


Special Issue

निर्माण सारिका

A Newsletter of BMTPC

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October 3
World Habitat Day
Housing at the Centre

निर्माण सामग्री एवं प्रौद्योगिकी संवर्द्धन परिषद्
आवास एवं शहरी गरीबी उपशमन मंत्रालय, भारत सरकार
BUILDING MATERIALS & TECHNOLOGY PROMOTION COUNCIL
Ministry of Housing & Urban Poverty Alleviation, Government of India

"Creating Enabling Environment for Affordable Housing for All"

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From the Desk of Executive Director

Roti, Kapada aur Makaan (Food, Clothing & Shelter) are the three basic needs of the human being world over and putting *Housing at the Centre* as the theme by UN habitat for 2016 World habitat day is an impressive step. It collectively reminds the authorities world over their responsibility of providing a decent safe shelter to all human beings. India has always been serious & committed about the housing and it is quite evident from Hon'ble President of India's proclamation in his address to the joint session of Indian Parliament on June 9th, 2014 "By the time the nation completes 75 years of Independence, every family will have a pucca (permanent) house with water connection, toilet facilities, 24x7 electricity supply & access".

The Hon'ble Prime minister of India envisioned Housing for all by 2022 and launched a comprehensive mission Pradhan Mantri Awas Yojna (PMAY) Urban as well as Rural through which, it is estimated that about 30 million houses need to be constructed in next seven years. The basic civic infrastructure like water, sanitation, sewerage, road, electricity etc. including social infrastructure i.e. community centres, schools, health facilities are part & parcel of the mission which need to be achieved through concurrently going on other schemes of Govt. of India & State governments. It is a gargantuan task and all stakeholders are geared up to make it a grand success. For the first time, the new models of PPPs (public-private partnership) are now redefining their structure and evolving towards a wider paradigm to also include 'people' participation and community engagement. Hence, the 3Ps within the PPP framework are now transforming into the 4Ps structure: public-private people partnerships so as to realize the dreams of housing for all.

In order to accomplish the huge housing demand, it is imperative to go for mass housing construction methodologies, which can deliver safe, sustainable, resilient & quality houses in quick time. BMTPC, a technical arm of Ministry of Housing & Urban Poverty Alleviation has been entrusted with the task for identifying, evaluating & certifying new systems which have been successful world over and can be adapted in Indian geo-climatic conditions. BMTPC has successfully shortlisted 16 such construction systems after due diligence and they can broadly be classified as (a) large formwork systems including structural-stay-in-place formwork systems (b) sandwich panel systems (c) Precast concrete construction systems (d) steel structural systems (e) light gauge steel structural systems (f) prefabricated precast modular housing systems etc. Now, it is time to create an ecosystem which facilitates mainstreaming of these new methodologies into different states and a technology submission has been set up under housing for all mission to accomplish the task in collaboration with state govts and our academic institutions like IITs/NITs/SPAs etc. States are coming forward and willing to embrace these new systems. At Centre also, CPWD & other main construction agencies like DDA, NBCC and many more are exploring the possibilities to make use of these systems into projects being executed by them. It is now time for the technology providers and construction agencies to take plunge from the springboard created by BMTPC.

Let us contribute towards building Strong India.

(Dr. Shailesh Kr. Agrawal)

सत्यमेव जयते

M. VENKAIAH NAIDU
Minister of Housing and Urban Poverty Alleviation,
Urban Development and Information & Broadcasting
Government of India

MESSAGE

The first Monday of October is marked as World Habitat Day and being celebrated world over by United Nations and other Habitat related institutions to address the impending issues related with housing and human settlements.

Housing has always been an engine for growth and prosperity in cities. As urbanization increases, housing will continue to be key to providing stability for the families and neighbourhoods and in turn strengthening urban economies, creating jobs and improving both financial and physical well-being. The growing urgency to provide adequate housing to millions of households and the need to do so in ways to guarantee a sustainable future for cities calls for a paradigm shift in housing policy and practice.

The theme of the World Habitat Day this year "**Housing at the Centre**" becomes imperative given the emerging forms of urbanism that are producing cities as places of exclusivity, rather than opportunity. Cities, especially in the developing world, are growing fragmented with the current models of housing production. While the most common problem is the shortage of adequate housing, other important challenges are present in the form of poor quality and location of the stock usually far from job and livelihood opportunities, lack of accessibility and services, unaffordable costs and insecurity of tenure. The need of the hour today is an integrated housing framework that is consistently woven into urban plans and city investment strategies at both the national and municipal levels.

