coating gets removed during mortar making.

Rapid hardening cement (RHC)

Ordinary Portland cement develops the desired strength after 3 days, 7 days and 28 days. Sometimes design specifications require that the cement develop the desired strength in 24 hours. This type of cement is known as rapid hardening or high early strength cement. The setting time RHC is the same as that of OPC but it is not just quick setting cement. The methodology of manufacturing RHC differs from that of OPC. The raw mix composition, fineness of the raw meal, temperature and time of Calcination for these cements must be optimized in order to obtain the desired properties.

Low heat cement (LHC)

For large mass concrete work, such as in dams and piers, it is necessary to have cement which releases a lower heat of hydration so as to minimize chances of developing contraction cracks. This can be achieved either by adding some pozzolanic material or granulated blast furnace slag to the cement while grinding or by changing the mineralogical composition with higher C_2S in the cement which due to a lower rate of hydration produces loss heat of hydration.

Types of cement

In India, the following types of cement are used for making concrete: OPC grades, Portland blast furnace slag cement, Portland pozzolana cement, sulphate resisting Port-land cement, low heat Portland cement, rapid hardening Portland cement and super sulphate cement.

Unlike the Indian classification of cements, the European countries have a different classification which is grouped as followes:

- Cement I : Portland cement
- Cement II : Portland slag cement
- Portland silica fume cement
- Portland pozzolana cement
- Portland flyash cement
- Portland burnt shale cement
- Portland limestone cement
- Cement III : Blast furnace cement

Cement other than OPC

Cements other than OPC are used to reduce the effect of chemical attack on concrete and to change the rate of gain of strength and evolution of heat. Portland pozzolana cement and blast furnace slag cement are the two most important types of cement other than OPC. They are also called blended cements.

Such blended cements are also chosen with regard to their cost effectiveness and energy saving potential which are other equally important considerations. Blended cements are the following types:

- PPC
- PBFSC
- OPC + PFA
- OPC + GGBS
- OPC + Microsilica
- OPC + PFA + Microsilica
- OPC + GGBS + Microsulica

Portland pozzolana cement (PPC)

This cement is available in Grade 33 only and mixes of higher grades cannot be realized though a few factories do produce PPC having higher strengths. The rate of development of compressive strength during the first week is very low, necessitating the retention of formwork for a longer period and also a prolonged curing. (Table 10 & 11)

Concrete as a structural material

Concrete may be classified into three categories:

- Low strength : Less than 20 MPa
- Moderate strength : between 20 and 40 MPa
- High strength : more than 40 MPa

Table 10: Typical proportion of materials in concrete

	Low (Kg/m^3)	Moderate (Kg/m^3)	High (kg/m^3)
Cement	300	350	500
water	180	180	180
Fine aggregate	800	848	890
Coarse aggregate	1170	1030	872
strength	18 MPa	30 MPa	60 MPa

Table 11: Mix proportion for 1 m^3 concrete in a bridge in Norway

Cement	475 kg
Admixture	6.5 kg
Condensed silica fume	40 kg
Sand 0 to 8 mm	1080 kg
Natural gravel 8to 16 mm	720 kg
water	180 litres
Slump achieved	240 to 260 mm

Moderate strength concrete is used for most structural works whereas high strength concrete is used for special applications.

In India, low strength concrete (15 MPa) is extensively used for structural work. This has resulted in durability problems and unacceptable levels of maintenance costs as well as a shorter life of structures. In contrast, the minimum grade of concrete is between 25 and 30 MPa as per codes elsewhere, which is further enhanced in individual cases depending on exposure conditions and requirements of durability. The increase in the strength of is realized with only a marginal increase in cost. In all the three catergories of concrete, the aggregate and water cost are constant. There is only a marginal increases in cement consumption and, perhaps, the additional cost of mixtures.

Table 10 gives the typical proportion of materials in concretes of different strengths. The concret mix proportion for a bridge in Norway is given Table 11. It shows potential for economizing on cement. With a partial replacement by PFA or GGBS, the cement consumption can be further reduced.

Concrete

Concrete ids the most widely used structural material today. In many countries, the ratio of consumption of concrete to steel exceeds ten to one. Cement concrete is used for all kinds of constructions such as residential, commercial, institutional, industrial and sports buildings, hydraulic structures, transportation facilities and bridges. With the development of high strength deformed reinforcing bars, high strength cements, design and construction methods, it is now possible to produce concretes of high strengths and prolonged durability. Reinforced cement concrete thus competes directly and successfully with all other major construction materials.

Concrete scores over other materials mainly due to the fact that (a) structural elements can be formed into a variety of shapes and sizes easily, (b) concrete structures require less maintainance, (c) it is economical in terms of both money and energy and (d) various industrial wastes can be utilised as partial replacements of cement and aggregates.

Concrete is obligatory for a variety of structures. For instance, one would not think of using wood for a dam, steel for pavement, as asphalt for building frames. Even when other materials are used as principal componebnts of a structure, concreet is still used to support, enclose and fill.

Till a few decades ago any concrete having strength of more than 20 MPa was considered unusual. In the last five decades India has made spectacular progress in concrete technology. Today, , concrete grades of 40 to 50 MPa are routine in most construction projects. Even 70 MPa concrete is used in many precast on site structures.

Concrete mix design

The design of concrete mix is based partly on scientific principles and partly on past experience and expertise. As such, no single method of mix design is universally applicable. While published data may be used as a guide to start the process of mix design, the expertise available and the concerned construction agencies assurance given by the concerned construction agencies in arriving at mix proportions would primarily need to be relied upon. This is usually done by taking into account past performance and structuring the trial mix accordingly.

At present, substantial quantities of extra cement are being used for concrete in India as a result of stereotyped mix designs.

About 5 million tonnes of cement per annum is thus wasted. Apart from its impact on the depletion of sustainable resources and the cost of concrete, excessive heat of hydration with consequent cracking, etc.

The use of concrete as a structural material can take two forms: semi fluid like RMC and precast.

Aggregates

Aggregates constitute 70 to 80 percent of the volume of typical concrete mix. The size, gradation and shape of aggregate influence water demand, workability, strength and durability of concrete. In India, both natural gravel as well as crushed stone aggregate are available. Preference should be given to natural gravel which ahs minimum surface to volume ratio and, consequently, reduced water demand. IS383:1970 specifies coarse and fine aggregates.

Coarse aggregate

Natural gravel is easily available in graded forms which can be regarded by screening and recombining in required proportions. By the very process of the formation of gravel, all softer materials are converted into sand and it is a case of 'survival of the fittest' as gravel. Many parts of India are showed are endowed with large volumes of natural gravel. Wherever available, natural gravel should be preferred for concrete.

However, there are totally unfounded apprehensions and reservations regarding the use of natural gravel. In fact, natural gravel is the preferred option for the preparation of concrete. Only when such natural gravel is not available that crushed aggregate is used. IS383 concerning aggregates permits the use of both natural gravel and crushed stone or a blend of both.

In view of the reduced water demand by natural gravel, there is a corresponding reduction in cement content. It is possible to reduce the water to cement ration, resulting in higher strength. This has been demonstrated in a number of power stations and bridges, both in India and elsewhere. Natural gravel has been used successfully in RC and prestressed concrete structures in various regions of India where they are available. Fig. 4 shows a view of the concrete bridge over the river Ganga at Patna (Bihar) in which the concrete used contains natural gravel aggregate.

For a recently completely bridge in Norway, the concrete mix proportion given in Table 2 was successfully used to achieve the concrete grade of M-75. The aggregate-cement ration of 3.6 would not have been possible without the use of natural gravel.

Fine aggregate

Natural sand or crushed fine aggregate conforming to IS383 are used. In the Indian context, unlike a bias towards crushed stone as coarse aggregate, crushed stone as fine aggregate is not generally preferred. There is seemingly no justification for either preference. As long as the properties conform to IS383 there should be no objection to the use of crushed stone for fine aggregate.

In coastal areas natural sand is dredged from the creek or sea bed. Such material, even after washing, is not acceptable for use in reinforced or prestressed concrete. In such situations, crushed fine aggregate is preferred. For the recently completed Channel Tunnel connecting UK with France, the entire concrete used for the tunnel lining, involving about 6 million cubic meters of concrete was prepared with crushed sand. This requirement was specifically based on the use of proper aggregate to ensure durability. In India, concrete for a large number of dams is being produced with crushed fine aggregate.

Ready mixed concrete (RMC)

Concrete is a heterogeneous material and, as such, designing the mix and its production at site may result in quality deficiencies. This also requires a considerable infrastructure at each project site. These problems are overcome by purchasing concrete from centralized RMC plants. In many countries, a major portion of concrete is supplied by RMC plants.

RMC is defined as concrete manufactured at a centralized plant which can be transported and delivered to the purchaser in a plastic and unhardened state. These plants are equipped with automatic or semiautomatic batching systems and are computer controlled. RMC is transported using truck mixers. The transportation to the job site is required as quickly as possible and definitely before the initial setting time of concrete. While transporting RMC to the site there is no loss in consistency during the first half hour as the concrete is kept continuously agitated with the truck mixture drum rotating at a slow speed. (Table 12)

Table-12: Properties of fired bricks (22.80 cmx 11.40 cmx 7.60 cm) utilizing siliceous waste materials

Additive Location	Soil Location	Add. (w/w) %	Characteristics of bricks fired at temperatures					
			950°C			1020° C		
			C.S. (MPa)	W.A. (%)	B.D. (g/c)	C.S. (MPa)	W.A. (%)	B.D. (g/c)
Flyash								
Delhi	Roorkee	15	10-12	15-17	1.65-1.70	15.2-17.1	12-15	1.75-1.80
Kanpur	Kanpur	20	11-13.5	14-17	1.63-1.72	15.5-18.2	11-14	1.75-1.85
Titagarh	Calcutta	25	12-13	18-20	1.62-1.65	16.4-17.5	15-17	1.74-1.80
Korba	Korba	35	8-9.2	17-19	1.55-1.60	13.0-14.6	16-18	1.61-1.65
Nagda	Nagda	30	7.2-8.5	16-19	1.52-1.56	11.8-13.4	15-18	1.60-1.67
Vijaywada	vijayawada	40	-	-	-	14.8-17.8	16-18	1.42-1.51
Cinder/Coal Ash								
Indore	Indore	20	5.1-6.2	17-20	1.40-1.45	6.6-7.1	17-19	1.50-1.52
bhopal	Bhopal	20	5.5-6.0	18-20	1.42-1.46	6.5-7.6	16-19	1.50-1.53
Coal shale								
Kargali	Roorkee	25	8.0-9.2	13-15	1.60-1.65	17.7-20.5	7-10	1.70-1.75
Kargali	Kargali	25	8.6-10	12-14	1.62-1.70	22.2-25.0	6-9	1.71-1.77
Rice-husk ash								
Vizag	Vizag	15	7.5-8.2	20-22	1.32-1.35	12.0-12.5	18-20	1.60-1.68
Ramagun-dam	Ramagun-dam	15	5.2-6.3	23-24	1.30-1.35	8.2-8.7	18-21	1.61-1.66
Stone dust								
Guna	Guna	40	7.8-9.2	12-18	1.65-1.80	10.0-12.8	11-14	1.75
Khandwa	khandwa	40	9.6-10.2	12-15	1.67-1.79	11.6-13.4	11-15	1.74-1.82

Gypsum

Gypsum is a non-hydraulic binder occurring naturally as a crystalline rock or sand. Pure gypsum is a white translucent crystalline mineral. It is a major rock forming mineral that produces massive beds, usually from precipitation out of highly saline waters. Gypsum item have a number of valuable properties like relatively small bulk density, incombustibility, good sound absorbing capacity, good fire resistance, rapid drying and hardening with negligible shrinkage, superior surface finish, resistance to insect and rodents and low energy input during burning to produce gypsum plaster. Since it forms easily from saline water, gypsum can have many inclusions of other minerals and even trapped bubbles of air and water. Gypsum has several variety names that are widely used in the mineral trade.

"Selenite" is the colorless and transparent variety that shows a pearl like luster and has been described as having a moon like glow.

Another variety is a compact fiberous aggregate called "satin spar". This variety has a very satin like look that gives a play of light up and down the fiberous crystals.

A fine grained massive material is called "alabaster" and is an ornamental stone used in fine carvings for centuries, even eons.

Crystals of gypsum can be extremely colorless and transparent, making a strong contrast to the most common usage in drywall. The crystals can also be quite large. Gypsum is a natural insulator, feeling warm to the touch when compared to a more ordinary rock or quartz crystal. Sheets of clear crystals can be easily peeled from a larger specimen.

Plaster of Paris is made by heating gypsum to about 300 degrees

Fahrenheit, driving 75% of the water out of the mineral. This reaction absorbs energy, enabling a sheet of drywall to resist fire for a while. Heating further to about 350 degrees F drives out the remaining water and results in conversion to the mineral an hydrite. On heating gypsum loses water and gives the hemihydrate (CaSO4. 1/2H2O) or the anhydrite. The hemihydrate known as Calcined gypsum/ Plaster of Paris is an important building material. Main uses of plaster of Paris are:

- *Plaster boards* - a layer of plaster sandwiched between two sheets of cardboard.
- *Fibrous plaster* - plaster with fibers (often made of glass fibers but natural fibers are also used) mixed into it to increase its strength. Fibrous plaster is usually cast into a mould then used in slabs. Ceiling boards for false ceiling and partition boards)
- *Plaster cornices* - the decorative plaster projections used under the eaves and above doorways and windows in buildings, making statues, film settings
- *Plaster mouldings* – ceramic industry and engineering industry
- *Chalk plaster*- Plaster of paris is also used for manufacturing building plasters

Table 13 : Classification of gypsum building products and uses

Products	Application	Remarks
Plaster of Paris, $CaSO_4$.1/2 H_2O	Ceramics	Highest purity, free from salts; sets in 5-10 min
Retarded gypsum plaster, $CaSO_4$.1/2 H_2O	Internal plaster and plaster board	Require 0.5-1% retarder to facilitate plastering work; sets in 20-30 min
Keenan's cement, $CaSO_4$ baked in potash alum	Plaster	Perforated and non-perforated
Gypsum plaster board (incorporating glass or polypropylene fibre)	Wall board for partition, ceiling	Use of long glass fibre or polypropylene products high tensile strength
Solid and perforated gypsum plaster block	Internal walling, partitions	Bulk density: 300-500 kg/m^3 compressive strength 0.4-0.65 MPa
Light weight gypsum plaster block	Internal partition	Bulk density: 300-500 kg/m^3 compressive strength 0.15-0.45-0.65 MPa
Acoustic gypsum plaster tiles	Sound absorption board	In the form of slotted or unslotted tiles
Gypsum lath	As a base for plastering	Fibre in the board helps better bond

Classification of Gypsum

Different type of gypsum use in building materials lists in table-13

Gypsum Block

Gypsum block are characterize by good thermal insulation and small dead load, there by facilitating speedy construction. The blocks are generally used in construction of non-load bearing partition in drying conditions besides protecting columns, beams and elevated shaft against fire. The CBRI has developed light wight blocks bu adding a solution of aluminium sulfate to gupsum plaster which in reaction with calcium carbonate, an impurity present in gypsum plaster, produces CO_2.The physical properties of lightweight blocks are given in table-14.

Use of Gypsum in Building Industry

Among the products of gypsum, gypsum plaster and gypsum plaster board find the maximum application in building. The common impurities in gypsum are sand, chalky matter, illminite and gypsum anhydrite. Gypsum containing upto 70% of $CaSO_4.2H_2O$ can be used for building purposes. A less pure material needs some purification before use.

Table 14: Size of gypsum board and gypsum partition blocks

Material	Length (mm)	Width (mm)	Breath (mm)	Thickness (mm)	Circ. holes (mm) min.	Elliptic. or rectan. (mm) min.
Gypsum plaster board						
i.Wall board	1,800-3,000		400 / 600	9.5/12.5/15	-	-
ii.Base board	1,200 / 1,500 / 1,800		800 / 1200	12.5	-	-
Gypsum partition blocks	700 max. in multiple of	700 max. in multiple of		-	-	-
	100	100	75	-	15	20
	do	do	100	-	20	20
	do	do	125	-	25	30
	do	do	150	-	15	25

Gypsum as a Fire Resisting Material

The greatest lure of using gypsum in building is its fire resisting quality. A gypsum-plaster resists the onslaught of fire by virtue of its 20.9% of water by weight, which it holds. During conflagration, the weight of crystallization evaporates in the form of steam which condenses to water on reaching the cooler part of the plaster slab and the temperature cannot exceed more than 100degree Celsius until all the water is driven off in the form of steam. Thus there is a very efficient barrier between the passage of heat and the combustible material. Gypsum plaster is therefore widely used as an insulating material for protecting columns and beams of wood or metal from high temperatures. A porous gypsum plaster is an excellent sound absorbing material while dense and hard plasters are efficient reflectors of sound reflecting upto 97% of sound energy incident at their surface.

Gypsum Plaster Board

Gypsum plasterboards are very popular in many countries. They are commonly used for ceiling construction, for internal lining of wall and for partition walls. They are economical and easy to work and light in weight. They are fire proof and do not expand or contract with change in temperature and humidity. They can take all type of oil paints and wall paper; may be used without finish and can also nailed easily. For making gypsum plaster board, gypsum plaster is treated with water and made into slurry which is filled in the casts smeared with oil to get a clear release of the set which takes almost twenty minutes. Before the poured slurry hardens into a paste of required consistency, fibres (coconut fibre, sisal fibre, mesta fibre, bamboo fibre) are laid into the slurry. The reinforcement fibres are then pressed down and the extended fibres at the edges are folded to give extra reinforcement for nailing. When the slurry becomes sufficiently hard, the board is removed and kept in the sun for drying. Gypsum Hollow tiles and light weight gypsum blocks are made similarly with the exception that some solid rods or cubes are placed in the centre of the mould before filling it with slurry to give hollowness to the finished product.

Stone

The discovery of stone Age articles from Palghat in kerala and stone buildings of Late Archeulian to Lower Middle Palaeolithic period of 50000 BC establish the early use of stone as building material in Indian subcontinent. Stone has been define as the natural, hard substance formed from minerals and earth mineral which are present in rocks. Almost all rocks have a defined chemical composition and are made up of minerals and organic matter. some of the rock forming minerals are quartz, feldspar, mica, dolomite etc. The various types of rocks from which building stones are usually derived are granite, basalt, trap, marble, slate, sandstone and limestone. the condition which govern the selection of stone for structural purposes are cost, fashion, ornamental value and durability. Most of the forts world over, the TajMahal of India, famous pyramids of Egypt and the Great Wall of China are few examples. stones have also been extensively used the almost all the elements of building structures as load carrying units as well as for enhancing the beauty and elegance of structure. The properties of a stone that determine its fitness for construction purposes are durability, strength, hardness, density, and appearance.

Classification of building stones

Except serpentine and soapstone, all important building stones can be classified into three groups: igneous (granite, basalt), sedimentary (sand, clay) and metamorphic(marbles, slate) rocks. Ignitions rocks are the result of solidification from a molten state. Sedimentary rocks are composed of sand, clay and other substances resulting from disintegration of stone into small particles. Metamorphic rock is the products of both igneous and sedimentary rocks formed either by pressure, heat, action of water or a combination of this factor. Natural stone is classified by its mineral composition, size & shape of particle and strength. Table-1 lists stone according to type properties and general uses, common types of stones used in construction are listed in table-15 & 16

General properties

Limestone and marble should be free from soft veins, foreign inclusions, cracks and other flaws. Marble is valued for its different colors like white, grey etc. the color in some stones depend upon the types of feldspar associated in their compositions. Laterite blocks of red & yellowish color are quite fragile and soft when cut from the rock and required drying and hardening for a couple of week before using. The average chemical compositions of various stones are given in table-17.

We need to have visionaries for the future development of technology, who dare to dream and have the willpower to turn the rhetoric into reality. History speaks of instances where visionary dreams, creative imagination, logical reasoning and science fiction have led to unveiling new and revolutionary practical applications for technological innovations. let us rededicate ourselves by changing our mindset to shed mediocrity and adorn a pioneering attitude towards furthering cause of innovative technology for constructive purposes. What we require is the quest for excellence, a fair risk appetite and an unrelenting drive to put technology to work for the progress of mankind.

We would like to dwell with the constructive powers of technology in the larger context of sustainable human settlement development in general and the building and construction sector in particular. It is always said that development and environment are always at crossroads and every effort made for development in all its spheres always lead to negative fall-outs on environment. Therefore, the biggest challenge today in the early years of the new millennium is to see how best development can take place with the least amount of negative impact on the environment and at the same time create environment friendly, ecologically appropriate and energy saving and sustainable human settlements - sustainable not only for the current generation using the various natural resources but also sustainable to the emerging generations 25 years, 50 years, 75 years down the line for each new generation.

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Table 15: Stones: types, properties and uses

Stones	Properties					General uses
	Dens.	Water absorp.	Comp. Streng.	Resistance to		
				abrasion	acid	
Granite and basalt	2,500	0.04	140-240	VG	G	Decorative facing, flooring, walls, foundation, concrete slabs and tiles
Limestone				G	P	Aggregate for concrete and tiles, walls, special types for flooring
Low density	1,700	7.5	20-50			
High density	2,400	3.0	50-150			
Marble						
Compact & white	2,500	0.75	50-180	G	P	Flooring, decorative facing, slabs & tiles, aggregate for concrete tiles
With flaws & colors	2,500					
Sandstone						
Standard	2,200	5.0	25-150	G	VG	Aggregate, decorative facing slabs and tiles, walls
Quartzite	2,400	3.0				
Bluestone	2,550	1.0				
Slate	2,400	0.5	70-100	G	G	Roofing, fine aggregate, decorative facing
laterite	1,700	20	50-80	P	F	Walling blocks
Serphentine & Soapstone	1,500	1.5	80-100	F	F	Decorative facing hearths, fillers and ceramic

Table-16: Common types of stones for construction

Name of stone	Characteristics			General applications
	Texture	Appearance	colour	
Black granite	Fine to coarse Grained, polished	Uniform	Black	Veneer for exterior facing, aggregate for concrete and mastic asphalt
Other granite	Fine to coarse grained	Uniform	Various colours	Veneers, paving, monuments
Limestone	Fine grained	Uniform	White grey	Veneer for exterior facing, copings, aggregate for concrete and bitumen mastics
Marble	Fine grained, polished	Uniform	Wide range Of colours	Veneer for exterior or interior, monuments, table tops, flooring tiles, terrazzo floors, power in concrete tiles and in situ flooring
sandstone	Rough	Generally Uniform	White, grey, yellow, red	Veneer, interior finish, floor slabs & tiles, flagstone
slate	Smooth to rough	Generally Uniform	Blue, grey, green, reddish	Roof shingles, flagstones, black board slabs for exterior or interior in polished form

Table- 17: Chemical composition of stone

Constituent	Types of Stone			
	Granite	Limestone	Dolomite	Marble
SiO_2	68-76	10-13	10.4-13	0.01-0.02
Al_2O_3	13-17	0.3-0.7	0.025	0.05-0.06
Fl_2O_3	0.9-4.5	0.8-0.3	1-1.2	0.02-0.025
K_2O	2.5-5.5	-	-	-
Na_2O	2.0-6.5	-	-	-
CaO	1.5-3.5	54-55	27.5-28	55.8-56
MgO	-	0.5-0.7	-	0.25-0.35
Loss on ignition	1-2	-	-	0.25-0.35
CO_2	-	43-43.43.5	38.7-42	43.7-43.8
SO_3	-	0.05-0.07	0.05-0.07	

Policy Agenda for Affordable Urban Housing in India

*K.K. Pandey**

The year 2017 has a special significance in the context of Affordable housing and urban housing policy in India. The affordable housing, is the theme of Habitat Day for 2017 and the government of India is revising its first ever National Urban Housing and Habitat Policy – 2007 (NUHHP) exclusively meant for urban sector with a special mention to Affordable Housing in its preamble itself. Thirdly, housing as part of construction sector is recognized for its multiplier effect on household income and employment. It is noted that one direct employment in housing (as part of construction) involves eight indirect jobs elsewhere[1]. Another study indicates that income multiplier in housing investments is 3 and employment multiplier is 4[2]. It is also noted that employment generation in housing covers 99% of jobs in the informal sector. Therefore, housing is labour intensive and low income job oriented activity. This is further important in the context of decline in the employment elasticity of GDP as recorded in the recent years[3].On the other hand it is noted that urban housing supply has serious imbalances in its demand and access to a cross section of households.

Imbalance in Supply of Housing

Although 69 percent urban households in India own a house, 37 percent houses are stated to be in the category of one room meaning a high level of congestion covering 5 persons (on average household size of 4.9) per room. At the same time number of vacant houses being 11.09 million constitute a share equivalent to more than 50% of percent housing backlog[4]. At the same time 96% of backlog is constituted by low income population who have access to only 4% formal housing finance whereas more than 96% housing loans are extended to middle and high income category of households[5]. (Table 1)

Table 1: Housing status in urban areas

Housing backlog[6] (2012)	18.8 million
Ownership housing[7] (2011)	69 percent
Low income backlog[8]	96 percent
Housing with one room accommodation	37 percent
Flow of funds(formal finance) to low income Households[9] (National Housing Bank)	4 percent
Vacant Houses[10]	11.09 million

Data on housing backlog suggests that 97 percent cases require reconstruction, extension or upgradation in the existing / occupied residential areas. Urban housing backlog as estimated in 2012 is to the tune of 188 million DUs (Dwelling Units). It is especially important to note that 80 percent of this backlog is constituted by congestion among existing one room houses occupied by more than one married couple. Further, twelve percent backlog is constituted by dilapidated (obsolescent) houses and 5 percent backlog is caused by non-serviceable kutcha houses. (Table 2)

Table 2: Distribution of housing Backlog[11]

Households in	2012 (million)
Non-serviceable Kutcha Houses	0.99 (5%)
Obsolescent houses	2.27 (12%)
Congested houses requiring new houses	14.99 (80%)
Homeless condition	0.53 (3%)
Total	**18.78**

Successive programmes and schemes launched by GoI in recent decades have made efforts to minimize the imbalance. PMAY (Pradhan Mantri Avas Yojana) is most recent and significant step in

* Professor, Urban Management and Coordinator of Centre for Urban Studies, IIPA, New Delhi

this regard. The scheme has subsumed the existing programmes of Govt. of India as applied in 2015. (Box 1)

The Focus Areas for Revision of NUHHP 2007

In the light of imbalance in the supply of urban housing as above and the nature of backlog, the revision of the NUHHP-2007 has to give due cognizance to the factors causing imbalance in the supply of urban housing w.r.t. coverage to all urban areas, upgradation in a systematic and phased manner and rental housing. Successive initiatives have given specific attention towards increased supply of housing units. The policy should give special attention, accordingly, to convert the backlog into effective and realistic demand. The potential of existing areas is locked up in the low rise high density sprawled development[12].A large part of this development exists in the form of illegal land subdivision and unauthorized construction.

The Coverage of Affordable Housing

NUHHP while indicating its focus on 'Affordable Housing to All' with special emphasis on the economically weaker sections and low income sections should be able to cover all eligible segments of households. There are different estimates on affordability for respective income groups[13]. The affordability for low income was suggested with a size of 300-600 sq.ft. carpet area with four times Annual Gross Household Income (AGHI) and repayment capacity as 30 percent of monthly household income, the middle income was suggested to have a size of <1200 sq.ft along with five times AGHI and repayment capacity of 40 percent of monthly household income.

Box 1: Pradhan Mantri Avas Yojana

Pradhan Mantri Avas Yojana (2015) is the Government of India's pioneering scheme, administered by Ministry of Housing and Urban Affairs (MoHUA) to provide affordable housing for all. The scheme has four verticals namely in-situ rehabilitation of slums, credit-linked subsidy (6.5 percent interest), affordable housing in partnership (a subsidy of Rs.1,50,000 to Rs.2,50,000/- per unit for schemes developed in partnership with the private sector) and subsidies to the tune of INR 1,50,000 for housing/upgradation PMAY has urban and rural component. Rural part has subsumed Indira Avas Yojana whereas the Rajiv Awas Yojana for slum upgradation and redevelopment was subsumed by urban component which also included the Basic Services for the Urban Poor (BSUP) and Integrated Housing and Slum Development Program (IHSDP) components of the JNNURM (Jawaharlal Nehru National Urban Renewal Mission).

PMAY has given due flexibility to states to decide affordability in the local context. As overwhelming backlog is constituted by households from existing built up areas the size limit for affordability may be suitable liberalized. FSI/FAR relaxation should also be included in these areas to recover the cost on infrastructure/services and other habitat related inputs.

Who need support for Affordable Housing?

There is a little doubt that low income urban households need housing support in one form or other. Yet, affordability should be seen in a larger context of distribution of income and assets. As per Oxfam International study only one percent Indians own 58 percent assets and 58 Indians own assets equivalent to bottom 70 percent of population[14]. Therefore, it is the economy of 99 percent households which need suitable facilitation from the housing and related policies. The household saving from these 99 percent households have vast potential to improve liquidity and outreach of housing finance.

Inclusion of Habitat

At the same time, the inclusion of HABITAT in the national housing policies in India since the policy of 1998 has widened the scope of housing to cover services, infrastructure and livelihood opportunities[15]. The merger of two central ministries as Ministry for Housing and Urban Affairs (MoHUA) by Government of India in September 2017 is a positive step to converge efforts on habitat from the two ministries and have more synergy and consolidated approach on the issue. It should now more easily facilitate affordable housing with convergence of urban missions of Govt. of India.

Coverage of Urban Population

The policy should cover all urban households. It is noted that a large chunk urban households and settlements are not covered by official/ census classification to identify urban areas. Similarly, the areas classified as urban do not have city governments and are not treated as urban by governance system[16] (Box 2). Efforts should be made to revisit the classification method and procedure to identify all eligible areas within the cat-

Box 2: Underassessment of Urbanisation

Although 31.2 percent population live in urban areas as per census 2011, only 26 percent is governed by urban local bodies. The census and administrative coverage of urban areas vary from state to state. On the whole almost half (3891) urban centres are still governed by Panchayat-raj Institutions.

Mid–term Economic Survey of GoI has examined the urbanization level and expressed the need to revisit the method due to underestimation of urban population as compared to the classification used by other countries and related norms. It may be observed that population size as officially recorded is significantly low as compared to other methods of classification. The current size is estimated to be in a range of 47 to 65 percent. However, GHSL data of European Union appears to be more realistic than the population criterion alone. Yet, the point of underestimation is convincing. The mid-term Economic Survey released in early August 2017 giving due cognizance to comparable factors expressed a need to reexamine the census method in the light of growing importance of cities and towns in the economic development, productivity and investment promotion.

The midterm Economic Survey released in August 2017 of Government of India while acknowledging the variation in the size has also indicated the gap between the administrative city and the physical city. Out of nearly 8000 urban centres, barely half of them are covered by city governments and remaining by Panchayat raj institutions. As against the population size of 31.2 percent only 26 percent is governed by three types of Urban Local Bodies.

egory of urban and create statutory towns (city governments)[17]. Housing plans should be prepared to include entire city region and not the municipal jurisdiction only. Suitable institutional mechanism involving city government at a centre place should be evolved to capture the needs of entire urban population.

Rental housing

Government of India is already planning to bring tenancy law and model rent Control Act[18]**.** The Union Minister of State-Independent Charge (MoS I/C) indicated that interest of tenants and landlords would be secured with a view to unlock the vacant houses (11.09 million) for use of urban households. It should also pave way for reconstruction and upward growth of core city areas.

There is enormous scope for employee housing which is currently used in a limited sense. This needs to be taken up for suitable concessions and incentives to employers and employees.

Increased Supply of Affordable Housing

The government of India is also planning stimulus package to restore rapid pace of economic development. Housing would be an important component of such package. Indication was given by Honb'le MoS I/C on 21st September that Private sector would enjoy interest rate (credit linked) subsidy as planned in PMAY for individual buyers. Ease of doing business in relation to permissions and approvals would be extended to all metros in line with Delhi and Mumbai[19].

In this regard housing should not be seen in isolation from city region. Housing potential of city region as a whole should be assessed. In this connection suitable mechanism needs to be drawn to prepare housing plan for administrative city, physical city and city region. These plans should also include mobility and connectivity to integrate the region for economic activities and social interaction. Government of India is already planning expansion of urban housing to the helmets located in the surrounding areas[20]. It should be seen in a wider sense of city region and expansion of urban areas as per modified classification.

Decadal Feedback

It is also important to give due cognizance to the sectoral development occurred during last ten years since inception of the NUHHP-2007. Rio+20 gave us the focus on environment, climate change along with poverty alleviation. The adoption of UN Sustainable Development Goals (UNSDGs) -2015 and Habitat III – 2016 have drawn a global agenda along with country specific inputs. GoI has also prepared its national report and presented a commitment in the form of follow up actions[21] (Box 3). These need to be included in the form of inter-governmental agenda for the policy. Similarly the commitments from government of India under the urban sector missions of GoI[22] are equally important to have mutual feedback and support. These include:

- Pan city development, Green Field development, Retrofitting under smart cities.
- Open Defecation Free (ODF) status, Area Development and

ODF+(waste collection) and ODF++(waste disposal) from SBM.(Swachh Bharat Mission)

- Credit Linked Subsidy
- Income generation from NULM (National Urban Livelihood Mission)
- Financing outreach through PMJDY (Pradhan Mantri Jandhan Yojana)
- Skill India and Start up India Mission for promotion of economic base along with housing.
- Urban Housing
- Actions on disaster (manmade and natural) and environmental improvement (Greenhouse gas emissions and PM2.5) should also be given due attention.

As the majority of housing backlog needs to be provided in the existing built up areas the above convergence is essential. The policy has to distinguish the two aspects direct shelter support and Habitat areas (other than four walls and a roof). Such a distinction would also include Indian commitment to Habitat III (Box 3) and involve actions by local institutions and intergovernmental commitments and support. These commitments include specific action areas such as (i) economic growth and productivity, (ii) improving quality of life, (iii) inclusive development, and (iv) sustainability and issues of climate change.

Follow Up

The government of India is giving due cognizance to the importance of housing to sustain our economic growth and promote employment elasticity of Income. Hon'ble MoS I/C MoHUA has rightly announced the government intention to encourage private sector and liberalise rent control regime. It will improve the liquidity in the housing finance and accelerate supply of affordable housing. Policy response towards promotion of affordable housing in India, therefore, has to cover:

- Include Habitat related inputs in the NUHHP with special reference to Poverty, disaster management (manmade and natural) and climate change.
- Distinguish between shelter construction and habitat inputs.
- Commitment of GoI for habitat III should be included in the policy agenda.
- Unlock the supply of land and finance for construction/upgradation of housing of units.
- Ensure secure title to existing residential/built up areas to enable reconstruction or upgradation in these pockets of land. Unauthorised colonies and illegal land subdivision would require specific attention.
- Include all sections up to middle income group in the stimulus package through concession and incentives.
- As the overwhelming majority of backlog is constituted by households living in existing areas the size limit for affordability may be relaxed. FSI/FAR relaxation should also be included in these areas to recover the cost on infrastructure/services and other habitat related inputs.
- Revisit the classification method of Census of India to cover all eligible urban settlements to expand affordable housing.
- Prepare a suitable housing plan for city region including the areas outside municipal jurisdiction.
- Take up capacity building of ULBs to prepare local action plan for affordable housing,
- Rationalise the data on land and properties through compulsory registration process,
- Create enabling environment for rental housing including employee housing through tax concessions, incentive and modifications in the respective Rent Control Act.

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Box 3: National Commitment by Government of India for Habitat 3

Economic Growth and Productivity	
• Fully planned and sustainable human settlements • High travel speed, above 30 kmph peak time • Well-distributed business district centres	• Intensive use of technology/innovations • E-governance • Smart grid • Normative - norms/ self-declaration/ approvals of buildings/ town layouts
Improving Quality of Life	**Inclusive Development**
• 100 percent sanitation • Well-developed public facilities • Easy access to public utilities and services	• Composite living representing socio-economic population dynamics – inclusive development • Adequate and affordable housing for urban poor and senior citizens
Sustainability and Issues of Climate Change	
• 60-90 percent population to travel by public transport • Dominant mode of travel does not emit pollution in immediate environment • Local travel, E-rickshaw, walking, etc. for last mile connectivity • Street light LED with dimmer, low consumption, almanac micro-processor controlled • Rainwater harvesting in all roads, streets and buildings • Barrier-free pedestrian pathways and bicycle-ways • Natural drainage pattern, climate change, cloud burst	• Waste-water treatment, on-site and re-use in immediate surroundings for gardening, sprinklers for dust control, etc. • Reclaiming water bodies • Bringing water use to half from standard use • Cut down electricity consumption to 50 percent level than normal use and 50 percent generation from non-conventional sources • Waste (collection 100 percent) to electricity • RCC roads, supported by pipes, integrated with future expansion plans, no digging • Disaster preparedness
Improving Quality of Life	**Improving Quality of Life**
• High-security streets and buildings by CCTV • Crime-free society and access to social justice and gender equity	• Full of greenery/ plantation, bamboo and other suitable trees • Green and barrier-free buildings

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Demonstration Housing Projects
using Emerging Technologies

BMTPC has identified, evaluated and certified 16 new construction systems for mass housing which facilitate faster delivery of quality, sustainable and safe houses. For its field level application, BMTPC has initiated construction of model demonstration housing projects in Andhra Pradesh, Odisha, Telangana, Bihar & Uttar Pradesh. These projects are aimed to spread awareness and disseminate new emerging systems across India. The demonstration housing project at Nellore, Andhra Pradesh has been completed. The details of other projects are as given below:

Demonstration Housing Project at Bhubaneswar, Odisha

Housing & Urban Development Department, Government of Odisha allotted 0.43 acres land for construction of Demonstration Houses with Expanded Polystyrene Core Panel System (EPS) Technology. Based on the discussion held with the officials of Bhubaneswar Development Authority (BDA), the plan, sections, layout plan of Demonstration Housing Project was finalised. The demonstration housing Project has one block having 32 DU in G+3 configuration. The carpet area of the unit is 23.09 sq mt. (248.45 sq.ft) having living room, cooking space, bed room, Bath and W.C. as per the State Govt. typed design. The project also includes the on-site infrastructure work such as construction of pathways, boundary wall, water supply work, horticulture work, drainage & disposal and external electrification using solar panels etc. At the time of reporting, the finishing work of the DUs is going on.

Demonstration Housing Project at Bhubaneswar, Odisha

Demonstration Housing Project at Aurangabad Jagir, Lucknow

State Urban Development Agency (SUDA), Lucknow has identified 0.385 hectare of land at Aurangabad Jagir, Tehsil Sarojini Nagar, Lucknow for undertaking the Demonstration Housing Project. Based on the discussions held with the officials of SUDA, the Plan, Sections and Layout Plan of Demonstration Housing Project was prepared by BMTPC and was approved by SUDA. Five blocks for 40 Demonstration Houses (G+1) having carpet area of 26.40 sq.mt. and covered area of each DU is 40.31 sq.mt. with emerging technology Stay in Place EPS based Double Walled Panel System are being constructed at the site. The onsite infrastructure development work comprises of internal and external roads & pavements, Septic Tank, water supply, sewerage, external electrification, Drainage, Landscaping, Boundary Wall, Bore well, UGT, Transformer, etc.

Shri Rajnath Singh, Hon'ble Home Minister laid the Foundation Stone of Demonstration Housing Project at Lucknow, Uttar Pradesh through video conferencing on January 3, 2017 from New Delhi. The programme was attended by more than 200 local officials from State Govt. and general public. The for ground floor roof slab for two blocks have been completed. The erection of the wall panels for

Shri Rajnath Singh, Hon'ble Home Minister laid the Foundation Stone of Demonstration Housing Project at Lucknow, Uttar Pradesh, U.P. through video conferencing on January 3, 2017

Demonstration Housing Project at Aurangabad Jagir, Lucknow, U.P.

super structure of third & fourth blocks has also been complete and erection of wall panels for fifth Block is under progress.

Demonstration Housing Project at Biharshariff, Bihar

The Govt. of Bihar has designated Biharsharif Nagar Nigam as nodal agency for the demonstration project. The site for the demonstration project in Biharsharif was allotted for the purpose by local administration. BMTPC visited the site and based on the interaction & consultation with Biharsharif Nagar Nigam, the housing technology has been identified and building drawings have been finalized.

The demonstration houses comprising of 36 DUs (G+2) are being constructed using Structural Stay-in-Place CR Steel specially Designed Formwork System. Each DU comprises of multi-purpose room, a bed room, kitchen, separate w.c & bathroom. The carpet area of DU is 29.67 sq.mt. (319.25 sq.ft) and built-up area of DU including area of common staircase is 45.54 sq.mt. (490.0 sq. ft.). The infrastructure work includes internal road, pathways, boundary wall, septic tank, external electrification and water supply work, horticulture work, drainage & disposal, etc. After completion of work upto plinth level for two blocks (36 DUs), erection of wall panels and slab shuttering for block 2 (5 DUs)

Demonstration Housing Project at Biharshariff, Bihar

has been completed. The casting of concrete in this block is under way. The erection of wall panels for block 1 (7 DUs) is under progress.

Demonstration Housing Project at Hyderabad, Telangana

Telengana State Housing Corporation Limited (TSHCL), Hyderabad has identified 1085 sq.mts. of land at Nirmithi Kendra, Gachibowli, Hyderabad for undertaking the Demonstration Housing Project. After inspection, the proposed site was found suitable for construction of demonstration houses. Based on the discussions held with the officials of TSHCL, the Plan, Sections and Layout Plan of Demonstration Housing Project was prepared by BMTPC and was approved by TSHCL. In order to demonstrate different emerging technologies, the Council is constructing two blocks for 32 Demonstration Houses (G+3) using two different technologies i.e (i) Monolithic construction with structural stay in place CR steel specially designed formwork system (Coffor) (16 houses) and (ii) Light Gauge Steel Framed Structure (16 houses). The DUs have carpet area of 38.74 & 39.50 sq.mt. and covered area of DU is 53.18 & 53.10 sq.mt. Each DU comprises of two bedrooms, multi-purpose room, kitchen, two WC & bathroom. The onsite infrastructure development like internal road, pathways, Septic tank, external electrification and water supply work, horticulture work, drainage & disposal, etc. are also part of the project. The foundation work upto plinth Level for the project has been completed. The erection of wall panels (for 16 DU) using Coffer technology is under progress.

Apart from the above, BMTPC has also received request from Govts. of Uttarakhand, Tamil Nadu, Assam, Punjab, Jharkhand, J&K, Kerala & Manipur for undertaking DHPs in their respective States.

Demonstration Housing Project at Hyderabad, Telangana

Manufactured Sand: A Foreseeable Alternative to River Sand

*S. K. Singh** *S. K. Kirthika***

Abstract

The impending issues of sustainability and stringent guidelines of National Green Tribunal (NGT) mandates construction industry to bring perceptible changes in use of conventional building materials without compromising the quality of construction. Concrete is one of the ubiquitous composite conventional building material in which natural aggregates play an important role. Natural sand is being utilized as fine aggregate in concrete for more than centuries. However, increase in demand, depletion of natural sand and ban on sand mining by Hon'ble Supreme court/ NGT have necessitated researchers to do R & D on alternate to natural sand i.e. manufactured sand. The studies on manufactured sand have shown the possibility of its utilization in construction as replacement of natural sand. Manufactured sands can be produced by crushing rock deposits or old building stock as fine aggregate that is generally found more angular and has rough surface texture. Manufactured sand can be classified as Natural crushed rock sand, industrial by-products and recycled fine aggregates. Manufactured sands are used either full or partial replacement of natural sand (NS) in mortar or concrete. The paper presents gives an insight into manufactured sand and its use in construction industry. The paper also attempts to elaborate the reason why manufactured sand is a potential construction material for future.

Keywords: Manufactured sand, natural crushed rock sand, recycled fine aggregate, river sand, concrete

Introduction

The unprecedented increase in urbanization and industrialization puts pressure on conventional building materials which are based on finite natural resources. Further, in view of Paris agreement and India's commitment to Climate change, the problems related to environmental imbalance and GHG emissions are more evident in our construction sector. Further, there is always a difficulty in acquiring good quality of natural material especially river sand which is used as fine aggregate in concrete. Thus, it is logical to use sustainable approaches to make a resource efficient concrete. Concrete can be made as a sustainable material right from raw material production to demolition of buildings [1, 2, 3]. It is a composite material, consisting of binding materials, aggregates, water and admixtures. Among these ingredients, aggregates play a vital role which occupies about 60–75% total volume of concrete [2, 3] and whereas sand occupies about 35% of aggregate volume. It is expected that the demand of raw materials for concrete will be doubled in the next two to three decades with the present rate of consumption [3, 4]. Rapid extraction of sand from river bed or quarries causing environmental problems is unsustainable practice and its short supply make it a very costly material. Therefore, a suitable alternative which is eco-friendly and sustainable to replace natural sand is call of the day [4]. Manufactured sand (MS) in general is produced or artificially made. The researchers have started working with the properties of concrete using manufactured sand as fine aggregate over past few years. This sand is used either full or partial

* Senior Principal Scientist, CSIR-Central Building Research Institute, Roorkee, E-mail: sksingh_cbri@yahoo.co.in
** PhD Student, AcSIR-CSIR-Central Building Research Institute, Roorkee, E-mail: sakurakirthi@gmail.com

replacement of natural sand in mortar or concrete. Even offshore sand and dune sand are used in concrete in many countries such as UK, Sri Lanka, Continental Europe, Saudi and Singapore [1-4].