The Government of India is implementing Pradhan Mantri Awas Yojana (Urban) with a vision of 'Housing for All by 2022' to meet the housing shortage among the urban poor. A comprehensive approach is adopted to cover all urban poor through four verticals namely (a) Slum Rehabilitation; (b) Promotion of Affordable Housing through credit linked subsidy; (c) Affordable Housing in Partnership with Public & Private sectors; and (d) Subsidy for beneficiary-led individual house construction or enhancement.

I am happy that Building Materials & Technology Promotion Council (BMTPC) is bringing out the Special Issue of its newsletter "**Nirman Sarika**" to highlight the issues related to the theme of the World Habitat Day. BMTPC plays a significant role in supporting the provision of shelter to all through the promotion of emerging building materials and technologies. I hope this issue will also provide further insights and knowledge of such alternate building practices that will contribute to our Governments aim of providing housing for all.

I wish BMTPC success in this endeavour.

(M. Venkaiah Naidu)

सत्यमेव जयते

RAO INDERJIT SINGH
Minister of State (Independent Charge) for Ministry of Planning and MoS for Ministry of Urban Development and Housing & Urban Poverty Alleviation, Government of India

MESSAGE

To provide adequate housing to millions of households with commitment to achieve sustainable development goals to make cities and human settlements inclusive, safe, resistant and sustainable, calls for a paradigm shift in housing policy and practices.

This year's theme "Housing at the Centre" of the urban agenda, reminds the world to shift the focus from simply building houses to a holistic framework for housing development, orchestrated with urban planning practice and placing people and human rights at the fore front of urban sustainable development.

There can be no sustainable urbanization without a roof over everyone's head but that is not sufficient, unless other aspects like job, transportation, health, sanitation, education and safety are considered.

People's need and aspiration, their future place of living and their existence at the Centre of city development are important. Pradhan Mantri Awas Yojana "Housing for All (Urban)" and other schemes of the government related to urban development bring the desired shift in approach of the government for an integrated approach for urban development with housing as main focus.

I congratulate BMTPC for bringing a Special Issue of its Newletter "Nirman Sarika" on the occasion of "World Habitat Day".

(Inderjit Singh)

सत्यमेव जयते

DR. N. CHATTERJEE
Secretary
Ministry of Housing & Urban Poverty Alleviation
Government of India

MESSAGE

World Habitat Day is celebrated across the world every year to create awareness on the collective responsibility of stakeholders on the need for sustainable habitat and to promote such habitat in the interest of future generations.

The theme for 2016, namely, ‘Housing at the Centre’ is an extension of “Global Housing Strategy” which has been promoted as a collaborative movement towards adequate housing for all as the foundation to the sustainable urban development.

All member countries in United Nations are committed to the Sustainable Development Goals to make cities and human settlements inclusive, safe, resilient and sustainable and aims to ensure adequate, safe and affordable housing, basic services and improved infrastructure.

The Housing for All (Urban) Mission which intends to provide decent shelter to all by 2022 is in line with the UN Global Agenda. It is drafted with the objective of inclusive development with convergence of civic amenities and infrastructure development planned under Atal Mission for Rejuvenation and Urban Transformation (AMRUT) and Smart Cities programme.

Building Materials and Technology Promotion Council is playing an important role of identifying, evaluating and promoting building materials & construction technology for safe, affordable and sustainable housing on a fast track mode.

I am happy that BMTPC, as in previous years, is bringing a special issue of their Newsletter “Nirman Sarika” on the occasion of ‘World Habitat Day’.

I wish BMTPC all the best in its future endeavors.

(N. Chatterjee)

RAJIV RANJAN MISHRA
Joint Secretary (Housing)
Ministry of Housing & Urban Poverty Alleviation
Government of India

MESSAGE

The World Habitat Day celebration on 1st Monday of October every year brings forth the need of better shelter all over the world and positive changes required in the systems including policies and awareness worldwide of joint responsibility for the future generation's habitat.