The use of natural crushed rock sand (CRS) in Portland cement concrete has significantly increased over last 25 years, especially in areas where natural sands are scarce [5, 6]. Cortes *et al.* [5] found that a larger volume of paste of cement mortar will be required to attain adequate flow-ability and strength when angular CRS is used instead of natural round aggregates of the same grain size distribution. Although the cost of CRS is relatively more as compared to natural sand, it can be used as an alternative to manufactured self-compacting concrete (SCC) with natural sand with 25-60 MPa compressive strength [4]. Increased environmental awareness concerning potential hazardous effects, the recycling or utilization of industrial by-products have also become an attractive alternative to disposal. Noufal *et al.* [7] found that 30% replacement of river sand with iron slag fine aggregate is found effective in concrete. Similarly Saha *et al.* [8] found that the compressive strength of the mortar specimens increased with addition of ferronickel slags (FNS) up to 50% replacement in concrete and then decreased further increase in FNS. The use of C&D as coarse and fine aggregates in concrete production is a logical step with both economic and environmental benefits that has been growing in the last two decades [9-11]. Many researchers have found 30% replacement of river sand (RS) with recycled fine aggregate (RFA) is more suitable [10]. However, utilizing of RFA produces low density concrete and RFA increases mechanical properties of the concrete with appropriate proportion of superplasticizer. Kou *et al.* [11], found that 10% replacement of silica fumes with cement in the RFA concrete increases both mechanical and durability properties of the concrete. In addition, the incorporation of recycled concrete fine aggregate significantly increase the shrinkage and creep deformation [10, 11].

In this paper, a brief review of the work done by the researchers on different types of manufactured sand in concrete is reported. Although, few researchers have worked in MS, but there are more studies only on CRS, hence there is a need to study other suitable MS in concrete as fine aggregate. In addition characterization and optimization of different types of MS in concrete has to be done so that it can be utilized commercially. A Very few applications of MS can be seen in the construction industry, this is because of less knowledge about the effectiveness of the different types of MS in concrete and how it makes the concrete sustainable. Through this paper, the idea of utilizing MS which is an inevitable replacement to river sand in construction industry is being envisaged.

Need for Manufactured Sand

There are various sources for the natural sand that can be used in concrete as fine aggregate such as river sand, marine sand, quarry dust and dune sand. Among which, river sand is widely used in construction industry. These natural sand have their own demerits like marine sand have high percentage of salt, quarry sand have large amount of dust in them and because of the loosely packed soil particles dune sand are unfit to be used in the concrete. Although these sand have demerits, they are still used extensively because of which there is a huge depletion of natural sand. In addition, using these sand of-late cause environmental imbalance like change in river course, disappearing of beaches, contamination of ground water, killing of flora & fauna etc. as shown in Fig 1. Therefore, various steps are taken by different organizations to restrict the exploitation of these natural resources. For example, in National Green Tribunal (NGT) report 2016 [12], it is reported that there is huge loss of sand mining about 1,611 crores due to rampant illegal sand mining.

Fig. 1: Problems leading to environmental imbalance

Likewise, MoEF & Supreme Court of India has also given various directives to ban the sand mining and other illegal activities in order to protect these natural sand. Therefore, these issues have forced the construction industry to use alternative materials like manufactured sand as fine aggregate in concrete without compromising the quality of construction.

Manufactured Sand

Manufactured sand can be defined as fine aggregate, manufactured from other than natural sources, by processing materials, using thermal or other process such as separation, washing, crushing and scrubbing [13]. Over past few years various researchers have studied that natural crushed rock sand, copper slag, waste foundry sand, coal ash, recycle sand etc. can also be used in concrete as fine aggregate [3, 14-17].

Natural Crushed Rock Sand (CRS)

Natural crushed rock sand are produced from crushing rocks, which creates grains with distinctive particle shape, that depend on the parent rock composition, fracture mode, crushing process. CRS are generally angular and rough in nature. However, CRS contains considerable amount of stone dust in them. All over the world in all the standards natural crushed rock sand is considered as manufactured sand and particles finer than 75 µm shall not exceed 15% in CRS [13]. The properties of the CRS varies based on their lithology and geographical locations. The sources for CRS are generally crushing the natural rocks like diorite, metamorphic siltstone, granite, limestone, sandstone, feldspathic quartzite etc. [18, 19]. In last ten years, there have been investigations on various types of CRS i.e. in characterization of CRS, properties of CRS in mortar, concrete and SCC. In general from all literature studies, it was found that CRS have more fine particles as compared to NS, so the workability of concrete mixes decreases for which adequate gradation of CRS, dosages of superplasticizer, proper mixing approach and particle package density model is needed. Although, it absorbs more water, concrete with CRS have better shrinkage and durability properties.

Natural crushed rock sand are generally produced after drilling and blasting of rock deposits and it is transported to primary crushers where these rocks are crushed to produce coarse aggregates after screening [20]. The others are sent to secondary crushers where they are further crushed to produce fine aggregates from them. This is usually done by impact crushers or VSI crushers. The fine grinding process is either dry or wet. Dry process is highly economical but have high possibility of ultra-fines which may cause air pollution [20]. Therefore, a wet process is used. The water used is generally recycled and again used in process. The sludge obtained is removed separately and utilized to make lightweight products. Therefore, the obtained finished product (MS) is then taken and transported. A schematic description of production is given in the Fig. 2. The major advantage of this method is sand obtained after crushing is sustainable, eco-friendly and Vaastu friendly.

Industrial By-products

The generation of industrial waste is increasing day by day due to industrialization. It is reported that only 15% of these waste are used as resource material whereas, the remaining are just dumped as landfill [21, 22]. Dumping these waste in landfills also cause environmental imbalance. India is nowadays facing not only the problem of environmental imbalance, it is also facing the non-availability of land for landfills and increase in cost of the landfill. Thus, it leads to huge problem for various industries and choice of using these waste products as an alternative source. The initial studies have reported on utilization of industrial

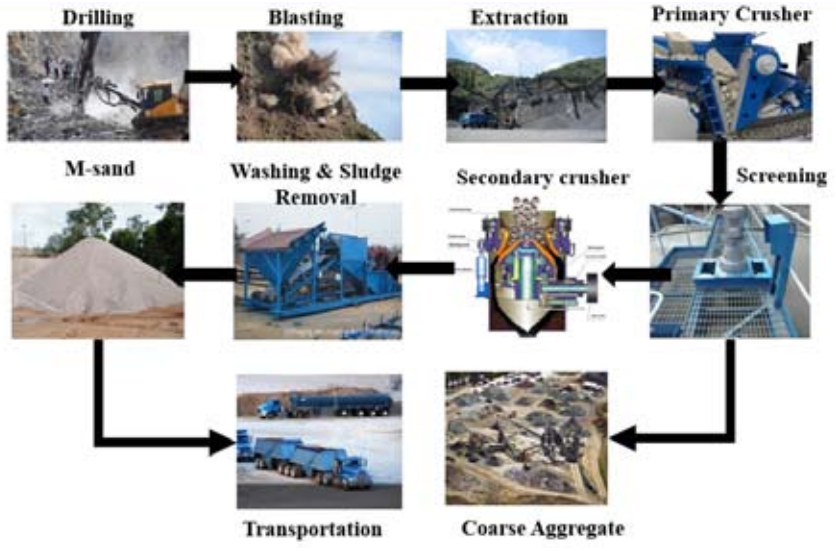

Fig. 2: Schematic production process of natural crushed rock sand

by-products such as blast furnace slag, waste foundry sand (WFS), coal bottom ash (CBA), cement kiln dust (CKD) and wood ash (WA) as fine aggregate in concrete [14, 22-23]. The Indian standard has also allowed copper slag, iron slag and steel slag are also better option in concrete as fine aggregate [13]. The major advantage of utilizing these industrial by-products unlike crushed rock sand, is that no further process is needed and it is energy saving material. However, the problem in industrial by-product utilization is it contains high fines which makes concrete more susceptible to shrinkage problems and also workability of the concrete gets affected. Various steps are taken to remove these ultrafine particles like air screening, Hydrocyclone process etc.

Industrial by-products are produced from various industries right from iron mills, steel mills, thermal power plants, oil-fuel industries etc. A typical production of bottom ash or boiler ash production from coal thermal power plant is shown in the Fig 3.

During this process, a collection of residuals produced during the combustion of coal called coal ash are also collected and used [24]. Likewise each industrial by-products are further used to overcome the problem of landfills and other environmental issues.

Recycled Fine Aggregate (RFA)

The recycled fine aggregate is also used as MS in concrete. Recycled aggregates are produced from the re-processing of mineral waste materials with the largest source from C&D waste [9-11 & 25]. The coarse portion of the recycled aggregates has been used as a replacement to natural coarse aggregates for concrete production. The benefits and drawbacks of using recycled coarse aggregates in concrete are well understood and extensively documented [9, 10]. However, nowadays the trend of replacing natural sand with recycled fine aggregate (RFA) is also gaining importance. Large-scale recycling of demolished concrete will contribute not only to the solution of a growing waste disposal problem, but, it will also help in conserving natural sand. Recycled concrete fine aggregate, recycled brick fine aggregate, recycled glass fine aggregate, recycled bitumen aggregate etc. are some of the major used recycled fine aggregate in construction industry [2]. Based on the application, the type of recycled fine aggregate to be used varies, for example in recycled bitumen aggregate are used in making pavements etc. In addition, experimental investigations by various researchers on RFA found that it requires more high range water reducer admixtures than CRS because of their high fineness.

Generally, RFA from C&D waste of building consists of concrete rubble, bricks, tiles, dust, paper, cardboards, metals, organics, cement paste adherence etc. in which concrete rubble is usually considered to be largest proportion of C&D waste. It is very important to remove those impurities from the sand, otherwise it will reduce the quality and consumer perception of recycled fine aggregate [27]. A schematic production process of recycled fine aggregate is given in the Fig. 4.

Experimental Investigations

Experimental investigations on characterisation of crushed granite sand (CGS) and river sand, mechanical properties like compressive strength was carried out.

Physical Properties

The basic physical comparison between river sand and CGS was done which is shown in the Table 1.

Sieve Analysis

Generally, river sand is classified as Zone I, Zone II, Zone III and Zone IV (i.e. Coarser to Finer). Gradation is made in accordance with the usage of the sand. There are

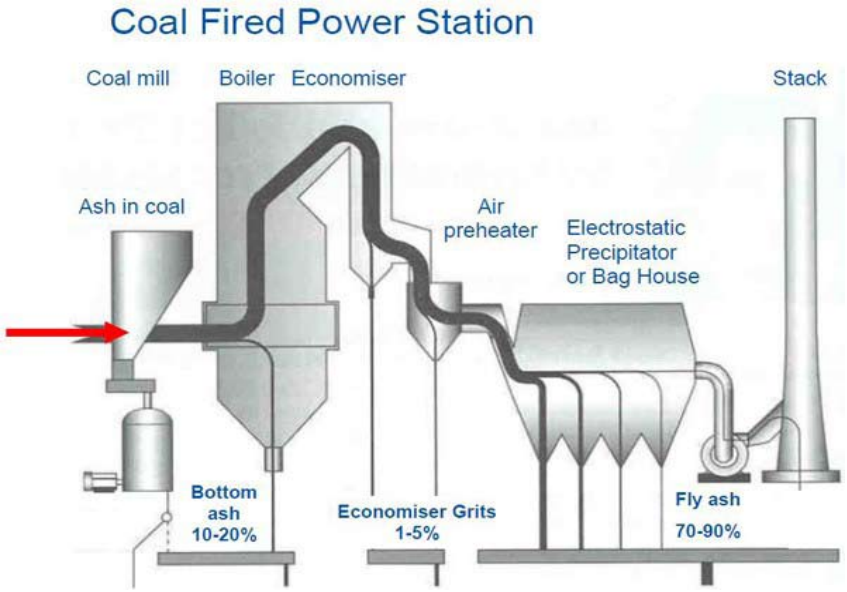

Fig. 3: Schematic production of bottom ash from coal thermal power station [24]

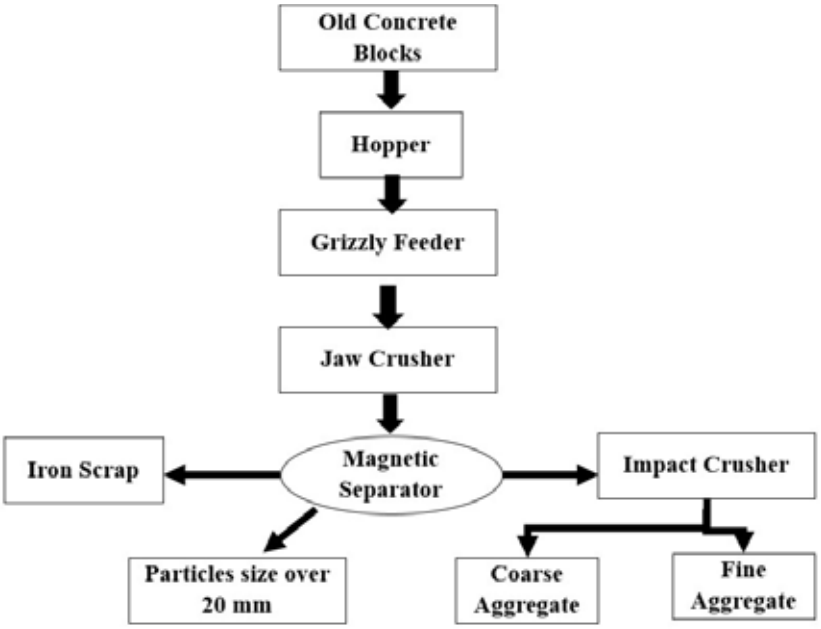

Fig. 4: Schematic production of recycled fine aggregate

Table 1: Physical Properties of the River sand and CGS

Properties	River Sand	Crushed Granite Sand
Appearance	Dark Grey	Grey
Shape	Round	Angular
Texture	Smooth	Rough
Water Absorption	1.3%	2.0%
Specific Gravity	2.64	2.58
Samples		

testing sieves, consists of 4.75mm, 2.36mm, 1.183mm, 600microns, 300 microns, 150 microns and a pan. Sieve analysis of the river sand and manufactured sand was carried out as per IS 383: 2016. Based on the percentage passing in 600 micron sieve, gradation of the sand is done. Table 2 shows the comparative sieve analysis results between river sand and CGS.

It was observed that the fineness modulus of river sand was 2.31 and that of CGS was 2.60. In addition with the percentage passing at 600 µm CGS falls under zone II confirming from IS 383:2016. Fig. 5 shows the sieve analysis graph drawn for CGS and river sand.

Table 2: Sieve Analysis

IS Sieve	% of Passing River Sand	% of Passing CGS
4.75 mm	99.60	100.00
2.36 mm	98.77	90.70
1.18 mm	76.67	66.20
600 µm	57.70	39.80
300 µm	32.28	25.50
150 µm	03.92	09.90
75 µm	02.00	10.00

Mix Proportioning

Concrete of M30 grade was proportioned in accordance with the Indian standard IS: 10262-2009. Ordinary Portland cement (OPC) with 43 grade confirming to IS: 269, 2015 and Zone II river sand with 2.69 specific gravity and fineness modulus of 2.31 confirming to IS: 383, 2016 was used in this present experimental investigation. Superplasticizer confirming to IS: 9103, 1999 which is a third generation carboxylic ether was used to increase the workability of the concrete. The mix proportion adapted here is given in Table 3.

Compressive Strength

Compressive strength tests were carried as per IS: 516, 1959. Test was conducted for concrete cubes after 3, 7 and 28 days of curing respectively in Universal Testing Machine (UTM) of capacity 1000 kN and with 0.5 mm/min loading rate. Compressive strength obtained by concrete with CGS was compared with control concrete. Compressive strength of a par-

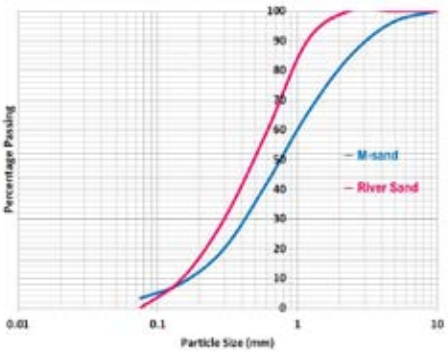

Fig. 5: Sieve analysis of CGS and river sand

Table 3: Mix proportion used for M30 grade concrete

Material	Cement (kg/m³)	Fine aggregate (kg/m³)	Coarse aggregate (kg/m³)		Water (kg/m³)	Superplasticizer Dosage (kg/m³)
			10 mm	20 mm		
RS	380	720	729.6	486	171	1.9
CGS	380	720	729.6	486	190	0.5

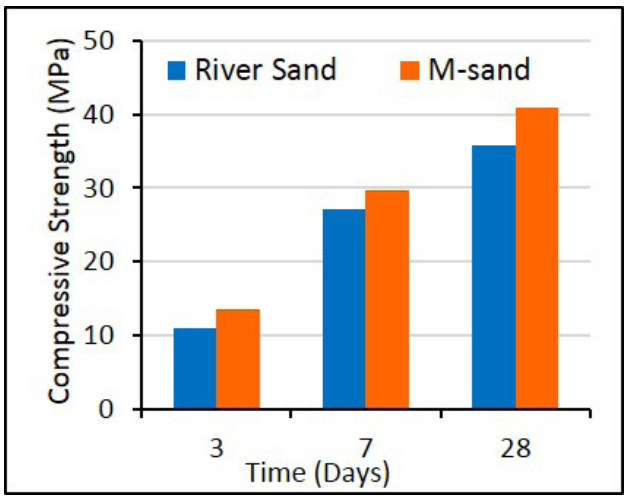

Fig. 6: Compressive strength of the CGS concrete and control concrete

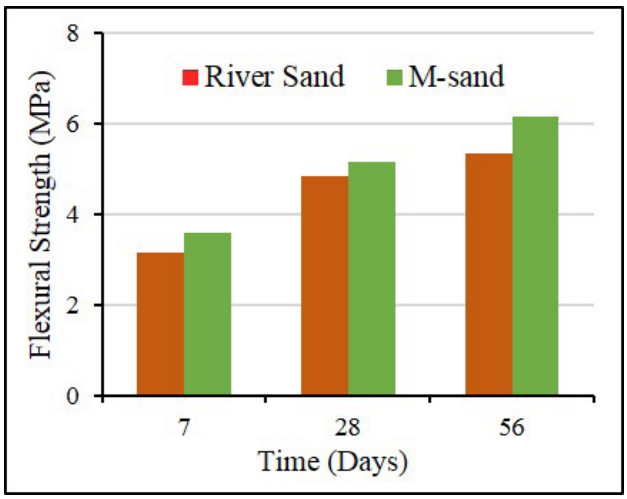

Fig. 7: Flexural strength of the CGS concrete and control concrete

ticular specimen is calculated with following formula:

f_{ck}=P/A .....(3)

Where,

f_{ck} – Compressive strength (N/mm²)

P – Ultimate Load (N)

A – Cross sectional area (mm²)

It was observed that the concrete with CGS showed better compressive strength when compared with control concrete. It was found the CGS concrete have 14.08% higher strength than control concrete after 28 days of curing. In addition almost 22.5% strength higher at early stage (3 days) of curing. Fig. 6 shows the compressive strength of the CGS concrete and control concrete.

Flexural Strength

Flexural tensile strength or modulus of rupture of concrete has been determined by applying the failure load on prismatic specimen after 7, 28 and 56 days of curing in UTM under four point loading and with rate of 0.5 mm/min. The location of the crack was also checked, in case if the cracks had been appeared away from mid span, then the distance of the crack from the end were noted. The flexural strength of the specimen is expressed as the modulus of rupture f_{cr}, which is stated as below:

$$f_{cr} = \frac{Pl}{bd^2}\frac{Pl}{bd^2} \quad \text{.....(5)}$$

Where,

f_{cr}= Flexural strength (MPa),

b = Measured width of the specimen (mm)

d = Measured depth of the specimen at the point of failure (mm)

l = Length of the span on which the specimen was support (mm)

P = Maximum applied load (N).

The flexural strength for the control concrete and CGS concrete is shown in the Fig. 7. It was observed that the flexural strength of the CGS concrete was 15% higher than the control concrete after 56 days curing.

Summary

The experimental investigations carried out on concrete with CGS manufactured sand showed better quality and better properties than control concrete. Sieve analysis results showed that CGS also falls under zone II category as per IS 383: 2016. In addition nearly 14.08% higher compressive strength was observed than control concrete. The flexural strength of the CGS concrete was also found to be higher (15%) than control concrete after 56 days curing.

Based on the literature, there is possibility to replace natural sand

with manufactured sand. However, there is a need to optimize the effective replacement of NS with MS in concrete by characterizing different types of MS in concrete. The major gaps from different studies are limited study on characterization and optimization of manufactured sand in concrete, there is no standard/ guidelines for mix proportioning of concrete, no life cycle cost analysis including CO_2 emission for sustainable structural design are made. Therefore, a detail study on different types of MS is a topic of further research in order to accept the replacement material for NS with compromising properties of concrete. Nevertheless, manufactured sand is certainly a viable emerging alternative to river sand which is scarce.

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Capacity Building Programme on Good Construction Practices including Emerging Technologies for Housing

In order to build capacities, one of the priority area for BMTPC is to impart training to professionals on regular basis. The purpose of these programmes is to update the Engineers & Architects at ULB & State level in the area of Quality Control and Good Construction Practices in housing projects and to introduce emerging technologies which may be useful for mass housing projects in the States. Some of the programmes are listed here:

Sensitization Programme at Thiruvananthapuram,Kerala on August 3, 2017

Sensitization Programme at Gandhinagar, Gujarat on February 9, 2017

Sensitization Programme at Bhubaneshwar, Odisha on May 15, 2017

- "Training on Good Engineering Practices including Disaster resistant aspects in Construction" to ULB/State engineers & construction professionals from North Eastern areas during the Regional Workshop on PMAY-HFA (Urban) for North Eastern States & UTs was held on 20-21 January, 2017 at Agartala, Tripura. Hands-on Training Prgramme for Masons was also conducted on January 20, 2017 alongside the Workshop wherein 44 masons from 3 ULBs of Tripura were imparted training.
- Sensitization Programme including training to beneficiaries on Quality and Disaster-resistant aspects was conducted in Bihar Sharif, Bihar on 13 February 2017, for the beneficiaries engaged in construction of their houses sanctioned under Housing for All. The masons involved in the construction and supervising engineers participated in the programme, making total participants as 80.
- Organized Sensitization Programmes at Gandhinagar, Gujarat on February 9, 2017; Port Blair, Andaman & Nicobar Islands on February 23, 2017; Bhubaneshwar, Odisha on May 15, 2017 and Thiruvananthapuram, Kerala on August 3, 2017. These programmes were attended by State Govt. engineers, architects and other officials.

Knowing your client: Residents of Rental Housing

*Mahua Mukherjee, PhD.**

Rental Housing, both formal and informal, constitutes a large component of urban shelter in India; as per Census 2011, over 27% of urban residents of the country stays in rental housing. India's urban housing sector experiences huge shelter shortage vis-à-vis stunning stock of vacant ones (11.09 million houses, as per Census 2011) simultaneously. Introduction of apt legislations may encourage the owners to convert urban land and rent out for steady income.

To outreach urban India's large informal workforce with quality living provisions is difficult. The migrant labours pay heavy house rent (approximately 30% of their monthly income) (MoHUPA, 2015) without any incentives of quality living. Overcrowded spaces with severely stressed water and sanitation services, lead them to stay in slum like situations. In absence of affordable rental housing options, they don't bring their families to their rented accommodation; this can result into unbalanced gender equation and raises concern for social safety. Even if they are accompanied by their families, women and children are forced to live in overcrowded houses. Solution like the 'Social Rental Housing (SRH)', owned and managed by the government, local authorities, public sector undertakings or any non-profit organizations may be the apt provision for below poverty level migrant workforce. This is probably going to be the most important social infrastructure to bring best possible change for large informal urban workforce.

It is very important to 'Know Your Client (KYC)', where 'you' are the local government, the landlord, the service providers, the housing experts, the housing finance companies like banks and the non-government organizations. A recent ethnographic survey of an authorized yet unorganized neighbourhood of Gurgaon is a real-time shock for the author to realize that the migrant labours are hard to track as tenant. The landlords are not able or unwilling to provide any exact numbers of their tenants, their names or photos; rental agreement on paper does not exist there. The outsider migrant labours outnumber the local people listed in voter list atleast by 10 to 20 times. This reality continues as the landlords can earn easy, steady income without going outside their neighbourhood. They don't even pay attention to their own substandard physical living quality. Additionally, the unwritten norm that the tenants need to purchase regular household items from respective landlords' shops only, that too in higher price, adds to the easy kitty of landlords.

Poor quality infrastructure service is not the only thing to worry. Addiction to liquor, limited scope for education, vocational training and sports activity, lack of concern to environmental (socio-physical) degradation, inactions to resist degradation, not-so-encouraging environment for women to join workforce of different cadre etc. are long list for aspects to improve. Education and training in housing study in technical and architectural schools shall match the logic of real-time informal rental housing scenario. Learning from the 'clients', exploring their needs, preferences, perception about solutions hold key for successful SRH intervention.

These are the neighbourhoods

* Associate Professor, Department of Architecture & Planning, IIT Roorkee, INDIA, Email: mahuafap@iitr.ac.in

which require the smart development badly. Emergency action plan for fully equipped studio apartments with dual pipe plumbing for basic potable water service and recycled water for WCs, garbage to energy, intelligent lighting system, smart façade to generate solar energy, CCTV-enabled surveillance of staircase/ lift, other public areas including streets, monitored green infrastructure for the neighbourhood etc. shall be the scope for the SRH. The country's big data initiative will be useful not only to know these people who don't have access to address; it can also monitor improvement of Human Development Index.

Conclusion

Consideration of the SRH as social infrastructure for providing safer and better living to our workforce is not only socially appropriate; this will bring direct and cascading positive impact on country's economy and environment too. Healthy workforce can be more productive, and contribute to various Government initiatives like 'Housing for All by 2022', 'Smart City Mission', 'Make in India 'and 'Skill India'. Formal education and training on housing to be linked with the logic of real-time informal housing scenario and shall be primer for knowing the people on both sides of rental housing.

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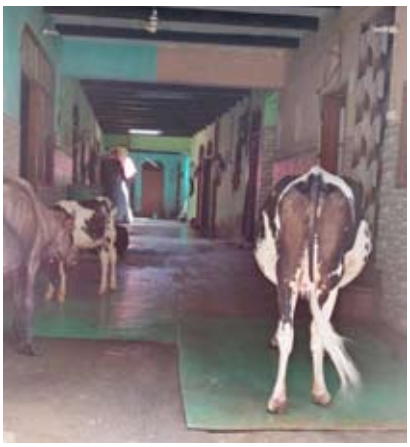

Can they change for better?

India Housing Construction Technology Challenge (IHCTC)

Government of India had launched Pradhan Mantri Awas Yojana (Urban) - Housing for All Mission. The Ministry of Housing and Urban Affairs (MoHUA) is facilitating the adoption of modern, innovative and green technologies for faster and quality construction of houses under PMAY (U) Mission as part of its Technology Sub-Mission.

The Ministry has proposed to adopt the mechanism of "India Housing Construction Technology Challenge (IHCTC)" to bring in the desired technology from all across the globe involving all the stakeholders. The IHCTC is proposed to be organized in 2018 and the end objective of this technology challenge event is to bring innovative technology into the affordable housing construction sector in India which could be widely propagated and sustained for at least 25 years.

In this context, the Ministry of Housing & Urban Affairs organized a Round Table Discussion with multi-stakeholders on August 25, 2017 at New Delhi and delibrated various aspects like Rollout of the challenge, branding and awareness creation, financing the challenge, role of stakeholders, criteria for technical evaluation for selection of technologies, Awards & Incentives, B2B discussions and Signing of MOUs, Institutionalizing and adoption of selected technologies by Centre and State Govts etc. BMTPC is preparing Technology Information Sheet for online applications.

Impediments in using Emerging Construction Systems for Mass Housing

*Dr. Shailesh Kr. Agrawal**
*& Pankaj Gupta***

With the launch of Pradhan Mantra AwasYojna – Urban & Rural by the Government of India with the objective of Right to shelter to each household in India, it is projected that about 20 million housing is required to be delivered in statutory towns by 2022 & about 10 million in rural areas in next three years. In order to meet these stern targets, besides issues related with land, finance, capacities & skills, technical & legal framework, the potential of existing construction practices to ensure faster delivery of houses is also being put under scanner. BMTPC in its quest to bring innovations in construction, started looking globally and through global expression of interest could identify a basket of construction systems/technologies which are time tested & proven and could fast track the delivery of houses with a better quality, structural & functional performance. BMTPC also operates Performance Appraisal Certification Scheme (Gazette Notification No. I-16011/5/99 H-II in the Gazette of India No. 49 dated December 4, 1999) under which sixteen new technologies for mass housing have been identified, assessed for their suitability in different geo-climatic regions of the country & certified them for usage by public & private agencies. These technologies along with other potential technologies are broadly classified and are as follows:

Engineered Formwork Systems

- Monolithic Concrete Construction using Plastic/Aluminium/ composite formwork
- Modular Tunnel form
- Slip form work systems

Insulated Form work systems

- Glass Fibre Reinforced Gypsum (GFRG) Panel System
- Sismo Building Technology
- Insulating Concrete forms - Reliable Insupacks
- Plasmolite&Plaswall – lost in place formwork system with fibre Cement board, plastic spacer & foam concrete

Stay-in-place Structural Form work systems

- Coffor

Precast Sandwich Panel Systems

- Advanced Building System – EMMEDUE
- Rapid Panels
- Reinforced EPS Core Panel System
- QuickBuild 3D Panels
- Concrewall Panel System

Light Gauge Steel Structural Systems

- Light Gauge Steel Framed Structure (LGSFS)
- Light Gauge Steel Framed Structure with Infill Concrete Panels (LGSFS-ICP)

Steel Structural Systems

- Factory Made Fast Track Building System
- Speed Floor System

Precast Concrete Construction Systems

- Waffle-Crete Building System
- Precast Large Concrete Panel System
- Industrialized RCC Precast 3-S system of frame construction i.e. RCC precast columns-beams-slabs framing system with/without precast shear walls
- Precast Prefab Technology Us-

* Executive Director, Building Materials & Technology Promotion Council, New Delhi
** Dy.Chief (I&D), Building Materials & Technology Promotion Council, New Delhi

ing Hollow Core Slab, Beams, Columns, Solid Walls, Stairs, etc.

- Moducast systems
- 3D monolithic Volumetric construction
- 3D printing of houses

Aluminium Structural Systems

- Aluminiumframing structures - infinium

These systems not only being used world over successfully but also bring speed, safety, sustainability with much improved structural & functional performance than conventional cast-in-situ RCC construction in vogue. Most of the states along with govt. agencies &departments, construction agencies, development authorities & housing boards have shown interest in these systems & are willing to adopt them with sincerity. However, as on ground, there are very few projects using these potential systems or if it is to be seen in numbers, only a few lakhs of houses out of millions are being constructed using these new systems. The natural question comes to the mind that if these systems provide better options then why they are not being mainstreamed? There are certain inherent impedimentsrelated with our preparedness, implementation&procurement strategies which demand immediate attention and redressal, if we were to achieve housing for all by 75th year of our independence i.e. 2022. These impediments are discussed in what follows.

Impediment No. 1 : Misconceptions about new systems

Since these systems are new, the technical fraternity is apprehensive about their usage and in turn they create fallacies about these systems such as performance of joints, earthquake resistance, functional performance etc. All these can be addressed scientifically by looking at various testimonials instead of rejecting them with preconceived notions.

Action : Develop a knowledge base on new technologies

Impediment No. 2 : Risk avoidance by policy makers and Technocrats

It seems that Policy makers and technocrats are apprehensive of using new technologies because of the element of risk which they might be perceiving as 'bell the cat'& why do I put myself into risk by using new construction technologies? They feel comfortable with the current system as they don't have to take any 'out of the way' decision which might need deviating from the standard technical &financial norms.

Action : Policy level interventions through a committee of experts representing technical and financial departments.

Impediment No. 3 : Apathy at Implementation level

Any innovation requires an initial push which may be in form of recognition or incentive or rebate. Any public organisation adopting new technologies may be suitably rewarded and same holds good for technology providers and contractors. A national recognition on innovation in construction sector may help mainstream new construction system.

Action: Incentivize innovation in construction

Impediment No. 4 : User Acceptability

In our country, people are so accustomed to 'brick and mortar' construction that they are not receptive to new construction methods even if these technologies are superior in terms of quality, safety &speed. People have their own criteria of acceptance like easy nailing in wall, no sound on knocking, no light material and lesser thickness of wall, easy to modify in future etc. Such factors sometime prevail even if a technology is technically and financially acceptable at Government level.

Action : Awareness creation and construction of some public buildings to build confidence in public.

Impediment No. 5 : Inadequate Capacities at Professional level

There is an urgent need to build capacities and create a pool of experts, technocrats, architects, consultants & practitioners on new construction systems who can actually help in conceiving the projects & its implementations.

Action: Create a pool of specialists

Impediment No. 6 : Paucity of Contractors

Technology providers which bring technology are not contractors and therefore, they are unable to participate in the tenders. It calls for creating a pool of contractors who are willing to join with technology providers. In India, at present there a very few contractors who have technology know-how and participating in Govt. tenders.

Action : Build a platform for technology providers & contractors

Impediment No. 7 : High Initial cost & Economies of Scale

All new systems require a manufacturing set up and therefore initial costs may be higher. This is one major reasons for rejection of the technologies at the very first instance. In this era of climate change and our commitment towards sustainable development, life-cycle costs (sum of initial construction cost (non-recurring) and all recurring costs (running & maintenance) over the full life span of a building) need to be accounted for.

Action : Digress from initial cost to life-cycle cost

Impediment No. 8: Do away with item rate business and adopt EPC contract system

Normally contracts are given on tenders which are prepared on item-rate basis. In order to bring new systems, instead of waiting for SORs to be prepared, the EPC approach needs to be adopted. Engineering, Procurement, and Construction (EPC) is a contracting arrangement where the contractor does all the activities from design, procurement, construction, to commissioning. This is also known as Turnkey basis, Lump Sum, design & build etc. Fix the rate per sqft along with specifications and allow the tenderer to innovate and design. In addition to EPC contract, quality cum cost based selection(QCCBS) may also adopted in which separate weightage can be given to technical parameters (like quality, speed, Life cycle cost, etc.) and financial cost. In order to bring in new technologies, lowest bid (L1) system needs to be replaced.

Action : Bring new Procurement Policy

Impediment No. 9: Conventional pre-qualification criteria

Presently, as per Government norms, the bidder must have done certain quantum of 'similar work' to get qualified. It is to be understood that being new technologies, quantum of 'similar work' may not be presently available in India. Therefore, till these technologies are well established, there is need to modify and relax the pre-qualification criteria to create conducive environment for adoption of these technologies.

Action : Modify and relax existing pre-qualification criteria in tender documents.

Impediment No. 10: Lack of modular/standardized planning & design

Whenever industrialization or mechanization of construction is talked about, it is utmost important that we modularize & standardize our room sizes, window sizes, door sizes, house sizes, services, fittings, etc. Can't we have standard designs region wise, if not pan-India.

Action :Prepare modular plans & design for different geo-climatic regions of India.

Impediment No. 11 : Absence of Demonstration at grass-root level

There is need to construct demonstration buildings in different parts of India with such new systems so as to showcase and educate the masses about the technologies. Unless, successful case studies are created, it is difficult to build user-acceptance.

Action : Demonstration Construction with new technologies

Impediment No. 12 : Skill Development

The training needs need to be assessed immediately and formal training programmes need to be launched immediately for artisans. It will not only open new avenues for employment but also create interest amongst masses about new technologies.

Action : Capacity Building & Skill Development

Impediment No. 13 : Need of IEC activities

Information, Education & Communication (IEC) is required for generating awareness. It is needed to work continuously with individuals, communities & societies, stakeholders, students, professionals, policy makers & politicians to create a progressive & positive setting for innovations & new technologies.

Action : Initiate IEC

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New Construction Technologies for Mass Housing

Dr. Vimal Kumar &*
*Gopal Krishna Jha***

Abstract

The Housing for All Mission under Prime Minister Awaas Yojana (PMAY) to provide 20 million dwelling units to EWS by 2022 has envisaged employment of new construction technologies capable of fast, economical and sustainable (green) construction. A Technology Sub-Mission under the Mission of Housing for All is catalysing the employment of required technologies with critical support and motivation from BMTPC. The construction industry has also come forward and is supporting the efforts with full vigour.

The paper provides an over view, to develop a general understanding and appreciation, of new construction technologies employed at large scale in the states of Karnataka, Maharashtra, West Bengal and NCR of Delhi wherein detailed field study has been under taken by Centre for Fly Ash Research and Management (C-FARM), New Delhi.

Impressive in-roads have been made by the new construction technologies that need to be supported and facilitated through policy frame work to harness the vast potential that these technologies hold.

Key Words: Mass Housing, New Construction Technologies, PMAY, Housing for All Mission, Construction.

Preamble

India's Urban Population has grown from 109 million in 1971 to 419 million in 2014 and is expected to grow to almost 600 million by 2030. While rapid urbanization and growing cities provide various opportunities, there is fallout in terms of proliferation of slums, high prices of land and building materials which render houses unaffordable for the segment at the bottom of the pyramid. The technical committee constituted by Ministry of Housing & Urban Poverty Alleviation (MHUPA), Government of India has estimated housing shortage for urban areas at 18.78 million during the 12th FYP period of which over 95% of this housing shortage is estimated in the Economically Weaker Sections (EWS) and Low Income Group (LIG) categories. Accordingly, to address this shortage intensive efforts are being put in place by the Government to substantially increase affordable housing stock.

Housing for All Mission launched in June, 2015 envisages construction of 2 crore dwelling units by 2022 by providing central assistance to Urban Local Bodies (ULBs) and other implementing agencies through States/UTs. All statutory towns as per Census 2011 and towns notified subsequently would be eligible for coverage under the Housing for All Mission

The scheme targets urban poor including economically weaker sections (EWS) and low income groups (LIG) in urban areas. Centre will provide a financial assistance of Rs 2 trillion.

Dimension of the task at present is estimated at 2 crore. Exact number of houses, though, would depend on demand survey for which all States/Cities will undertake detailed demand assessment for assessing actual demand by integrating Aadhar number, Jan

* Secretary General, Centre for Fly Ash Research & Management (C-FARM), New Delhi and Former Mission Director & Head, Fly Ash Unit, DST, GoI, Email: dr.vimal.kumar@gmail.com
** Senior Scientist, Centre for Fly Ash Research & Management (C-FARM), New Delhi Email:cfarm.org@gmail.com

Dhan Yojana account numbers or any such identification of intended beneficiaries.

A Technology Sub-mission under the Mission has been set up to facilitate adaptation of modern, innovative and green technologies and building materials for faster and quality construction of houses. The Technology Sub-Mission will also facilitate preparation of appropriate layout designs and building plans suitable for various geo-climatic zones. It will also assist States/Cities in deploying disaster resistant and environment friendly technologies.

The Technology Sub-Mission will coordinate with various regulatory and administrative bodies for mainstreaming and up scaling deployment of modern construction technologies and material in place of conventional construction. The Technology Sub-Mission will also coordinate with other agencies working in green and energy efficient technologies, climate change etc.

Need for the New Construction Technology

Keeping in view the set target of 2 crore dwelling units by 2022 there is urgent need for fast and affordable construction technologies. As per forecast for the seven years and statistics of present scenario, approximately 7828 number of dwelling units is required to be made per day. This calls for multi fold approach and technology that could work at par with the demand. With technology comes the challenge of acceptability, availability and feasibility in the vicinity of the project, followed by affordability. Conventional brick, masonry construction technology are time taking, costlier and labour intensive. Shortage of construction material especially bricks and labour becomes a bottle neck. New construction technologies are much faster, replaces bricks with walling technologies which are less labour intensive. Generally new construction technologies are better in quality, consistency and reproducibility. The new construction technologies also reduce wastage of construction materials & make housing more economical.

The Era of adaptation of new construction technologies that are well practiced in other countries has started in India. C-FARM has undertaken a detailed market survey and interaction with stakeholder agencies on the subject in the states of Maharashtra, Karnataka, West Bengal and Delhi-NCR. The findings about the emerging new construction technologies for mass housing being adopted along with their salient features are delineated.

New Construction Technologies for mass housing

A number of new construction technologies and their variants are getting in to practice in the country. These technologies can be broadly grouped in the following 5 categories:

- Monolithic in situ casting
- Precast concrete technologies
- EPS Panel Systems
- Light Gauge Steel Structural Systems
- Walling/floor technologies

The paper provides general overview information about these technologies in a simple & comprehensive way to enable the end users, the house owners and the occupants and the public at large, to develop an understanding and appreciation of these technologies. Employment of these technologies is practically essential to fulfil the need of large number of EWS dwelling units of replication type.

Monolithic in situ casting

Instead of traditional column and beam construction here, all walls, floors, slabs, columns, beams, stairs, together with door and window openings are cast in place monolithically at site by use of specially designed, easy to handle modular form work. Using the formwork system, rapid construction of multiple units of repetitive type can be achieved. Under this technology there are variants in terms of formwork systems as given below:

Plastic/ aluminium form works

Though plastic form woks are reported in literature has not been seen in the field. It has been reported that these form works are amenable to development of cracks due to mishandling and hence shorter work life. Aluminium form works are being used as its working life is relatively high. Generally aluminium form works are being imported. Now these are being manufactured in India also.

Plastic/ aluminium form work

Modular tunnel form works

Tunnel form is a formwork system that allows the contractor to

Modular tunnel form work

cast walls and slabs in one operation on a daily cycle. It combines the speed, quality and accuracy with the flexibility and economy of in-situ construction. Construction durations are reduced significantly by this rapid system when compared to conventional methods. Tunnel Form System brings speed, quality and accuracy to concrete construction with reduced number of joints and provides big savings in finishing and M&E works. Hi-tech technologies for steel formwork production make tunnel forms strong & durable. The system creates efficient load-bearing structures which are known as the most earthquake resistant structures

The result is a cellular reinforced structure, the surfaces of which are sufficiently high quality to require only minimal finishing for direct decoration, while the end walls and facades are easily completed with thermally insulated units that can be clad as required. The system creates an efficient load-bearing structure for use in a wide variety of applications. It is particularly effective in projects suited to repetitive cellular construction such as residential blocks, hotels, student accommodation, barracks and prisons

Coffor form works

Coffor is a structural stay-in-place formwork system, used to build monolithic load bearing walls. It is composed of two filtering grids made of rib lath reinforced by vertical stiffeners. The grids are connected by articulated rebar loops that fold for cost effective transport. The concrete volume used is 7 times less than the equivalence in bricks, concrete blocks or insulated concrete formwork. It is very light: less than 11 kg/m^2. A standard panel 1.22 m x 2.70 m (4' x 9') weighs 35 kg. It can easily be carried by 1 or 2 workers.

After coffer is placed, concrete is poured inside. Excess water is eliminated by gravity through the grids. The fluid concrete becomes semi-solid decreasing pressure against the grids. It remains in the construction to reinforce it after

Coffor form work

the concrete is poured. It is primarily used for building walls in all types of construction: single-family homes, multi-unit apartment buildings, lavish residences, luxurious high rise buildings and all types of industrial or commercial buildings. It is so versatile that it can be used for radius walls, blind walls, retaining walls, slabs, floors, inclined or flat roofs, infrastructures, foundations, columns, beams, rehabilitation, reinforcement, swimming pools, water tanks, civil works and much more.

Precast Concrete Technology

Precast concrete panels

Precast concrete technology is a process through which concrete is cast into a reusable mould, cured in controlled environment, then transported to a construction site by suitable arrangement and hoisted and assembled into a complete structure. It overpowers the conventional on economic, environmental, quality and speed. Precast construction system is generally a large panel system, modular system or a combination of both. Precast large construction panels consists of various precast element such as walls, beams, slabs, columns, staircase, landing and some customized elements that are standardized and designed for stability, durability and structural integrity of the building.

Precast residential building construction involves design, strategic yard planning, lifting and transportation of precast elements. This technology is suitable for construction of high rise buildings resisting seismic and wind induced lateral loads along with gravity loads. The building framing is planned in such a way that maximum number of

Precast concrete panels

repetitions of mould is obtained. These elements are cast in a controlled factory condition. The factory is developed at or near the site which provides an economical solution in terms of storage and transportation.

Industrialized 3-S System using Precast RCC Columns, Beams & Cellular Light Weight Concrete RCC Slabs

Pre-stressed precast reinforced cement concrete technology using hollow core slabs, beams, columns, solid walls, stairs etc. are designed and manufactured in factory, shipped and erected at site. Multi-storey precast concrete frames are constructed with columns and beams of different shapes and sizes, stair and elevator shafts and floor slabs. The joints between the floors elements are executed in such a way that concentrated loads are distributed over the whole floor. This system is widely used for multi storey buildings.

The structural frame is commonly composed of rectangular columns of one or more storeys height. The beams are normally rectangular, L-shaped or inverted T-beams. They are single span or cantilever beams, simply supported and pin-connected to the columns. Hollow core floor slabs are by far the most common type of floor slabs in this type of structure.

Industrialized 3-S System

Precast concrete panels using concrete, welded mesh and plates, polystyrene core

Precast concrete load bearing panels are made of reinforced concrete with a polystyrene insulated core that varies in size from 40mm to 200mm depending upon the insulation requirements. The reinforced concrete panels are moulded in specially designed steel moulds under controlled factory conditions. Then the panels are removed from the moulds and stacked vertically for curing. Power and water conduits are installed in the panels during production. The buildings and houses can be de signed to suit any geographical position or environment and can withstand wind speed in excess of 285km/hr. The system does not impose any design restrictions and can be used for any kind of architectural and aesthetic design as these panels are custom designed and manufactured. The panels have smooth surfaces. However, any kind of texture can be added on to the panel surface. Due to cohesive structural design, the system requires only strip foundation for most buildings. The panels are assembled in the factory to create the dwelling unit in 2 or 3 part, with all fittings and fixtures. The part-dwelling units are shifted to the site and assembled together to create the dwelling unit.