This year, the United Nations has chosen the theme ***"Housing at the Centre"*** to bring housing at the core of national and local urban agendas. ***'Housing at the Centre'*** aims to shift the focus from simply building dwelling units to a holistic framework for habitat development, orchestrated with urban planning practice and placing people and human rights at the forefront of urban sustainable development. At the national level, the goal is to integrate housing into National Urban Policies through planned urbanization. At the local level, the approach is to reinforce the importance of housing for urban planning and concomitantly to the development of cities and people.

Government of India has launched Pradhan Mantri Awas Yojana (PMAY) to provide Housing for All by 2022. This year's theme of ***"Housing at the Centre"*** is in tune with PMAY, where Central Government is providing assistance to implementing agencies through State Governments, for providing houses to various economic sections through different verticals of the policy. The scheme is being implemented through synchronization between Centre and States to realize the overall objective of "Housing for All".

I am pleased to know that Building Materials and Technology Promotion Council (BMTPC) is bringing out a special issue of Newsletter "Nirman Sarika" on the Occasion of World Habitat Day 2016. Over the years, BMTPC has played important role in taking forward the agenda of affordable housing through dissemination and mainstreaming new technologies for construction of mass housing.

I take this opportunity to wish success to BMTPC in all its endeavors.

(Rajiv Ranjan Mishra)

सत्यमेव जयते

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

MESSAGE

World Habitat Day theme of this year "Housing at the Centre" is highly appropriate for our rapidly growing major urban centres, wherein large number of slums with shanties & poor houses are common phenomena. The inhabitants of these slums are deprived of adequate shelter, basic services such as water supply, sanitation, health & education facilities and most importantly the opportunities.

The challenges of main-streaming these foot soldiers of our economy is indeed not simple & requires policy level initiatives including efficient city planning, innovations & time bound implementation with commitment of all stakeholders. The risk of disaster, climate change & Sustainable Development Goals (SDGs) are other important issues which clearly need to be integral part of planning & implementation process.

The Govt. of India has taken several initiatives & most ambitious amongst them is "Pradhan Mantri Awas Yojana -Housing for all (Urban) by 2022" which envisages provision of pucca house with water connection, toilet facilities, 24x7 electricity supply and access to every urban poor. Similar scheme has been launched for rural area to take care of rural poor. In order to ensure sustainable development, as a part of Housing for All (Urban) Mission, a Technology submission has been set up to facilitate adoption of modern, innovative and green technologies and building material for faster and quality construction of houses with disaster resistant features.

BMTPC has been playing a vital role in evaluation & promotion of emerging technologies for mass housing & presently entrusted with running the Technology Sub mission, in collaboration with IITs, NITs & SPAs.

I am happy to learn that BMTPC is bringing out special issue of Nirman Sarika on the occasion of "World Habitat Day" highlighting important issues related to the theme.

I wish BMTPC all the success in their continued efforts.

(Amrit Abhijat)

5 Actions to Strengthen India's Housing Development Effort

*Prof. C.V.R.Murty**

India's Housing challenge today is larger than ever before. There are two challenges that face India today – (a) Over 3 Crores of houses to be built on the whole to eliminate the housing shortage, and (b) India needs to accommodate the flip of *Urban : Rural* population ratio from 30:70 today to 70:30 by 2035. India needs to take giant strides; because of this rural to urban migration, *India* needs to build in urban areas about 2.7 times the houses it has now. Thus, a large number of *towns* are likely to grow into *cities*, and *cities* into *mega polis*.

The focus should be on putting in place *systems & processes* that will affect behavioral changes in the people of India, rather than on the housing stakeholders simply filling the housing shortage or special groups steering additional urban housing development through a *purely* contractor driven system without the engagement of the people of India. In this regard, 5 actions are needed to strengthen *India's Housing Development* effort (Figure 1). These five actions are in the directions of *Typologies, Safety, Human Resources, Practice and Policy.*

Typologies

India's housing can be classified broadly under 3 Housing Typologies, 11 Housing Sub-Typologies and 30 Housing Sub-Typology Variants. And, there is an uncountable number of variants of the housing sub-typologies practiced in India – some place this number at about 800. A detailed analysis of these variants needs to be documented through a scientific methodology developed to assess structural and non-structural safety of the housing sub-typology variants. The methodology classifies the information related to a house into Life Threatening Factors and Economic Loss Inducing Factors. Further, the latter is developed for such an that presents five aspects of the housing typology from the structural point of view (namely Siting Issues, Soil & Foundation Conditions, Architectural Features, Structural Aspects and Constructional Details) and two aspects from non-structural elements point of view (namely Acceleration & Displacement Hazards, and Lifelines). The last step of the documentation process is an overall analysis of the housing sub-typology (in totality), which clarifies where the said housing sub-typology stands in terms of safety and sustainability.