Concrete panels can be de-

Precast concrete panels

signed with strength of 5000 psi. These results in stronger panels than concrete blocks or most poured concrete walls but are thinner and light weight. The panels are of good quality and uniformity as they are cast and cured in controlled factory environment. The panels can be installed in fraction of time. The foundation takes two hours to prepare and the panels are set in three hours

EPS Panel Systems

Reinforced EPS Core Panel System

The panel Building system is a load bearing wall construction which is seismic resistant and thermally insulated. It is reported that buildings of any typology or architectural structure, ranging from most simple to the most complex one, could be constructed. The base element of the building system is a modular panel composed of two electro-welded galvanized steel meshes , reciprocally joined by connectors , in the middle of which is a suitably shaped foam polystyrene plate. High resistance steel meshes composed of bars having dia. 2.5 to 5 mm. are made in factory. Panels could be supplied with meshes having different dia. and different geometrical characteristics. Polystyrene is self- extinguishing foam polystyrene suitably shaped, used both as a disposable form and as an insulating layer. The EPS is made of carbon, hydrogen and 98% air. Thickness, shape and density of the polystyrene core may change according to specific requirements. The minimum density normally used is equal to 15 kg / m^3.

Once the panels are installed, they are anchored and finished with the application of light concrete on both of their sides. Thus, buildings with load bearing walls consisting of two reinforced concrete plates are made integral by a thick network of connectors, with an insulating core. Single panel is finished, by applying on each a layer of chipping concrete having characteristic resistance of 30 Mpa at least. As load bearing element, the double panel and the floors are finished during the installation with concrete of suitable grade placed into the slab ribs as well. Should the panels carry out a non load bearing function , a concrete plaster , even a pre mixed one , is applied for a thickness of at least 25 mm.

Double layer EPS Panel with in situ casting

This is a system of formwork for reinforced concrete usually made with a rigid thermal insulation, made of self extinguishing EPS (Expanded Polystyrene) that stays in place as a permanent interior and exterior substrate for walls, floors, and roofs. The forms are interlocking modular units that are dry-stacked (without mortar) and filled with concrete. The units lock together somewhat like giant Lego bricks and create a form for the structural walls or floors of a building. Insulated concrete form (ICF) construction has become commonplace for both low rise commercial and high performance residential construction as more stringent energy efficiency and natural disaster resistant building codes are adopted.

Over the last two decades, ICFs have become the most preferred construction material for green buildings in many countries with extreme weather conditions due to their reduced construction time, compatibility with any inside or outside surface finish, strength, mould & pest resistance, noise reduction, reduced dust & dirt infiltration and significant and continuing energy savings

Light Gauge Steel Structural Systems

Light Gauge Steel Framed Structures (LGSF) is based on factory made galvanized light gauge steel components, designed as per codal requirements, produced by cold forming method and assembled as panels at site forming structural steel framework of a building of varying sizes of wall and floor. The basic building elements of light gauge steel framing are cold formed sections which can be prefabricated on site using various methods of connection. The assembly is done using special types of screws and bolts.

Cold formed sections are widely used in construction including residential floors, industrial buildings, commercial buildings, hotels and

Reinforced EPS Core Panel System

Double layer EPS Panel

Light Gauge Steel Structural Systems

are gaining greater acceptance in the residential sector. LGSF is already well established in residential construction in North America, Australia and Japan and is gaining ground in India. LGSF is typically ideal for one to three storey high buildings, especially in residential homes, apartments and commercial buildings. Due to its flexibility fast construction and durability, this technology has great potential for counties like India.

LGSF can be combined with composite steel / concrete deck resting on light steel framing stud walls. Apart from having potential for mass housing, modular buildings can be used for long term temporary or permanent structures such as schools and classroom, military and civil housing needs, post – disaster relief structures and industrial buildings. Advisable span for LGSF buildings should be 7.5 m. Wall panels are generally made by using heavy duty Cement Particle Board and Gypsum board. It can also be made using high density extended polystyrene core plastered from outside using wire mesh and chicken mesh.

Walling/ Floor technologies

Technologies under this category can be categorised as component technologies, unless these technologies are employed in conjunction with other matching technologies to provide a complete solution for setting up of a dwelling unit.

The technologies that are fall under this category include:

- Glass Fibre Reinforced Gypsum Panel Building System
- Prefabricated Fibre Reinforced Sandwich Panels
- Speedfloor System

Summing up

The new construction technologies pertaining to (i) monolithic in-situ casting and (ii) precast concrete technology except "Pre cast concrete panels using concrete, welded mesh and plates, polystyrene core" have been employed successfully at large scale in the country to construct dwelling units in 1000s of numbers, blocks ranging from 4 storey structure to more than 30 storey. These constructions are generally in Metro & mini Metro cities. However, can be executed anywhere. Interactions with the designers, architects, executers & user agencies including the dwelling unit occupiers do not reflect any major bottleneck or shortcoming of these technologies. Trained manpower is required to be developed. Further, rate of inflow of funds for the construction activity needs to match the construction speed. In some of the cases this has been reported as the bottleneck. These technologies can complete a project in 1/3rd of the time required by conventional technology. EPS panel systems (single as well as double layer) are very promising with special features of insulation & light weight with sufficient strength and stiffness for safety. Dwelling units up to G+1 have been constructed successfully. Multi-storey blocks are feasible, have been done abroad, but need user confidence building. Double layer EPS panels with in-situ casting provide more confidence for high rise buildings. The cold regions of Himalayas, Rajasthan and hot regions of northern India including Rajasthan can derive maximum benefit from EPS panel dwelling unit construction technology. In high seismic zone, it is best suited being a light weight structure.

Conclusion

New construction technologies is the need of hour to execute large number of dwelling units with repeat design in short span of time, with economics, low wastage and eco-friendly.

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Impact of Increased Heights and Floor Area Ratio (FAR) on Housing Environments

*Dr. Ashok Kumar** *Sayantani Lala*** *Dr. K.S.Kulkarni****

Introduction

The quality of living environment involves many parameters including overall environment and typologies of houses catering to the needs and aspirations of different lifestyles, as well as accessibility to community, social and commercial facilities and recreation options. It also depends upon adequate livelihood creation with jobs closer to home by sustainable development of commercial and business hubs along with ample green open space for balancing out the resulting congestion. The Master Plans show that our towns are planned with such comprehensive criteria to meet the needs of current and future residents. The land use proposals give provisions for safeguard of housing, shops, schools, libraries, sport facilities, community clubs and parks; each essential in ensuring livable, self-sufficient towns. Consequently, the facilities are carefully distributed across each town supported by efficient transit networks, to ensure seamless accessibility. However, this very fabric of sustainable breathable cities comes under threat due to unplanned rapid urbanization.

Metropolitan cities in India are currently experiencing rapid urbanization, leading to the spreading out built up areas. As per Indian Census Report 2011, all major cities have increased their built up areas between 1981 and 2011. India's urban population has grown up to 31% in 2011 with more than 270 million people urbanizing in cities. It is estimated that this trend is set to further increase and expected to reach 50% by 2050. Similarly, as per the Technical Group (TG), set up by Government of India in 2012, the total housing shortage was estimated at 187 lakhs in urban areas, out of which 96 % relates to social housing i.e. Economical Weaker Sections (EWS) and Low Income Groups (LIG). Hence, it is a great challenge to provide quality housing which is not only durable, and cost-effective, but also safe, energy - efficient and locally acceptable.

For this purpose, various building bye-laws and development controls are prescribed in each municipality, however without proper execution. The development controls are known by different terms around the world. Some of the major indices include FAR, Floor Space Index (FSI), Floor Lot Ratio, Plot Ratio, and Gross Floor Area (GFA); and despite subtle differences, all are essentially the same. Of these, FAR is a simple measure, which can be used effectively to ensure the optimum performance of a city. It is worth mentioning that Floor Area Ratio (FAR) has not been the primary motivator for spatial planning in India that has led to (i) rapid rural migration to urban areas, (ii) better living standard, and (iii) change in transportation system from public to private etc. This study takes an insightful look into urban form and spatial planning in Indian metropolitan cities and testing of various FAR to provide an overview of energy efficiency in housing layouts which is directly relevant to the context of applied energy in the built environment [1]. Maximum FAR regulation has great significance in cities to mitigate congestion. Several studies on FAR indicate that

* Senior Principal Scientist and Head, Architecture & Planning and Efficiency of Building, CSIR- Central Building Research Institute (CBRI), Roorkee. Email: ashokkumar@cbri.res.in
** Scientist, CSIR- Central Building Research Institute (CBRI), Roorkee. Email: sayantani.lala@cbri.res.in
*** Scientist, CSIR- Central Building Research Institute (CBRI), Roorkee. Email: kishorsk@cbri.res.in

maximum FAR regulation alone is generally insufficient and should be accompanied by minimum FAR regulation [2]. As the population in cities is increasing and the land is a scarce commodity, there is a necessity to increase the FAR. This study investigates a number of urban forms and their impact on energy consumption at various FARs.

International Scenario

FAR is an index which is globally prevalent with minor modifications and hence it is used here as a measure of efficiency of cities. Despite its simplicity, in practice, its use is very complex with different definitions, viz. with various rules pertaining to the inclusion of service and maintenance areas and areas with low eaves heights, basements, semi-basements and parking lots, definition of permissible area of the plot etc. In USA, for example, it is common for plans to be accompanied by certifications that the calculations have been done in accordance with the zoning ordinance, with staff time amongst planners being largely devoted to meticulous checking of these calculations.

Modern zoning derives from the desire of several central European rulers at the end of the 19th Century to 'police' their urban expansion, a practice brought into the USA during the early years of the 20th Century by lawyers familiar with the use of such 'policing powers'. 'Bulk zoning' controls began in New York in 1916. As New York grew taller and more intense there were concerns about overshadowing and loss of light and dark 'canyon' effects in streets. These concerns became tangible with the construction of the Equitable Building.

Several studies have been reported in the literature related to FAR and many researchers believe that large scale urban form has impact on energy. Ayotunde and Ali [1] modelled four configurations using FAR 1, 2.5, 3 and 4 in which maximum of 30 floors were considered due to the rules and regulations for building height in urban areas of Ningbo at Dinghai, China. The major parameters observed through the study were the solar radiation incident upon building walls. The authors conclude that there is clear relationship between FAR, energy production and consumption. Wider surface areas and higher buildings allow for more indirect solar radiation which is linked to higher gains. However, if the buildings are too short this would affect radiation coverage and also productivity of solar energy technologies such as solar facades. Furthermore, FAR of 2.5 and 3 provided a safe middle ground between FAR 1 and FAR 4. The results indicated that when using FAR, a 0.5 addition would bear no significant loss but would have huge economic advantages by increasing usable floor area. This implies that an optimum height can be evaluated in terms of energy. That means the higher the building, the more are the losses [1]. Several studies on FAR indicate that maximum FAR regulation alone is generally insufficient and should be accompanied by minimum FAR regulation [2].

Johansson [3] focused his studies on wind directions in urban canyons, that allow or block day lighting, provide shade etc. and results infer that principles of density and energy management can be regulated through FAR. Steadman [4] focused on energy implications of large scale urban form and on high density development, and infer that that high density linear growth would be more energy efficient than centralized dense growth. This would increase the prospects of passive solar gains, natural lighting and local food production. But a compact versus spread urban form has been debated by Holden and Norland [5]. At the same time Mindali [6] recommended density as equivalent to energy efficiency with its negative impact on natural lighting, solar gains and ventilation.

Yannas [7] concluded that 40% heat savings were observed during his comparative study of apartments and detached housing. The results infer that buildings with 2.5 FAR might represent the optimum density in neighborhood development. Capuleto and Shaviv [8] suggested that even at relatively high built density, the FAR of 1.6 to 1.8 was possible to maintain solar access to all buildings within a neighborhood. Arboit et al. [9] studied the solar potential of low density urban form in Argentina, using 32 sample urban blocks and augmenting parameters such as street width, glazing and trees. The results of the study conclude that solar energy could offset as much 34% of heat energy demand. The author also emphasized the importance of orientation and shape of building blocks. Where FAR controls are small, they result in a suboptimal distribution of density, making housing less affordable to the poorest. These examples in literature give the energy-oriented importance of urban form and FAR. These results may be helpful in developing strategies for land use using FAR 2, 3.0, 4.0, and 5.0 and more for Indian cities.

Table 1. Floor Area Ratio (FAR) of major metropolitan cities

Cities	Residential FAR values	Commercial Business District (CBD) FAR values
Paris	5.75	12
Bangkok	8	10
Singapore	2.8	13
Vancouver	3	5
Denver	4	17
New York	10	15 (Special district : 23)
Hong Kong	7.5	12
Los Angeles	10	13
Chicago	10	16
Bahrain	12.5	17
San Francisco	4.8	9
Tokyo	5	13
Seoul	4	13

In New York, the Zoning Resolution was enacted and took effect in 1961. Though much amended and now bewilderingly complex, it is still in place today. The delay between 1916 and 1961, between the initiation and implementation of FAR regulations meant that New York was not the first place to introduce FAR, or Incentive zoning. These honors lie with Seattle and Chicago respectively. The principles behind the 1961 ordinance were however copied globally. The City of New York offered developers a higher FAR in exchange for creating public plazas at new developments so, in theory, as the city would build a world-class skyline, it would also create world-class public spaces. The concern was not to increase density but to allow more light and air within the same density or even to 'thin' the city out at the height of cold war concerns about vulnerability to nuclear attacks. However in reality, it gave rise to under-utilized and haphazard public spaces, which adversely affected the compactness of the city.

The FAR values of some of the major cities around the world, in no particular order are tabulated in Table 1. As this index is being subjected to different incentives and restrictions in various cities, an entirely accurate comparison of the basic value conforming to same definition of FAR is difficult. If a site has a plot ratio of 5.0, a developer will be able to build a maximum of 5,000 sqm on a site area of 1,000sqm. However, a nearly adhering comparison of the different cities around the world has been presented.

National Scenario

In India, there have been no studies, with very little concern over possibility of optimizing thermal and energy performance through FAR and urban form design. Similarly, there are scarce studies on the impact of FAR on density and solar access to buildings. This study takes a brief look at some of these attributes in Indian cities where there is a huge shortage of land for development. In India, this index varies in the range of 1.2- 3.5 for residential spaces, an estimate gathered from major metropolitan cities [10], as shown in Figure 1. However, this value is lower than that prescribed in some of the major cities around the world.

Optimization of FAR

There can be far reaching consequences for both high and low FAR on the built environment of a city. A higher FAR value leads to the construction of closely-spaced buildings, each with inadequate access to natural ventilation and sunlight in the lower floors. Also, with greater FAR, buildings are too close to plot lines, thereby casting huge shadows on the streets, which again deteriorates the built environment of the surrounding neighborhoods. Throughout history, there had been numerous failed cases with large FARs. For example, the Equitable building, with a FAR of 30 and no setback, cast a 7 acre shadow on the neighborhood, thus adversely reducing the property value of these areas. However, a very low FAR value will be the cause of inefficient sprawling of a city, with wasted spaces. Hence it

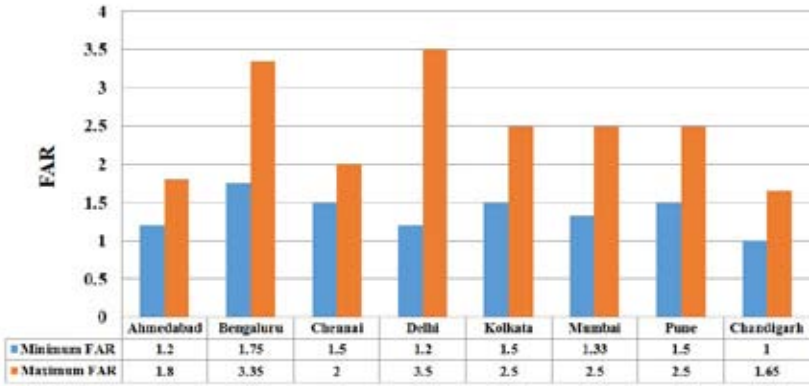

Fig. 1. FAR in major metropolitan cities of India

is very important that the value of FAR be optimized to increase the efficiency of a city.

It is noted that the values in India are significantly lower than the other cities shown in Table 1, some of which are amongst the most developed in the world. Hence it can be safely presumed, there is scope for improvement in the values of Indian FAR values, which will make the cities more efficient in terms of space utilization. However, the values should be optimized through proper planning principles to avoid both congestion and sprawling.

Optimum Densities for Different Number of Storeys

Planning Approach

The present trend of providing dwellings vary from single family to multi storied housing blocks housing blocks depending upon the feasibility of a particular form in an urban environment in relation to land use, social and economic aspects. The horizontal versus vertical housing developments are responsible for different land utilization and densities of housing area, different type of living environments and varying costs of housing comprising land cost. Currently, the cost of development are not being planned or designed for achieving optimization in relation to land use and number of storeys for desirable level environment. The environmental parameters should be quantified depending upon the specific location and applied scientifically in the development of layout patterns. The different parameters for this purpose include:

- Physical Environment – Sunlight, Daylight, Airflow, Noise Control
- Climatic Environment – Temperature, Humidity, Solar radiation, Rainfall etc.
- Social Environment – Child play, Parking, Recreation access, Outdoor sitting
- Aesthetic Environment– Privacy, Physiological, etc.

Similarly, the high rise blocks are designed without caring for the figures of optimum densities, thus increasing both the quantum of consumed land and developmental costs. Under present circumstances in India and other developing countries, the housing forms should result into economical housing and consume lower quantum of land without compromising on the desirable quality of living. Keeping in view these situations, the concept of "Low Rise High Density Housing" should be incorporated in the design of housing developments. However, in order to apply this concept it is essential to determine the optimum densities and costs under various situations for establishing the most efficient development (storey) under situations characterized by various planning parameters.

Nature of Housing Developments

The stipulation of dwelling area and open space per dwelling decide the optimum dwelling densities in relation to number of storey within the permissible limits of developmental control (i.e. floor area ratio and coverage). The optimum dwelling density determines the land use per dwelling for the specific type of developments and quota of built-up and open spaces, Developmental controls i.e. FAR and coverage are such measures to regulate nature of development. They restrict the maximum intensity of built up spaces in the minimum intensity of the built of spaces in the form FAR and minimum requirements of open space in the form of coverage respectively. Hence, the FAR stipulations decide the dwelling densities in relation to gross dwelling spaces per dwelling, while coverage regulations decide the dwelling densities in relation to total open spaces per dwelling. Thus optimum dwelling densities are formulated for the desired environmental levels (built up spaces and open spaces for dwelling) for varying number of storeys. In addition to this, the nature of development i.e. number of storeys is also a function of physical, economic and aesthetic considerations. The decision regarding the nature of development in relation to density and other parameter FAR and coverage can be taken by the following equation:

$$D = 100 \times S / (S \times P + A)$$

$$D = 100 \times F / A$$

$$D = 100 \times (100 - C) / P$$

Where,

F= Floor Area Ratio; D = Net dwelling density in dwelling / hectare; S= Number of storey; P= Open space per dwelling in sq. m at cluster level; C= Coverage in percentage.

The respective values of 54 sq. m dwelling for 4, 8 and 12 storeys are 90, 120 and 135 dwelling densities per hectare respectively at cluster level.

Impact of Increase in Heights i.e. FAR on Daylighting and Visual Comfort

Studies have demonstrated that access to daylight has profound implications in terms of human health, productivity, quality of life,

and an overall sense of well-being. It is to be noted that as human beings spend about 80% of the time within buildings, it is necessary that the essential environmental parameters for human comfort be maintained unequivocally. In this connection therefore, standard building codes such as SP: 41 (S&T) [11], National Building Code (NBC) 2016 [12] and Energy Conservation Building Code (ECBC) 2017 [13] have recommended the minimum distance between two building blocks to take care of these attributes such as sufficient daylight penetration and visual comfort.

The NBC 2016, (Development Control Rules and General Building Requirements), describes that the open spaces inside and around a building are meant for catering to the lighting and ventilation requirements of the rooms abutting such open spaces. Similarly, the open spaces around the building are also meant for fire safety requirements. Therefore, every room intended for human habitation shall abut on an interior or exterior open space/ open verandah.

The obstruction of 70 degrees and more creates unacceptable conditions of daylight and human comfort as shown in Figure 2. The solar shading and heat island effect increases which leads to creation of a microclimate by continuous absorption and emission of heat during summers leading to significant deterioration on built environment. Similarly, smaller distance between the blocks / buildings casts shadow on adjoining areas and also creates "Venturi Effect", which impacts the cross-ventilation potential of the buildings. In this phenomenon, the pressure difference within the gap causes wind to increase in strength and reach unreasonable high velocities, thereby creating complex patterns of air –flow thus adversely impacting human comfort and safety.

Hence, NBC has specified 6.0m to 16.0m distance between adjacent building blocks depending upon the height of buildings to avoid this effect. The spacing of 6.0m corresponds to 18.0m height buildings and spacing shall be increased by 1.0m for every addition of 3.0m in height. The scientific basis of the above regulations is prescribed in SP:41(S&T) -1987 [11] and is adopted by several development authorities like Noida for building regulation, and is the requirement of minimum separation distance between adjacent buildings from various functional considerations like light, ventilation, visual privacy etc.

The NBC-2016 [12] and SP: 41 (S&T) -1987 [11] also specifies the minimum flow in terms of number of air changes for rooms in all types of occupancies. The purposes of ventilation are related to heat exchange and cooling of space and thermal comfort in general. The distribution of air velocity is related to thermal comfort. The minimum spacing between adjacent buildings / blocks is necessary to be maintained to ensure visual privacy and to avoid shadow effect. As per NBC, Stack Effect is the convection effect arising from temperature or vapour pressure difference (or both) between outside and inside of the room and the difference of height between the outlet and inlet openings. Hence, the non-adherence to minimum spacing would invariably affect the ventilation performance, especially when wind is parallel to building envelope surface between two blocks, even when "Venturi Effect" minimizes the reduction in wind speed due to channelization as shown in Figure 3.

Similarly, NBC [12] prescribes guidelines to combat mass destruction in the event of fire outbreak. The fire separation is defined as the distance in meters measured from the external wall of the building concerned to the external wall of any other building on the site, or from other site, or from the opposite side of a street or other public space for the purpose of preventing the spread of fire. Thus, a minimum distance must be maintained between two buildings / blocks to take into consideration the aspect of fire separation. If the openings in the form of fenestration/windows are provided, fire can get transmitted to the next building by convection and radiation from the flame and hot gases. But for walls having

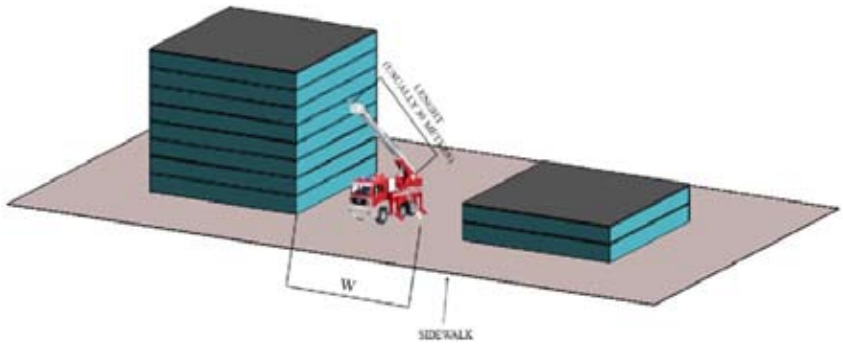

Fig.2. Minimum distance between two blocks for fire fighting and daylighting requirements

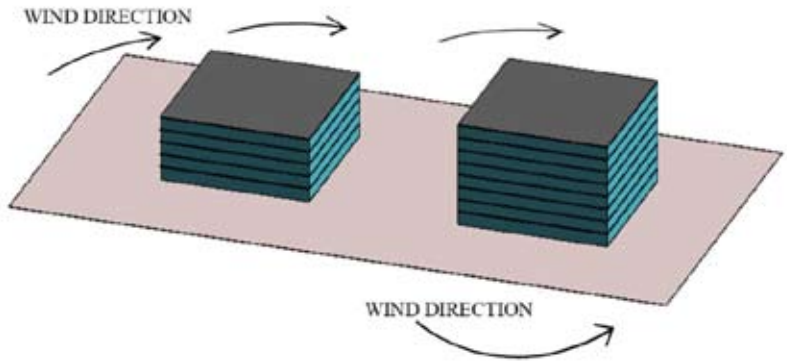

Fig. 3. Wind flow pattern between two blocks

no openings, distance maintained can be small. Therefore, when the buildings / blocks are facing each other, the distance for fire separation, has to be maintained as per NBC [12].

Summary

Looking into the present and future urbanization challenges, the FAR regulations should be upgraded in pace with the global scenario, for increasing the efficiency of cities in new India. This would further reinforce the capacity building strategies for the upcoming concept of smart cities. However, this article is a small step in introducing the importance of FAR and a lot more research is needed to further optimize the FAR values for future development, in line with the principles of urban spaces.

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Development of appropriate rural housing under Pradhan Mantri Awas Yojana (Gramin)

*Ar. S.K.Negi ** *Swati Kulashri***

Development of the rural regions of India depends greatly upon the economic betterment of people as well as their supporting infrastructure. The growth in housing infrastructure can have a constructive impact on the development by contributing to upward social and economic mobility. Many initiatives have been taken up by the Government of India in past to provide the rural people with better prospects for economic development, infrastructure provisions and improved enforcement of land reforms. In the past, many programmes and schemes were envisaged for providing employment opportunities, education, health, drinking water, sanitation, road construction, electrification, drains, street lights, solid and liquid waste management. The primary objective behind the initiatives was to bridge the urban-rural divide by upgrading the standard of living of people in rural areas.

CSIR – Central Building Research Institute, since its establishment in 1947 has aspired to improve the developmental situation of rural India. CSIR-CBRI through its projects with the states and central government has significantly contributed in each of the following areas in terms of rural development:

- Low cost local building materials and technologies
- S & T interventions in traditional technologies practiced in rural areas
- Upgradation of rural houses (from kutcha to pucca)
- Disaster resilient building systems
- Amenities in rural area like low cost sanitation systems & waste water treatment
- Rural Building Centres (RBCs)
- Skill development and trainings to masons and engineers.

"Housing for all" is a vital national agenda of the Government of India. India's rural population accounts for nearly 68.3 per cent of the country's total population and forms the backbone of the country's economy. However, the quality of rural housing as also the volume of rural housing shortage in the country is emerging as a critical and unique challenge considering the varied dimensions of the rural landscape and lifestyle. As per the Working Group on Rural housing for the 12th Five Year Plan, the total housing shortage in rural areas is estimated at 43.67 million units. Of these, approximately, 39.30 million units (90 per cent of the rural housing shortage) pertain to the Below Poverty Line population.

The Government of India, under its various schemes has been facilitating the rural poor in taking up construction of 'minimal house unit' partly with the government help and remaining by putting in his own resources in the form of money, material and labour for constructing a livable shelter for himself. With little knowledge of construction materials and systems and appropriate cost effective technologies his resources are often exhausted in building a mere structure of four walls, which can hardly serve a useful purpose of a livable house. Though the Central Government and the State governments have undertaken a number of initiatives to address the situation, the shelter conditions in the

* Sr. Pr. Scientist (Head), Development, Construction & Extension Group, CSIR- Central building Research Institute, Roorkee
** Scientist, Development, Construction & Extension Group, CSIR- Central building Research Institute, Roorkee

rural areas continue to pose a serious challenge to the Government's objective of "Shelter for All'. There is a significant lack of institutional finance for rural housing. Though the institutional infrastructure, particularly the banking sector has acquired reasonable depth in the rural areas, they continue to be hesitant in extending housing loans to the rural borrowers on account of various constraints and challenges associated with rural lending. Further, in absence of necessary flexibility in application of prudential norms, the lending agencies tend to keep away from such lending. As a result, the "availability" of institutional credit for rural housing and its "accessibility" by the rural population continue to be serious challenges.

Previous initiative by the Government of India to provide for rural housing was Indira Awaas Yojana, which started with an objective to construct free houses to members of the Scheduled Castes/ Scheduled Tribes, freed bonded labourers in rural areas and also to non SC/ST rural poor living below poverty line. Funds for the BPL beneficiaries were provided by the Centre and State in the ratio of 75:25.

Pradhan Mantri Awaas Yojana – Gramin

The Government of India has affirmed its commitment to provide "Housing for All" by the year 2022. In pursuance to this goal, the Pradhan Mantri Awas Yojana - Gramin scheme was approved to provide assistance for construction of pucca house in rural areas. Through a set financial assistance it is expected that by 2022, majority of the beneficiaries in rural areas shall find access to a safer and comfortable house for a better quality of life and dignity. PMAY-G was launched by the Prime Minister Shri Narendra Modi in Agra on 20th November 2016. Under this affordable housing scheme, the government aims to develop three crore homes by the year 2022 in rural areas for poor families.

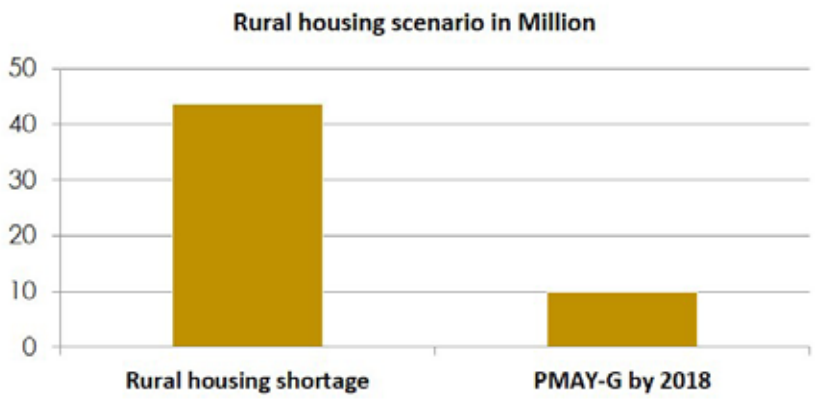
The intent of the programme is to provide housing for the rural poor in India. The expenditure involved in implementing the project in a span of three years from 2016-17 to 2018-19 is approximately Rs.82000 crore. By the means of the programme, the government proposes to provide assistance for construction of one crore from 2016-17 to 2018-19. The scheme is proposed to be implemented in rural areas throughout India except Delhi and Chandigarh. The cost of houses would be shared between Centre and States. The new scheme in addition to the stated objective of providing a housing unit to everyone also includes features that make the scheme more inclusive and universal. The salient features of the scheme are:

- Implementing the rural housing scheme of Pradhan Mantri Awaas Yojana – Gramin.
- Providing financial assistance for construction of 1.00 crore houses in rural areas.
- Enhancing the unit assistance to Rs. 1,20,000 in plain areas and to Rs.1,30,000 in hilly states/ difficult areas /IAP districts.
- Meeting the additional financial requirement through National Bank for Agriculture and Rural Development (NABARD).
- Setting up of National Technical Support Agency at national level to provide technical support.

CSIR – CBRI and Pradhan Mantri Awaas Yojana – Gramin

PMAY-G holds the potential to as a turning point in this journey given its multi-pronged strategy for addressing the need of quality housing in rural India. Realising the aspiration aspect of housing, complimentary assistance has been proposed apart from the base financial assistance. Assistance of Rs. 12,000/- for the construction of toilet for every PMAY-G house through Swachh Bharat and 90-95 mandays of unskilled labour under MGNREGS has been provided. These measures will hope to provide beneficiaries with dignified shelter.

To address the critical question of construction of quality houses on sustainable basis on such a large scale, the Ministry of Rural Development, Government of India initi-



ated the study of housing typologies for each state. Housing prototypes for thirteen states namely have been developed by United Nations Development Programme (UNDP). It was felt that within the limited resources of time and money, the aim of the PMAY-G shall be difficult to achieve using the traditional system of construction. To derive maximum advantage on cost, time, comfort and functional efficiency to the beneficiary, the developed house designs were to be validated by an appropriate building organization. Looking into the vast experience and expertise in cost-effective rural housing for different geo-climatic conditions and natural hazards prevalent in the country and being the single largest resource organization in the area of innovative and appropriate building materials and construction techniques, CSIR-Central Building Research Institute (CSIR-CBRI), Roorkee was approached by UNDP, under the advice of the Ministry of Rural Development, GOI, New Delhi, for architectural and structural validation of the rural housing designs.

CSIR-CBRI vetted typologies developed for each housing zone within a state based on climatic conditions, disaster risk factors, local materials and traditional skills. The institute also recommended materials and construction techniques for thirteen states namely: Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Sikkim, Tripura, Uttar Pradesh and West Bengal. These technologies can be put into use right away at village level with materials sourced from not to far. The technologies identified are sustainable which ensures the potential for long term availability of the materials. They are durable and designed to withstand the climatic variations and natural hazards that the specific housing zone is exposed to. CSIR-CBRI reviewed the designs, submitted by United Nations Development Programme (UNDP), to recommend appropriate S&T interventions to make the houses more durable, resistant to natural disasters and comfortable to live in using locally available materials and skills within the financial assistance provided under the PMAY-G and the contributions of the beneficiaries in terms of cash or kind.

The design alternatives for thirteen states namely: were developed by UNDP after detailed survey of the life styles and space requirements of the beneficiaries and keeping in view of their traditional architecture and vernacular construction systems. Whereas people feel more comfortable with the type of houses they have been living in but at the same time they aspire for better quality requiring minimum maintenance, safety against the vagaries of nature and a possibility to improve as and when they have some funds available with them to invest on their house. The houses are to be constructed with the financial support of about Rs 1,20,000 per house for plains and Rs 1,30,00 for hilly areas. It is expected that the support money is properly utilized to construct a durable house, requiring little maintenance, providing safety against prevalent disasters and give healthier living conditions and quality of life to the beneficiaries for at least 30 years without major repairs and maintenance.

The survey and design teams have suggested a plethora of specifications prevalent in different rural and tribal areas of thirteen states for which no design standards are readily available. Any paradigm shift in the vernacular architecture and specifications of new houses are likely to be a misfit to their living habits. The review of house designs and specifications maintaining social aspirations of the beneficiaries and technical adequacy of the dwelling structure was a big challenge to be met in a very short time available to CSIR-CBRI. However, the designs and specifications were reviewed by CSIR-CBRI based on Bureau of Indian Standards Codes, published literature on some of the recommended construction systems and experience of the reviewers. Besides vernacular architecture and traditional construction systems prevalent in different parts of India, building materials and components developed by Development Alternatives, ASTRA, Auroville, HUDCO building centres and COSTFORD have also been suggested by the designers in their designs.

To begin with the design improvements and validations, it was foremost to define the word 'Pucca house'. It was decided that a house can be considered 'pucca' irrespective of the materials and construction techniques adopted, if it

- can resist local hazards, rain, water, fire, cyclones, floods, earthquakes etc,
- requires low maintenance,
- provides a healthy and comfortable environment to live in for at least 30-50 years

The house design must be coherent with the life styles of the rural people and must create

a feeling of ownership and pride. The plans developed by the design agencies of UNDP have done an extensive survey and study of the lifestyle and expectations of the beneficiaries. The house plans have therefore been reviewed to meet the provisions of National Building Code (NBC) where ever needed regarding dimensions of spaces, ceiling heights, fenestration, thermal comfort and anthropometric requirements maintaining the original design.

While reviewing the designs it has been our effort to make good combination of traditional and modern construction materials and techniques supported by the financial assistance under the PMAY-G scheme to provide durable, maintenance free and safe houses with adequate comfort considerations for improving the quality of life of the people.

To ensure technical adequacy and safety against prevalent disasters the following BIS standards were consulted and recommendations were made. BIS codes like:

- IS 8888 – Low income Housing,
- IS 1080 – Shallow foundations,
- IS 1905 – Brick and Block masonry,
- IS 4326 EQ resistant design (including CSIR-CBRI developed building systems)
- IS 15498 Cyclone resistant Housing
- IS 9096 Preservation of bamboo for structural purposes,
- IS 6874 Test for round Bamboo
- IS 4920 Nail jointed timber Truss
- IS15912 – Structural Design using Bamboo,
- IS 456 – design of RCC members
- CSIR-CBRI published Building Research Notes
- Handbook on Earthquake resistant design and construction of Non-engineered Houses and
- The National Building Code (NBC) of India

The techniques given in Table-1 have been incorporated in the designs which were found appropriate to reduce cost and time of construction, and to improve durability, safety and living comfort;

Many designers have suggested use of mud construction like cob, adobe, daub and wattle, cement stabilized mud blocks (CSMB), mud plaster to bamboo ikra panels, rammed earth foundations and superstructure construction, stone / brick work in mud mortar, bamboo reinforced mud foundations and walls etc. Since the use of mud based construction system cannot be considered safe, CSIR-CBRI recommended the use of stabilized along with some additional protective measures have been recommended in the respective specifications. As a policy for durability, safety and low maintenance cost of mud based construction, it has been suggested that the load-bearing structure/ framework of the house may be constructed using permanent material like stones, bricks, blocks, RCC etc and the intermediate spaces may be filled using Compressed Mud Blocks (CMB) or adobe construction duly protected with ferrocement plaster. Bamboo Ikra walls (traditional wall panels of NE region made by fixing bamboo strips to a bamboo frame and later plastered with mud mortar) or bamboo strip mat walls (traditional walls made by bamboo strips woven into a strong panel without any binding wire etc) may also be provided a coat of ferrocement plaster in place of mud plaster. For structural soundness cross bracings have been suggested in walls and between rafters/ trusses in roofs. In gabled construction all rafters/purlins resting on walls are suggested to be fixed to the RCC roof/ gable bands and adjacent rafters be joined with a tie member to form a truss. Necessary improvements are suggested in stub foundations, strip foundations, rammed earth foundations, RCC driven pile foundations, sand

Table-1: Techniques incorporated in the design

1.	Stone Masonry Blocks *	for hills and stone abundant areas
2.	Solid Concrete Blocks *	for hills and stone abundant areas – mass production
3.	RC Plank and RC Joist roof *	Alternative of RCC slab flat roof
4.	Brick Panel and RC Joist *	Alternative of RCC slab flat roof – where bricks are cheap
5.	Precast Channel Unit roof *	Alternative of RCC slab flat roof
6.	C-bricks *	Alternative of clay bricks near flyash resource
7.	Rat-trap Bond	Saves 25% bricks
8.	Ferrocement Channels	Alternative of RCC slab roof
9.	MCR Roofing tiles	Alternative of country/ Mangalore pattern tiles
10.	CSMB blocks	Alternative of burnt bricks in low rainfall regions
11.	Stone roofing on RC joist/RSJ	If roofing stone is available

*(*CSIR CBRI developed technologies)*

cushion foundations, foundations in expansive soils, foundations in flood prone areas, foundations for holding bamboo, balli, timber or precast RCC columns have also been reviewed considering bearing capacity of soil of the corresponding regions along with other zone specific conditions.

CSIR-CBRI has reviewed and validated over 150 design typologies that were submitted by UNDP under the PMAY-G. Each typology worked meticulously analysed to recommend appropriate S&T interventions making the houses more durable, resistant to natural disasters and comfortable to live in using locally available materials and skills. Along with the region specific drawings, CSIR-CBRI also suggested alternate building options for improved adaptability and flexibility of choices to end users.

A Compendium, entitle "Pahal" has been brought out by the Ministry of Rural Development. Pahal is a compilation that aspires to support endeavours at the state and local levels to enable and empower PMAY-G beneficiaries to build quality, sustainable and disaster resilient homes. The designs validated by CSIR-CBRI also aims to assist government decision makers, engineers engaged in PMAY-G implementation, panchayats, masons and potential beneficiary households with a wide and flexible range of options related to designs, materials and technologies for efficient implementation of PMAY-G. CSIR-CBRI is also involved with the construction of PMAY-G model houses in the states to demonstrate the efficacy of sustainable design and construction technologies to potential beneficiaries. The effort by the institute is also to eventually enable PMAY-G beneficiaries to make informed decisions related to choice of size of dwelling, layout, materials and technologies for construction and the quality of house they would like to build through the PMAY-G financial assistance. The objective of this contribution is to ensure construction of a PMAY-G house that is appropriate, affordable, disaster resilient and aesthetic.

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National Seminar on "Emerging Building Materials and Construction Technologies"

The Council organized a National Seminar on Emerging Building Materials and Construction Technologies on November, 18, 2016 at New Delhi to bring Engineers, Architects, Technology Providers, Plant and Machineries Manufactures, Users, Govt. Agencies and other stake holders; looking for emerging building materials and technologies and construction practices on one platform & to take stock of new developments in this area.

The National Seminar was inaugurated by Dr. N.Chatterjee, the then Secretary, MoHUPA. Around 65 participants including representatives from govt. agencies, Academic, R&D Institutions, known experts of the country; agencies involved in bringing technologies from advanced countries also participated in the workshop.

The Council had planned the whole seminar under various sub-themes to have detailed discussions and each session was addressed by the eminent key experts working in that area for the benefit of participants during the seminar.

Pre Engineered Safe Homes: Housing for All

*Brig Kuldip K Tiku, SM (Retd)**

Abstract

Based on census of 2011 there was a shortage of 19 million Housing units which is likely to go up to 38 million units by the year 2030, without any intervention. Ninety six percent of this shortage is in the EWS & LIG segment. The urbanization is growing at 2.1% CAGR (double that of China) and by 2050 it is estimated that the population in cities will grow to 900 million.

The Honorable Prime Minister has rightly therefore put before us the target of housing for all by the year 2022 i.e. in the 75th year of our independence. It is therefore a race against time to achieve this vital milestone in the growth trajectory of our nation.

The challenges apart from financial, land and other issues being taken care of by the Govt. of India are as follows:-

a) Faster Delivery (Time)
b) Functional efficiency and Sustainable
c) Affordable costing
d) Quality of product & delivery
e) Minimal maintenance cost

In order to achieve this gigantic task, it would be well appreciated that the existing conventional technology of construction for mass housing is inappropriate & unworkable to achieve the target laid out. The conventional construction methods are not only time consuming but also a drain on the natural resources. The current methods are labour dependent & have an adverse impact on sustainability & environment. We therefore need a technology & system that is efficient, economical, fast & producible in large numbers with in the country. It is therefore prudent to take a paradigm shift from the existing approach and look for alternate systems which can overcome these limitations. There are a number of new construction technologies in vogue in advanced economies, however

Three Storied Residential Housing

Double Storied Guest House

* CEO , RCC Eco Build Systems Ltd., E-mail: kuldiptiku@rccinfra.com.

there adoption to Indian climatic conditions & usages is suspect & needs to be evaluated before taking them on board. **RCC Eco Build Systems Ltd** therefore has been working on this mission & have come up with a technology & system which meets all these challenges & is fully compliant with IS codes . The system consists of **Pre Engineered Safe Homes (PESH)** whose structural frame is made from high strength steel plates and flooring walls roofs & finishes can be modeled to suit local climatic conditions. These are not only flexible in adaption but can be tailored for any use and any climatic conditions at a cost which is at par with the current construction costs using conventional technologies & is faster to construct. The points are more elaborately discussed in the following paragraphs.

Why Pre Engineered Safe Homes (PESH)

Based on what I have stated above it is imperative to see how the **Pre Engineered Safe Homes (PESH)** fills this void. The same is briefly explained below.

Cost Effective - Efficient design & production techniques economize material usage. The cost is insulated against local conditions. It has minimal maintenance requirement, is energy efficient and has high salvage value which greatly reduces the life cycle cost.

Faster - Structures are manufactured and replicated on production lines and erected on site with sets of qualified teams & equipment reducing time of construction by 50 percent. It is mass producible and can be transported anywhere in the world.

Design Flexibility - Latest software and innovative designs compatible with IS Codes allow a vast flexibility of size, span & arrangements. It can be made to suit and improvise based on the customer needs & climatic conditions. The structures are easily expandable for future need.

Sustainable – There is minimal dependence on scarce resources like sand, aggregate and bricks which ensures sustainability & non exploitation of natural resources. There is no dust pollution which today forms over 40% of the Air Pollution in our country. Major components of the buildings are fully recyclable having very high residual value.

Durable – It can be treated to withstand any weather conditions internally or externally and is safer as per IS codes against earthquakes, snow loads etc. and is termite proof.

Having discussed the basic characteristics of what we are offering let us see as to how we achieve these parameters.

Faster Delivery

The Technology depends on pre design and economical fabrication of the basic structural frame work from high strength plates and accessories as per IS 800 ; 2007 in a state of the art manufacturing plant ensuring precision, high quality ,mass production & easy erection at site of work. This reduces the time of construction at site by 50 percent.

Functional Efficiency and Sustainable

The houses which area constructed are tailor made to be functionally efficient i.e. suitable to live in a comfortable manner as well as sustainable being non-dependent on materials affecting sustainability such as sand, cement ,aggregate etc. **PESH** construction technology thus is both functionally efficient as well as sustainable in all respects.

Cost Effective & Economical

The design efficiency, sustainability, non-use of depleting miner-

G + 3 Storied School Building at Jhansi Completed in Six Months from Start to Finish

als & depleting natural resources ensures most economical cost per Square feet of construction with minimal costs of maintenance & high residual value ensures a very reasonable cost of construction which in most cases is at par with the conventional construction costs.

Quality of Product & Delivery

Development of mass housing based on the mission laid out by the Honorable Prime Minister under the Pradhan Mantri Awas Yojna, i.e. Housing for all by 2022, it becomes imperative that the technology & systems for housing be so evolved so as to ensure mass construction in a short time, with quality being safe & durable. The current conventional methods are cumbersome, time consuming, a drain on natural resources & highly terrain, weather & labour dependent. The **PESH technology** as described above overcomes these constraints to a large extent. These are aesthetic & custom built to suit the individuals & local climatic conditions.