Unless India learns its current stock of buildings – the material preferences and the safety embed-

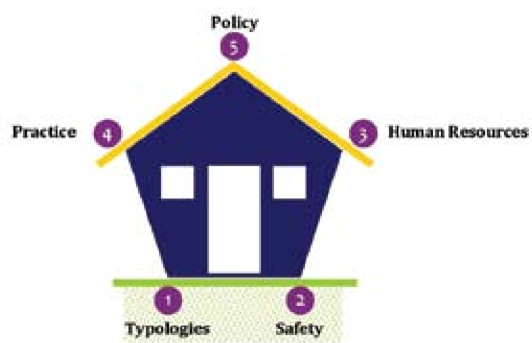

Figure 1: Five domains in which actions are essential to strengthen India's march towards self-sufficiency in Housing

* Director, Indian Institute of Technology, Jodhpur

ded, it cannot take any decisions on any of the aspects of technology, safety, human resources, practice and policy.

Action Needed

India should begin to formally document all variants of these housing sub-typologies (both traditional and current trend typologies), and place the information in public domain

Safety

While a large number of housing sub-typologies is practiced in the country (and even some of these are supported by the Architects and some Structural Engineers of the region), structural safety assessment is not undertaken by ANY municipal authority anywhere in the country as of today. This leaves the country under a silent threat of the impending natural hazards (if not under that of the man-made hazards). Even though appropriate framework exists in the form of a techno-legal regime in the Building Bye-Laws and Development Control Regulations of the municipalities, municipal corporations and development authorities, it has not been implemented.

Housing for masses and mass housing projects are implemented across the country with type designs repeated in a large number of small sized houses. In such cases, it is even more essential to examine the technology employed to provide safety to the residents of the houses through structural safety tests on prototype houses.

Action Needed

Safety of the people of India is enshrined in the Constitution of India. India should:

(1) Begin to examine safety of all new housing proposals first through an independent peer reviewer and then through the municipal authorities before issuing any permit to construct:

(a) Individual housing construction proposals submitted directly to municipal authorities, and

(b) Mass Housing or housing for masses proposals proposed to be undertaken by various departments and ministries;

(2) Build test facilities across the country to test prototype specimen of full-scale houses of the regional traditional, existing and new technologies of individual housing construction proposals offered by various vendors; and

(3) Prepare national standards for designing, constructing and testing of different typologies of houses.

Human Resources

Design and construction of components of housing is part of the engineering curriculum at the undergraduate level in the country. This needs to be integrated with the practical aspects sensitive to regional context of the environment, especially on construction of houses in hilly areas and with local skills & construction materials. Since the repository of knowledge is not available in public domain on the spectrum of typologies and new technologies available, the appreciation of graduate engineers is relatively shallow on: (a) skills needed by masons, and (b) standards related to new housing technologies.

Further, there is a large stock of buildings built, whose structural safety is not established publicly either by the client owner or by the municipalities. This brings forth two forceful requirements of the nation, namely: (a) retrofitting (especially from earthquake safety point of view), and (b) repairing & rehabilitating, of the large prevalent building stock.

Action Needed

Large number of hands are required to meet the technical work related to safety of over 31 Crores of existing houses and fill the shortage of 3 Crores of new houses for India, India should prepare to:

(a) Develop Teaching Resource Material (with the available limited persons specializing in the subject of housing technologies) for bachelors degree programs for fresh graduates, refresher programs for practicing engineers, and skill development programs for artisans; and

(b) Undertake construction of pilot Technology Demonstration Units for: (i) constructing new houses, and (ii) retrofitting and repair & rehabilitation of existing houses.

Practice

The country faces a huge challenge of (a) constructing new houses, (b) retrofitting of existing houses, especially in earthquake areas, and (b) repairing & rehabilitating many old buildings that now require to be upgraded. To achieve this vast work, specialist knowledge is required among the housing product vendors and task implementation contractors to undertake the work within the time & money targets set for the proposed activities.