Basic Specifications

The basic specifications can be modulated as required. The basic possibilities are as follows:-

FOUNDATIONS	RCC
STRUCTURAL FRAME	Built up Steel Sections with Painting system
FLOOR SLABS	RCC Slab with 0.63 to 0.80 mm decking sheet / Dry Floor panels/Wooden Boards
FLOOR FINISHES	Tiles of Various Sizes as required (Ceramic / Vitrified/ wooden)
WALLS	Brick/ PCC Blocks/ AAC Blocks/ Sandwich Wall panels/Cement Boards, PUF Panels etc.
FINISHING	Plaster / Plaster of Paris as required
PAINTING	OBD inside and External paint /Grit finish out side
WINDOWS	Aluminum/PVC Sliding/ open able as required
PLUMBING	UPVC

Conclusions

Pre Engineered Safe Homes is a proven technology fully compliant with IS Codes as a tailor made solution for mass housing needs and is adaptable to be planned as per any terrain conditions. It reduces construction time by more than 50 percent and the cost of construction is lower or at par with the conventional construction costs. It ensures consistent high quality being manufactured from IS certified materials in a fully controlled and mechanized environment and is sustainable with minimal use of scarce local resources. It is possible to mass manufacture these houses in a short time greatly assisting speedy construction with quality.

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Permanent Display Centre at IIT Kharagpur

BMTPC established a Permanent Display Centre on Emerging Building Materials & Construction Technologies at Department of Architecture and Regional Planning, IIT Kharagpur. The Permanent Display Centre consists of display panels and models depicting Demonstration Housing Projects using Green/ Emerging Technologies, Agro-industrial waste based building materials, Emerging technologies for mass housing, Performance Appraisal Certification, Bamboo based building materials and components, disaster mitigation & preparedness, Pradhan Mantri Awas Yojana (Urban), etc.

The Permanent Display Centre was inaugurated by Dr. Nandita Chatterjee, the then Secretary, Ministry of Housing & Urban Poverty Alleviation, Government of India at IIT Kharagpur Kolkata Centre through video-conferencing in the august presence of Prof. Partha Pratim Chakrabarti, Director, IIT Kharagpur on June 2, 2017 at Deptt of Architecture & Regional Planning, IIT Kharagpur.

पारंपरिक छत निर्माण प्रणालियां

डॉ. डी.एस. रामचंद्रमूर्ति *
डॉ.शैलेश कुमार अग्रवाल **
हिंदी अनुवादः अरुण कुमार तिवारी***

फूस (थैच) की छत/फूस की छप्पर

फूस की छत बनाना एक ऐसी शिल्प/कारीगरी है, जिसमें सूखी वनस्पति जैसे कि पुआल, पटेर (वाटर रीड) और खरई (सेज) एक किस्म की तिकोनी घास का पौधा (क्लैडियम मारीस्कश) जिसके द्वारा आंतरिक छत से पानी बाहर की ओर निकाला जा सके, का इस्तेमाल करके फूस की छत बनायी जाती है। यह छत बनाने की बहुत ही पुरानी विधि है और इसे दोनों उष्णकटिबंधीय और समशीतोष्ण जलवायु में उपयोग किया जाता रहा है। अभी भी विकासशील देशों में भवन निर्माताओं (बिल्डरों) द्वारा आमतौर पर कम लागत वाली क्षेत्रीय वनस्पति को ही थैच (फूस) के रूप में इस्तेमाल किया जाता है। इसके विपरीत, कुछ विकसित देशों में ऐसे कुछ समृद्ध लोग आजकल अपने घर को देहाती रूप देने के लिये इसे अपनाना पसंद करते हैं, जिन्हें पारिस्थितिकी अनुकूल छत की चाहत हो अथवा जिन्होंने मूल रूप से फूस वाला घर खरीदा हो। थैचिंग पद्धतियां पारंपरिक रूप से एक पीढ़ी से दूसरी पीढ़ी तक पहल की गयी है। नये भवनों में, छत पर एक ठोस अग्निरोधी अवरोध न हो तो आग लगने के कारण से फूस जल भी सकता है। फूस का प्रदर्शन छत की आकृति और डिजाइन, छत की ढ़लान सामग्री की गुणवत्ता, घरामी (थैचर) की विशेषज्ञता और स्थिति–भौगोलिक और स्थलाकृति पर निर्भर करती है।

फूस के अपने कुछ प्राकृतिक गुण हैं जो इसके प्रदर्शन के लिए फायदेमंद हैं। यह स्वाभाविक रूप से मौसम प्रतिरोधी है, और जब इसकी व्यवस्था सही से की जाये तो यह बहुत कम पानी सोखता है। जल प्रतिधारण के कारण छत के वजन में विशेष वृद्धि नहीं होनी चाहिए। कम से कम 50° की छत की ढ़लान की वजह से पानी के संरचना में घुस पाने से पहले ही, ढ़लान पानी को नीचे निकाल देता है। फूस भी एक प्राकृतिक इन्सुलेटर/ताप संवाहक है, और फूस की रिक्तता (पिट) के भीतर वायु की पकड़ गर्म और ठंडे मौसम दोनों में इमारत को बचाता है। फूस की छत गर्मियों में इमारत की शीतलता और सर्दियों में उसकी गर्माहट सुनिश्चित करती है।

फूस के घरों को अग्नि जोखिम माने जाने के कारण सुनिश्चित करना कठिन होता है चूंकि ये श्रम–गहन होते हैं और यह स्लेट या टाइल से ढकी जाने वाली छत की तुलना में अधिक महंगे होते है। पक्षी इन छतों को बर्बाद कर सकते है और कृतंक (चूहे, गिलहरी आदि) को भूसे में अवशिष्ट अनाज आकर्षित करते है जिसके कारण छत को नुकसान हो सकता है।

दक्षिणी भारत के ग्रामीण इलाकों और कभी–कभी शहरों में यदि जाया जाये तो थैच की छत वाले घर दिख जाते हैं। पकी हुयी/पूरा आकार लिये हुई घास की रीड का चयन किया जाता है। साफ सतह एंव थोड़े गीलेपन के साथ, जो कि उन्हें नरम बनाती है, वांछित पानी प्राप्त करने के लिए इसें धूप में सूखाया जाता है और फिर छोटे चटाई के रूप में एक साथ बांधा जाता है। इस तरह के चटाई बांस से या लकड़ी की डंडियों से बंधे होते है। घास की अतिरिक्त परत बिछायी जाती हैं, उन्हें कभी–कभी निचली परत पर बांधते हैं। नारियल या सुपारी के पत्तों को भी इसी तरह इस्तेमाल फूस के विकल्प के रूप में किया जाता है। अक्सर, बुना हुआ नारियल के पत्ते का इस्तेमाल थैच के अंदरूनी हिस्से की तरफ किया जाता है।

कई आधुनिक संस्करणों/नमूनों में, छत के नीचे जी.आई.(गेलवनाइज्ड आयरन) के साथ संरचनाएं होती हैं फिर फूस के साथ सबसे ऊपर लगी होती है, यह आग और कृन्तकों के भय से छुटकारा दिलाता है। एक–दूसरे पर सबसे ऊपर बहुत घनी छत की परत के लिए, घास पटेर को झाड़ू की तीलियों के समान एक साथ बांधा जा सकता हैं। यह कई सालों तक टिकी रहती है। दीवार के शीर्ष पर क्षैतिज आकार में

* पूर्व वैज्ञानिक, स्ट्रक्चरल इंजीनियरिंग रिसर्च सेंटर, चेन्नई
** कार्यकारी निदेशक, निर्माण सामग्री एवं प्रौद्योगिकी संवर्द्धन परिषद्, नई दिल्ली
*** प्रमुख (पीएमटी एवं एडमिन), निर्माण सामग्री एवं प्रौद्योगिकी संवर्द्धन परिषद्, नई दिल्ली

इसे लगाने से चूहों और सांप को रोका जा सकता है। थैच के संबंध में इसकी अग्नि सुरक्षा को लेकर आपत्ति होती है, वंरच रसायन से उपचारित थैच से अग्नि प्रतिरोधकता के लिए प्रयास जारी है।

फूस से बनी छतें अब कम हो गयी हैं, लेकिन कुछ मानदंडों को देखते हुए, सबसे अच्छे विकल्पों वाली अभी भी विद्यमान हैं। इनको मजबूत दिखने वाले रूप के कारण उन्हें रिसॉर्ट, रिट्रीट और खेतों में इस्तेमाल करना पसंद किया जाता है। ये अस्थायी होते हैं इस कारण, उन्हें जारी रखने या बदलने का विकल्प 6 से 10 वर्षों के बाद भी बना रहता है, लगभग 30° ढलान कोण से पर बनाना इस उम्दा छत की औसत जीवन अवधि के लिये आवश्यक है। फूस का मुख्य आकर्षण जलवायु परिवर्तन हो सकता है, जिसके कारण वे अभी तक सबसे स्थायी छत के रूप में मानी जाती हैं। कई गांवों में, फूस छतों को अभी भी बनाया जा रहा है, लेकिन थैच छतों को बनाने वाले कुशल लोग कम हो रहे हैं।

सीएसआईआर – स्ट्रक्चरल इंजीनियरिंग रिसर्च सेंटर ने थैच छत के लिये तूफान के दौरान तेज हवाओं का सामना करने के लिए दिशा निर्देश बनाये हैं। इसके अंतर्गत कार्बनिक रस्सियों के साथ विकर्ण दिशाओं में छत के शीर्ष को बांधने के लिये उपाय सुझाए गए है, जिसमें स्तंभ दिशाओं को लंबवत लकड़ी या इस्पात के टुकड़ों द्वारा सीधी दिशाओं में लंगर करना, और लकड़ी की छत गठ्ठर हिस्सों को हल्के स्टील प्लेट, तार या पट्टियों के साथ जीआई बोल्ट का उपयोग करते हुए बांधना जरूरी बताया गया है।

चित्र 1: थैच (फूस) की छत

एस्बेस्टोस छत (ए.सी. शीट की छतें)

एस्बेस्टोस भूमिगत रॉक संरचनाओं में मिलने वाला प्राकृतिक खनिज है। व्यावसायिक प्रयोजनों के लिए, यह खनन और पत्थर चूरा (रॉक क्रस्ट) द्वारा पुनर्प्राप्त किया जाता है। एस्बेस्टस की दो अलग–अलग किस्में हैं (।) विविध क्राइसोटाइल और (।।) एम्फिबोल किस्म। एम्फिबोल किस्म के अंतर्गत क्रोसिडोलाइट, एमोसाइट, ट्रेमोलाइट आदि शामिल हैं। अब केवल विविधता वाली क्राइसोलाइट (सफेद अभ्रक) ही वाणिज्यिक उपयोग में है। भारतीय एस्बेस्टोस सीमेंट (एसी) शीट और पाइप निर्माता, एसी शीट और पाइप के उत्पादन के लिए, क्रिसोटाइल फाइबर द्वारा अपनी सभी जरूरतों की पूर्ति हेतु इसे कनाडा, ब्राजील, रूस, जिम्बाब्वे और कजाकिस्तान से आयात करते हैं। भारत में क्रिसोटाइल एस्बेस्टोस अब बहुत कम और नगण्य मात्रा में खनन किया जाता है, जिसका हमारे एस्बेस्टोस–सीमेंट उत्पादन के लिए कोई फायदा या प्रासंगिकता नहीं है। अभ्रक की अन्य किस्में एम्फिबॉल्स (क्रोसिडाइलाइट, एमोसाइट, ट्रेमोलाइट, आदि) जिन्हें असुरक्षित माना जाता था, भारत सहित दुनिया भर में इन्हें प्रतिबंधित कर दिया गया है। जहां कहीं भी एस्बेस्टोस उत्पादित या उत्पाद में उपयोग किया जाता है, केवल क्रिसोटाइल की ही अनुमति दी जाती है।

क्रिसोटाइल एस्बेस्टोस फाइबर, (मुख्य रूप से मैग्नीशियम और सिलिका से मिलकर बनता है), उम्दा तनन गुणवत्ता का मजबूत एजेंट है। जबकि इसकी लचीली शक्ति स्टील की तुलना में अधिक है, इसके अन्य दुर्लभ गुणों में उच्च अग्निरोधकता, रासायनिक प्रतिरोधी और ताप–विसंवाहक शामिल हैं। वास्तव में यह चमत्कारी खनिज है।

चित्र 2: इमारतों के लिए एस्बेस्टोस शीट की छत

एस्बेस्टोस सीमेंट उत्पाद क्रिसोटाइल फाइबर (लगभग 8–9 प्रतिशत), सीमेंट (लगभग 40 प्रतिशत), फ्लाई ऐश (लगभग 30 प्रतिशत), शेष भाग लकड़ी के गूदे और पानी के मिश्रण से बना है। भारत में आयातित एस्बेस्टोस फाइबर का 90 प्रतिशत से अधिक भाग एसी शीट और पाइप उत्पादन में खपत होते हैं।

भारत में एसी शीट का इस्तेमाल लगभग 70 वर्षों से किया जा रहा है। मौसम रोधी और जंग प्रतिरोधी होने की वजह से ये छत व्यावहारिक रूप से लम्बी उम्र वाली और रखरखाव मुक्त होती हैं, जबकि धातु की चादरें जंग और खुले में रहने के जोखिम के कारण खराब होती हैं। एसी शीट्स भी गोदामों, कारखानों, कम लागत वाले आवास के लिए सबसे अधिक लागत प्रभावी, आसानी से स्थापित की जाने वाली, मजबूत और टिकाऊ छत सामग्री साबित हुई हैं। भारत, के अलावा रूस, चीन, थाईलैंड और ब्राजील भी एसी शीट्स के सबसे बड़े उपयोगकर्ता हैं।

जंग और कटाव मुक्त होने के कारण एसी शीट्स और पाईप को एक बार स्थापित करने के बाद रखरखाव की अथवा बदलने की आवश्यकता नहीं पड़ती। ये बहुत ही लागत प्रभावी भी होती हैं। एसी उत्पाद निर्माण प्रक्रिया में बहुत कम ऊर्जा का उपभोग करते हैं और किसी भी तरह से प्राकृतिक संसाधनों को व्यय नहीं करते। तेजी से बढ़ती आबादी और सीमित संसाधनों के संदर्भ में देश की विकासशीलता में महत्वपूर्ण रूप से जगह बनाते हैं। एसी उत्पादों के लिये निम्नलिखित भारतीय मानक दिशार्निदेश बताते हैं।

रूफींग सामान में नालीदार छत शीट्स के लिये आईएस 459, बिल्डिंग बोर्ड के

लिये आईएस 2098, समतल शीट के लिये आईएस 2096 और छतों के अवयवों के लिये आईएस 1626 (पार्ट-III) उपलब्ध हैं। आईएस 159 द्वारा एसी प्रेशर पाइप को कवर किया जाता है।

रीसाइक्लिंग (पुनर्नवीनीकरण) और निपटानः

ज्यादातर विकसित देशों में, आम तौर पर एस्बेस्टोस का लैंडफिल साइटों में खतरनाक कचरे के रूप में निपटारा किया जाता है। भवनों के गिराये जाने से अभ्रक आधारित सामग्री बड़ी मात्रा में निकलती है जो बिल्डरों और संपत्ति डेवलपर्स के लिए महत्वपूर्ण समस्याएं पैदा करता है – ऐसी इमारतों को अक्सर टुकड़े टुकड़े करना पड़ता है या संरचना को यांत्रिक या विस्फोटक साधनों से तोडने से पहले एस्बेस्टोस को अच्छी तरह से हटा दिया जाना चाहिए। एक उदाहरण के रूप में ग्लासगो, स्कॉटलैंड में रेड रोड फ्लैट्स ऐसे है जिसमें वॉल पैनलिंग के लिए बड़ी मात्रा में एस्बेस्टस सीमेंट बोर्ड का इस्तेमाल किया है। यहां ब्रिटिश स्वास्थ्य और सुरक्षा नियमों का कहना है कि किसी मंजिल/लैंडफिल वाले स्थल से एस्बेस्टोस सामग्री को किसी दिन निश्चित समय पर विशेष रूप से अनुकूलित वाहनों के माध्यम से हटा देना चाहिए।

एस्बेस्टोस को हानिरहित सिलिकेट ग्लास में परिवर्तित करके पुनर्नवीनीकरण किया जा सकता है। 1000–1250° पर थर्मल अपघटन की प्रक्रिया गैर–खतरनाक सिलिकेट का मिश्रण पैदा करती है, और 1250° से ऊपर तापमान में सिलिकेट ग्लास पैदा होता है। माइक्रोवेव थर्मल उपचार का उपयोग एस्बेस्टोस और एस्बेस्टोस युक्त कचरे को पोर्सिलिन स्टॉनवेयर टाइल, छिद्रपूर्ण सिंगल–फायरड वॉल टाइल और सिरेमिक ईंटों में परिवर्तित करने के लिए औद्योगिक निर्माण प्रक्रिया में उपयोग किया जा सकता है।

जस्ती/Galvanised Iron की छत

नालीदार जस्ती वाला लोहा या स्टील (सीजीआई) एक इमारत सामग्री है जो हॉट–डिप जस्तीदार हल्के (माइल्ड) स्टील की शीट से बना है, उनमें एक रेखीय नालीदार पैटर्न उत्पन्न करने के लिये कोल्ड–रोल्ड किया गया है। कोरूगेशन्स सीधी लम्बवत में दिशा में नालीदार शीट की मुड़ने (झुकाव) की शक्ति बढ़ाती है, लेकिन उनके समानांतर में नहीं। आम तौर पर प्रत्येक शीट अपनी मजबूत दिशा में लंबे समय तक टिके रहने के लिए निर्मित होती है। सीजीआई वजन में हल्की होती है और आसानी से ले जायी जा सकती है यह पहले और अब भी विशेष रूप से शेड और पानी के टैंक रखनें जैसे कार्यों के लिए ग्रामीणों और सैन्य भवनों में व्यापक रूप से उपयोग में लायी जाती है।

छत के प्रयोजनों के लिए, चादरें कुछ हद तक टाइलों की तरह बिछायी जाती हैं, जिसमें डेढ़ (एक और आधा) छतों के पार्श्व ओवरलैप होते हैं, और पानी के निस्तारण (वाटरप्रूफ) बनाने के लिये लगभग 150 मिमी का एक ऊर्ध्वाधर ओवरलैप किया जाता है। सीजीआई पूरे विश्व में औद्योगिक इमारतों के लिए अत्यधिक इस्तेमाल में आने वाली आम निर्माण सामग्री है।

गढ़ा हुआ लौह सीजीआई (गढ़ा लौहा सीजीआई) की जगह धीरे–धीरे 1890 दशक के आसपास हल्के स्टील ने ले ली और लौह सीजीआई अब मिलता नहीं है, लेकिन इसका सामान्य नाम बदला नहीं गया है। आम कोरूगेशंस के साथ जस्ती चादरें भी धीरे–धीरे 55% Al-Zn लेपित स्टील (Al-Zn coated steel), या कॉम्प्लेक्स प्रोफाइल के साथ कॉइल–पेंटेड शीट्स अब ज्यादा इस्तेमाल हो रहा हैं। अन्य सामग्रियों जैसे प्लास्टिक और फाइबर ग्लास को नालीदार रूप दिया गया है। इन उत्पादों का कई तरह से उपयोग उपलब्ध हैं जिनमें वे धातु शीट के साथ उपयोग की जाती हैं ताकि प्रकाश नीचे प्रवेश कर सके।

कोरूगेशंस पिच (दो क्रेस्ट के बीच की दूरी) और गहराई (एक शिखर के ऊपर से एक गर्त के नीचे से ऊंचाई) के संदर्भ में बताया गया हैं कि पिच और गहराई का समान होना बहुत जरूरी है, ताकि चादरें आसानी से परिवहन के लिए ढेर एकत्रित (स्टेकेबल) हो जाएं, और जोड़ते वक्त सुचारू रूप से ओवरलैप की जा सकें। पिच की रेंज 25 मिमी से लेकर 125 मिमी तक होती है यह सीजीआई के लिए एक बार सामान्य था, ऊर्ध्वाधर दीवारों के लिए इस्तेमाल की जाने वाली छत सीजीआई की तुलना में कम ढ़लान और गहराई की होती है इस छोटी सी पिच वाली सामग्री को 'नालीदार' के बजाय कभी–कभी 'रिप्लेड' कहा जाता था। हालांकि आजकल, लगभग सभी सीजीआई उत्पादन में 76 मिमी की समान पिच है।

क्ले छत टाइलें

ये टाइलें आवरण सामग्री के रूप में पिच्ड छतों के लिए उपयोग की जाती हैं। कई प्रकार की छत टाइलें बाजार में उपलब्ध हैं। कुछ टाइल प्रकार नीचे दिए गए हैं।

चित्र 3: भारत में आमतौर पर इस्तेमाल की जाने वाली छत टाइलें

सादे टाइल्स – ये 10 से 17 मिमी की मोटाई वाली आयताकार टाइल्स हैं। योजना में आकार 25 सेमी X 15 सेमी है। टाइलों का एक छोटा किनारा या तो नीचे की ओर रह जाता है या छत की तख्ती पर उन्हें लटकाने के लिए नीचे की तरफ करने वाले दो लग्स हैं जो टाइल में नोक के पास दो नट छिद्र स्थायी रूप से तख्ते (battens)से जोड़ने के लिए दिये जाते हैं।

इलाहाबाद टाइल्स – टाइल्स के दो हिस्से हैं। एक भाग चैनल आकार का है। दूसरा हिस्सा अर्ध वृत्ताकार है। चैनल के आकार का भाग 38 सेमी लंबा और एक छोर पर 23 सेमी चौड़ा है, और दूसरे छोर पर 27 सेमी चौड़ा है। अर्ध वृत्ताकार का एक भाग 38 सेमी लंबा है और 12 सेमी का व्यास एक छोर पर और दूसरे छोर पर 16.5 सेंटीमीटर है।

मैंगलोर टाइल्स – मैंगलोर टाइल्स मंगलौर शहर की एक किस्म की टाइल है। पूरे भारत में इन लाल टाइलों की बड़ी मांग है, यह कठोर लेटराइट क्ले मिट्टी से तैयार की जाती है यह उद्योग खूब फलफूल रहा है। इन टाइलों को मशीनों द्वारा ढाला जाता है। ये बहुत मजबूत और कठोर होती हैं बांधने के दौरान, कई टाइल्स टूट जाती हैं। सीबीआरआई, रुड़की ने सुझाव दिया है कि थोड़ी मात्रा में सोडियम क्लोराइड को क्ले मिट्टी में डालकर बनाने से इसकी टूटने की प्रकृति को कम किया जा सकता है।

सियालकोट टाइल्स – इन टाइलों का अनुदैर्ध्य दिशा में अर्ध–वृत्ताकार विन्यास होता हैं, इसका अर्थ हैं– लंबाई के साथ। कोरूगेशन्स नीचे की ओर उन्मुख होता है। अन्य अनुदैर्ध्य किनारा चैनल किनारे की तरह ऊपर की तरफ होता है।

पॉट टाइल्स – ये खोखले आधे होते हैं और अनुदैर्ध्य दिशा में निस्तारित पतले) होते हैं। टाइलें कुम्हार के चाक (पहिये) पर बनती हैं और कुम्हार अपने गीले हाथ करके पतली आकृति देता है। एक गीले कपड़े से अंदरूनी और बाहरी सतहों को चमकाया जाता है। टाइल्स की लंबाई 15 से 20 सेंटीमीटर के बीच अलग–अलग होती है और व्यास एक छोर पर 11.4 से 14 सेंटीमीटर और दूसरे छोर पर 8.9 से 11.4 सेंटीमीटर से भिन्न होता है। ये ऊपर की ओर एक के अंतर से इनकी अवतल और उत्तल दिशा में छत पर बिछायी जाती हे। चूंकि टाईल्स को हाथों से ढाला जाता है, इसलिए कुछ अवधि के बाद इनका टूटना संभावित और जिसकी वजह से बदलना भी पड़ सकता हैं।

पैन टाइल्स – ये आयताकार होती हैं। जब इसे लंबाई में काटा जाता है, तो यह एस–आकार देती है। टाइल की लंबाई 33 से 38 सेंटीमीटर के बीच होती है, और चौड़ाई 23 से 28 सेंटीमीटर होती है। ये टाइल तुलनात्मक रूप से भारी, मजबूत और टिकाऊ होती हैं।

मद्रास टेरेस रूफ

इसे देश के दक्षिणी हिस्सों में छत ईंटों और चूने के कंक्रीट से बना एक समग्र फर्श निर्माण व्यापक रूप से अपनाया जाता है। आमतौर पर यह मद्रास टेरेस कंस्ट्रक्शनस के नाम से जाना जाता है। तमिलनाडु में व्यापक उपयोग के कारण छत के इस प्रकार को मद्रास छत कहा जाता था, हालांकि यह दक्षिण भारत भर में लोकप्रिय हो गया है। सदियों के अनुभवों के फलस्वरूप, यह निर्माण काफी मजबूत, टिकाऊ और जलरोधक (वाटरप्रूफ) पाया गया है। अगर कारीगरी में उचित कौशल हो तो यह बहुत तीव्रता से निर्मित हो जाती है। ईंटों में आर्क प्रक्रिया से छत को सहारा मिलता है जो नजदीकी रिक्त जोइस्ट के माध्यम से एक समतल परत बनाने लिये पंक्ति में बांधी जाती है और यह सहारा आगे और एक ठोस परत द्वारा बढ़ाया जाता है जो ईंटो के साथ मजबूत संबध विकसित करता है और इस आधार पर इनकें साथ मिलकर प्रभावी होता हैं। इस प्रकार की छत के लिए भारतीय मानक आईएस 2119 विनिर्देश देता है।

मद्रास छत जमीन/मंजिल या छत में निम्न घटक होते हैं:

क) चूना मोर्टार मिश्रण का अनुपात 1:14 (चूना पुट्टी : रेत की मात्रा के अनुसार) जो किनारे पर छतों में ईट–सज्जा में लगा हुआ है, वह सधनता में या तो लकड़ी या पूर्व ढालें हुये सुदृढ़ कंक्रीट या स्टील ज्वाइंस्ट के साथ पकड बनाये होते हैं और एक उपयुक्त सिलिंग बनने के साथ छज्जे पर ईट–सज्जा में प्रभावी होते हैं।

ख) चूना, टूटन ईट कुल कंक्रीट को टेरेस – ईट–सज्जा के ऊपर निर्देशित मोटाई पर बिछाना और आवश्यक जमीन/मंजिल अथवा छत फिनिश के शीर्ष पर; और

ग) उपयुक्त जमीन/मंजिल और सीलिंग फिनिश ड़ालना होता है।

मद्रासी छत को सहारा देने वाले ज्वाइस्ट की जगह, स्पेसिंग केंद्र से केंद्र तक 450 मिमी से अधिक ली जाती है। जोइस्ट (कड़िया) को उनके ऊपर आने वाले छत के हिस्से को सहारा देने वाले

चित्र 4: मद्रास थैच छत

बीम के रूप में डिजाइन किया गया है। टैरेस–ईट सज्जा को दीवारों पर कम से कम 150 मिमी तक इसे बहनीय होना चाहिए या सभी तरफ से सहारा मिलना चाहिए। मद्रास छत की फिनिशिंग की औसत मोटाई 185 मिमी है। आम तौर पर मद्रास टेरेस का डेड–लोड डिजाइन के उद्देश्य हेतु 370 किलो प्रति वर्ग मीटर के रूप में लिया जा सकता है। आईएस 2119 के अनुसार जोइस्ट की झुकाव अवधि के I/480 से अधिक नहीं होनी चाहिए।

टेरेस ईंटों का आकार 150X75X25 मिमी है। टेरेसिंग ईंट को इस्तेमाल से पहले कम से कम 4 घंटे पहले पानी में डूबा कर रखा जाता है। उसके बाद उसे सुखाना होता है। छत– ईट सज्जा में मोर्टार के साथ आसंजन/चिपकन विकसित करने के लिए यह अति आवश्यक है।

छत ईंटें, छोरों से जोइस्ट के बीच तिरछी पंक्तियों में बिछाई जाती हैं। एक कोने से बिछाना शुरू किया जाता है और विपरीत कोने की तरफ आगे बढ़ता है। प्रत्येक पंक्ति को अगले एक से पहले पूरा किया गया है, जिसमें निकट इसे शुरू किया जाता है। टैरेस ब्रिकवर्क का दीवारों पर कम से कम 150 मिमी या चारों ओर से दीवारों पर सहारा होना चाहिए। टेरेसिंग ईंट को चूने मोर्टार मिश्रण 1:1.5 (चूना पुट्टी : रेत, मात्रा द्वारा) में बिछाया जाता है। मोर्टार जोड़ों की मोटाई 10 मिमी से अधिक नहीं होनी चाहिए। बिछाने के दौरान, ईंटें पहले से रखी आसन्न पंक्ति की ओर दबायी जाती हैं ताकि यह मोर्टार के साथ अच्छी तरह से बंधे और आंशिक रूप से पार्श्व चिपकन पैदा करती है जो इनको फिसलने से रोकता है। ईट–सज्जा के स्वयं आलम्बित आर्क प्रक्रिया को बढ़ाने के लिए, ईंटों को इस तरह लगाया जा सकता है कि ईंट के लिए जोइस्ट के बीच मामूली उठान हो, आम तौर पर यह उठान 5 मिमी से अधिक नहीं होना चाहिए। जोइस्ट को कमजोर ऊंचाइयों के नीचे से सहारा दिया जा सकता है, जबकि छत को ईट–सज्जा में दरारों से बचाने के लिए इस तरह बिछाया जाता है।

इस प्रकार के छत पर सेन्टरिंग निर्माण की आवश्यकता नहीं है। टेरेस पर ईंटों के सेट होने के बाद, चूने की खंडित ईंट द्वारा कुल कंक्रीट मिश्रण का अनुपात 1: 24 (स्लेक्ड/कम चूने की खंडित ईंट मात्रा द्वारा) में एक परत रखी गई है जिसे 100 मिमी की औसत मोटाई तक बिछायी जाती है। चूने कंक्रीट बिछाने के बाद, प्रारंभिक भराव 2 किलोग्राम से अधिक वजन वाले लकड़ी के भराव/रैमर (दूरमूठ) के साथ किया जाता है जिससे कि चूने कंक्रीट की परत 75 मिमी की मोटी हो जाती है। इसके बाद समेकन को कम से कम 7 दिनों के लिए हाथ से थपकी कर किया जाता है ताकि कंक्रीट को मजबूत किया जा सके और बीटर कंक्रीट पर कोई प्रभाव न ड़ाले, और सतह पर, जब उस पर चोट मारी जाये तो आसानी से रिबाउंड हो सके। हाथ से थपकी के दौरान सतह को चूने का पानी और शर्करा के संयोजन या एक टर्मिनलिया चेबुला (कडुकेई या हारढ़) या गुड़ (गुर और गुगल) के घोल जो पानी में भिगोने से तैयार किया जाता है, इससे छिड़काव किया जाता है। छत या फर्श फिनिश करने के साथ छत निर्माण का काम समाप्त हो जाता है।

पत्थर की पट्टीयां की छत

ग्रेनाइट, चूना पत्थर, बलुआ पत्थर, स्लेट इत्यादि जैसे प्राकृतिक पत्थरों के स्लैब बड़े पैमाने पर आंध्र प्रदेश, मैसूर, महाराष्ट्र, राजस्थान, उत्तर प्रदेश, आदि में फर्श और छत के निर्माण के लिए उपयोग किए जाते हैं, यहां इस तरह के पत्थर भरपूर मात्रा में उपलब्ध है। यह भारतीय मानक IS 2792 के अंतर्गत हैं। संरचनात्मक फर्श या छतों का निर्माण जहां पत्थर की स्लैब निकटता से जुड़ी जोइस्ट को सहारा देती हैं और चूने के ठोस या सीमेंट कंक्रीट की एक परत के रूप में आवश्यक मंजिल या छत की फिनिशिंग में आवश्यक योगदान देती है।

पत्थर की पट्टिया और जॉइस्ट फर्श में निम्नलिखित घटक सम्मिलित होते है:

ए) फर्श स्लैब को सहारा देने के लिए जॉइस्ट 30 से 80 सेमी के अतिरिक्त दूरी पर होने चाहीये।

बी) निर्दिष्ट आयामों की स्टोन स्लैब सहारा देने के लिये नजदीकी से बिछाया जायेगा ताकि उनके बीच का विस्तार हो सके। स्लैब को जोइस्ट के शीर्ष पर या नीचे के किनारों पर बिछाया जा सकता है, जैसे कि रोल्ड स्टील के जोइस्ट के साथ, इनको नीचे निकले हुए किनारे पर रखा जा सकता है। तब तक छत के पानी के छिद्रों के लिए विशेष सावधानी बरती जाती है, निचले किनारों पर स्लैव में जंग खाना छत के लिये उपयुक्त नहीं होता है। फर्श के लिए, इस निर्माण को डिजाइनर के विकल्प के रूप में लिया जा सकता है क्योंकि आवश्यकताओं और दृश्य के आधार पर जोइस्ट का चयन किया जाता है।

सी) इन्सुलेशन और वॉटरप्रूफिंग प्राप्त करने के लिये चूना कंक्रीट या सीमेंट कंक्रीट की एक परत पत्थर की स्लैब पर लगायी गई है। छत की फिनिशिंग के लिये पत्थर के फर्श को या तो अनुपात 1:3 का म्रिश्रण या 20 मिमी मोटे प्लास्टर से या अन्य प्रकार के सिमेंट प्लास्टर के साथ फर्श/छत बना सकते हैं।

विभिन्न प्रकार के स्टोन स्लैब के लिए आड़े झुकाव में मुनासिब बल स्लैब की अंतिम आड़ी मजबूती 1/10 से अधिक

चित्र 5: स्टोन स्लैब छत

नहीं हो। ग्रेनाइट, बलुआ पत्थर और चूना पत्थर की गणना में अनुमेय तनाव के लिए निम्नलिखित मानों का उपयोग किया जा सकता है:

ग्रेनाइट : 15 किग्रा/वर्ग से.मी.

बलुआ पत्थर : 8 किग्रा/वर्ग से.मी.

चूना पत्थर : 8 किग्रा/वर्ग से.मी.

उपयोग किये जाने वाले पत्थर का यूनिट वजन गणना के लिये, विशेष रूप से इस्तेमाल किए जाने वाले पत्थर के विशिष्ट मानदेय की अनुपस्थिति में 2,700 किग्रा/घन मीटर के रूप में माना जा सकता है। हर बिंदु पर एक स्लैब की मोटाई कम से कम 3 सेंटीमीटर के अधीन, संरचनात्मक गणना के अनुसार उपयोग के लिए बताये गये निर्देशों से कम नहीं होनी चाहिए।

बांस निर्मित घर

बांस लकडी का एक उत्कृष्ट विकल्प है। भारत में, विशेष रूप से पिछड़े ग्रामीण इलाकों में जहां सड़क और संचार विकसित नहीं हैं, बांस घरों के निर्माण में एक महत्वपूर्ण भूमिका निभाते हैं, घर के उपकरण आदि के लिए तथा विभिन्न कारणों से जंगलों में लकड़ियों की अनुपलब्धता से, बांस अधिक से अधिक आधार प्राप्त कर रहा है। भारत दुनिया में बांस उपलब्धता का दूसरा सबसे बड़ा उत्पादक देश है। देश बांस के कुल उत्पादन का 45 प्रतिशत का उपयोग कागज उद्योगों में किया जा रहा है।

बांस निर्माण अक्सर उष्णकटिबंधीय देश में गरीब ग्रामीण आवास से जुड़ा होता है, लेकिन एक इमारत/भवन सामग्री के रूप में, बांस अपने संरचनात्मक और यांत्रिक गुणों के कारण बना हुआ है, जिसमें ताकत/वजन अनुपात मुख्य एक कारण है। हालांकि बांस को 'गरीबों के लकडी' के रूप में संदर्भित किया गया है, लेकिन अब यह तेजी से लोकप्रिय हो रहा है। गैर प्रदूषणकारी, टिकाऊ और भूकंप प्रतिरोधी निर्माण सामग्री की वैश्विक मांग के कारण, आर्किटेक्ट्स के बीच बांस के निर्माण में तेजी से दिलचस्पी बढ़ रही है। बांस न केवल छोटे संसाधनों वाले समुदायों के लिए इष्टतम समाधान प्रदान करते हैं, बल्कि यह रिसोर्ट्स के लिए उच्च आर्थिक स्तर के पेशेवरों और संस्थानों के लिए एक लोकप्रिय संसाधन और अध्ययन का विषय भी है।

बांस का निर्माण में उपयोग के लिए कीड़ों और सड़ांधों से बचाव किया जाना बहुत आवश्यक है। इसके लिए सबसे सामान्य तरीका बोरेक्स और बोरिक एसिड का मिश्रण है। एक अन्य प्रक्रिया में कीटों को आकर्षित करने वाले स्टार्च को हटाने के लिए कटे बासों को पानी में उबालना भी शामिल हैं। बांस को उन क्षेत्रों में कंक्रीट के लिए सुदृढीकरण के एवज में इस्तेमाल किया गया है जहां यह भरपूर मात्रा में है। बांस में इस कार्य को पूरा करने की जरूरी ताकत होती है, लेकिन अनुपचारित बांस कंक्रीट से अवशोषित जल के साथ फूल जाता है, जिससे इसमें दरार (फटने की स्थिति) आ जाती है। इस कमी को पूरा करने के लिये कई प्रक्रियाओं का पालन किया जाता है।

भारत के उत्तर–पूर्वी क्षेत्र में पारंपरिक निर्माण में ज्यादातर घर ठेठ बांस के होते हैं, जिन्हें स्थानीय रूप से 'इक्रा' नाम से जाना जाता है, और इसे आसामी घरों के रूप में भी पहचानते हैं। पूर्वोत्तर भारत में इन आवासों की कार्यप्रणाली सामान्य हैं इस तरह के अधिकांश घरों को आवासीय उद्देश्यों के लिए उपयोग किया जाता है।

चित्र 6: शंघाई में एक्सपो 2010 में भारत मंडप का बांस गुंबद

आमतौर पर इन घरों को स्थानीय हल्के वजन वाले बांस, लकड़ी के तख्ते, थैच इत्यादि के साथ बनाया जाता है। ऐसे घरों में बांस/लकड़ी के बीम–स्तंभ की उचित व्यवस्था होती है और आयताकार होने से हल्के भूकंप से सुरक्षा भी प्रदान करते हैं।

इक्रा घर ईंट या पत्थर की चिनाई वाली दीवारों के साथ एक मंजिला संरचनाएं हैं जो लगभग 1 मीटर उॅचाई के चबूतरे पर बनाई जाती है। यह चिनाई लकड़ी के फ्रेम के साथ बांस की चटाई वाली दीवारों को सहारा प्रदान करती है, जिसे सीमेंट या मिट्टी के प्लास्टर के साथ बनाया जाता है। छत में आम तौर पर लकड़ी/बांस ट्रस पर समर्थित जीआई शीट होती हैं, जो बाद में समानांतर दीवारों को जोड़ते हैं। बांस अधिरचना स्टील के एंगल का उपयोग करती हुयी चिनाई वाली नींव की दीवारों से जुड़ा है, और बोल्ट और कील से समतल किये जाते हैं। पिछले भूकंप के दौरान इक्रा संरचनाओं में किसी भी महत्वपूर्ण क्षति की कोई रिपोर्ट नहीं आयी थी।

शंघाई में एक्सपो 2010 में भारत मंडल (चित्रः 6) के संरचनात्मक सदस्यों के लिए बांस का इस्तेमाल किया गया था। मंडप विश्व का सबसे बड़ा बांस गुंबद है, लगभग 34 मीटर का व्यास है, बांस की बीम/सदस्यों को फेरो–कंक्रीट स्लैब, जलरोधी/वाटरप्रूफ, तांबा प्लेट, सौर पीवी पैनल, एक छोटे से पवनचक्की और जीवित पौधों से सम्पन्न बनाया हुआ है। कुल 30 किमी वर्ग क्षेत्र मे बांस का प्रयोग किया गया था।

चित्र 7: बांस आवास प्रणाली –इक्रा आवास

गुंबद 18 मीटर लंबे स्टील पाइल के साथ और स्टील की छल्लेदार बीम की शृंखला से बना है। बांस को बोरैक्स और बोरिक एसिड से साथ उपचारित किया गया था, यह अग्निरोधक और कीटनाशक था और आवश्यक आकार में मुड़ा हुआ था। बांस के वर्गों को आवश्यक लंबाई देने के लिये सुदृढ सलाखों के साथ और कंक्रीट मोर्टार के साथ जोड़ा गया था।

कंक्रीट छत

सबसे व्यापक रूप से उपयोग होने वाली निर्माण सामग्री सीमेंट मोर्टार और कंक्रीट हैं। जिन स्थानों पर मजबूती, स्थायित्व और आग प्रतिरोध की आवश्यकता होती है वहां पर यह पसंदीदा सामग्री है। कंक्रीट किसी भी आकार में बदली जा सकती है और वास्तुकला के अनुरूप हो सकती है। भवनों और अन्य संरचनाओं के फर्श और छतों के लिए सुदृढ सीमेंट कंक्रीट (आरसीसी) व्यापक रूप से उपयोग की जाती है। प्रबलित कंक्रीट संरचनाओं के डिजाइन और निर्माण को विभिन्न प्रक्रियाओं के कोड में शामिल किया गया है। भारतीय मानक आईएस:456 संरचनात्मक डिजाइन को ध्यान में रखते हुये यह समतल और सुदृढ कंक्रीट से संबंधित है। यह मानक स्थायित्व के लिए न्यूनतम आवश्यकताओं को भी निर्दिष्ट करता है। कंक्रीट प्रौद्योगिकी और सुदृढ और कंक्रीट संरचनाओं के लिये विश्लेषण, डिजाइन और निर्माण विधियां इतनी विकसित की गई हैं कि अब किसी भी प्रकार की ठोस संरचना को तैयार करना संभव है। यह किफायती और टिकाऊ हो सकता है।

आरसीसी स्लैब का इस्तेमाल एकल

चित्र 8: आरसीसी भवन/बिल्डिंग

और बहु–मंजिला आवासीय भवनों के फर्श और छतों के लिए किया जाता है। बड़ी अवधि के लिए, स्लैब आरसीसी बीम पर आश्रित होते हैं जो कि पूरी तरह से स्लैब्स के साथ भरी जाती हैं। आरसीसी संरचनाओं के लिए कंक्रीट का न्यूनतम ग्रेड एम 20 (28 दिनों में 20 एमपीए की एक विशेष दबाव वाली मजबूती है) सुदृढीकरण करने के लिये विरूपित सरियों जिसका व्यास और स्पेसिंग संबंधित डिजाईन एवं मानकों के अनुसार तय की जाती है।

आरसीसी स्लैब के निर्माण के लिए, लकड़ी या स्टील का इस्तेमाल करके सेन्टरींग और फॉर्मवर्क रखे जाते हैं। आजकल स्टील के फॉर्म बहुत लोकप्रिय हैं। कंक्रीट के बिछाने और संघनन के दौरान फॉर्म को ठोस होना चाहिए। कंक्रीट के स्वयं का भार और जो लोग काम कर रहें है के वजन में तालमेल बहुत जरूरी है क्योकि कंक्रीट काफी शक्ति मांगता है। पार्श्व सहारे के लिए सेन्टरींग में पर्याप्त ब्रेसिंग होना चाहिए।

तैयार मिश्रित कंक्रीट प्लांट (आरएमसी) द्वारा तैयार मिश्रित कंक्रीट को प्राथमिकता दी जाती है। बड़ी और मध्यम परियोजना स्थलों के लिए कंक्रीट तैयार मिश्रित ठोस प्लांट से या ऑन साइट या ऑफ साइट बैचिंग और मिक्सिंग प्लांट से प्राप्त किया जाना चाहिए। कई शहरों में कई आरएमसी प्लांट आ रहें हैं और आवश्यक मात्रा में मजबूत कंक्रीट और उचित समय पर इन प्लांट से आदेश देकर मंगाया जा सकता है।

बहु–मंजिला इमारतों में, आरसीसी संरचनाएं आरसीसी कॉलम, बीम और स्लैब सिस्टम के साथ उपयोग की जाती हैं। वे हवा और भूकंपीय भार के लिए तैयार किए गए हैं, जिनमें प्रासंगिक मानकों के अनुसार मूल और लाइव भार शामिल हैं। सुदृढीकरण का विवरण करना बहुत महत्वपूर्ण है। भूकंपीय प्रतिरोधी संरचनाओं के लिए, भारतीय मानक आईएस 13920 के अनुसार गठनीय विवरण प्रदान किया जाना चाहिये।

बड़ी परियोजनाओं के लिए, निर्माण कार्य को कम करने के लिए पूर्वनिर्मित कंक्रीट इकाइयों का उपयोग किया जाता है। पूर्वनिर्मित कंक्रीट उच्च गुणवत्ता का हो सकता है। पूर्वनिर्मित फर्श और छत इकाइयों के विभिन्न प्रकारों का उपयोग किया जा सकता है। फ्रेम की गयी संरचनाओं के लिए, पूर्वनिर्मित कंक्रीट बीम और कॉलम का इस्तेमाल किया जा सकता है। पूर्वनिर्मित कंक्रीट संरचनाओं में जॉइंटस् बहुत महत्वपूर्ण हैं।

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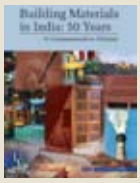

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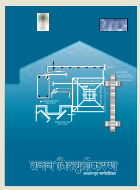

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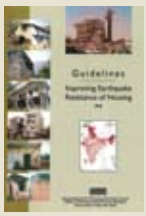

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