Action Needed

India needs to build systems and processes at the level of each state government for:

(1) Preparing wide base vendors, who will supply different items needed in housing development, which are certified by national accredited laboratories to have met the national standards; and

(2) Undertaking construction of pilot Technology Demonstration Units towards: (i) constructing of new houses, and (ii) retrofitting and repair & rehabilitation of existing houses. With an IIT and NIT now operational in each State (almost), this task needs to be taken up with a great sense of urgency, towards ensuring high quality constructions.

Policy

The country's housing development needs a backbone, which will bridge between the needs of the people of India, the technology competencies available in the country, and the techno-legal regime that Stage Governments need to enforce. The Government of India needs to play the role of an integrator to bring synergies between the common needs of at least the adjoining states of India. Towards this end, it needs a think tank that will document, study, analyze, bring out special needs that should be addressed, suggest ways of unknotting the tough and special demands, and make clear recommendations to the Government of India for necessary steps.

The think tank should engage with the people of India in arriving at the proposed policy changes or new policy development, and continually feedback to the people through electronic and print media the way forward to resolve outstanding issues, in addition to the traditional interaction schemes.

Action Needed

India needs to make operational urgently:

(1) National Housing Technology Task Force comprising of technical persons, which will advise the Ministry of Urban Development, Government of India, on current projects and future projections;

(2) National Center for Safe Housing, which will focus on spectrum of issues related to Housing, including education, prototype testing, research, implementation, and policy;

(3) Dissemination of Knowledge on Housing, which will empower the National Housing Technology Task Force to achieve its objectives, especially Indian Housing Encyclopedia, Enthusing young India, and Taking Housing to Communities.

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BMTPC's Exhibition at IITF, November 14-27, 2015, New Delhi

Housing Model for Urban Area

*Dr. Kumar Pallav**

Abstract:

Present work, review about an Urban model for development of Housing. It discusses about the scarcity of space with loads population that is amalgamated with fragile infrastructure make Authority, Planner, designed to think of making a holistic housing approach for Urban center. In this regards, Sinclairs model in detail, along with other popular framework for housing are discussed in brief. It reflects an overall balance of social, cultural, environmental, economic, political and other aspects of design sustainable environment in a holistic manner. Further, framing of legal policies to restrain unplanned, fatal design and workmanship urban center for its protection.

Introduction

Urbanization is one of the key factors which decides whether a country is on the right path of development or not. For India, the statistics have revealed that the country will be the hub of economic growth over the ne two decades. Currently the contribution of urban cities in the GDP is 62-63% which was only 29% in 1950-51. Fraker, (2013) stated in his work, that half of the world population lives in cities. This directly elucidates the increase in pressure on civic infrastructure systems, water supply, waste management systems, parks and open spaces, transport, etc. There are many programs launched by the government for ameliorating the urbanization process, but due to lack of proper planning and negligence on the use of technology and innovation, the fruitful results are still an imagination.

During the Mid 1970 s, sustainable development began to draw attention to provide a facility to residents that influences the price, type of location, and that cost of infrastructure. Housing in urban areastrives for limiting spaces, increase in pollution,budget restriction, and escalating regulations for construction. Nature friendly housing in urban areas is directly influenced the overall budgets of housing. This article is going to focus on diversity, accessibility and affordability of housing. Often struggling with the rapid growth of slum there may be possible to transform and modify the urban fabric insensitive, sensible and sustainable way. Here Sinclairs framework and Gestalt theory is discussed for housing affordability, that must not narrow and restrictive, should consider all the necessary parameter qualities through interdisciplinary relationship.

Friedman (2007) emphasized that there is "need for space adaptation to on-going life circumstances is important in New Urbanism and architecture". To make urban housing, holistic, more interdisciplinary approach between different sectors need to be formulated. Gehl (2010; 2011) recommended the provision for new urban area housing where places are complete, affordable, people friendly, walkable, accessible, and connected. The goal of urban housing design includes a series of associated building, green campus, suitable location, sufficient production, and effective policies.

In past sustainable and affordable house were rare in urban contest and was negatively correlated with one another as "more sustainable" means "less

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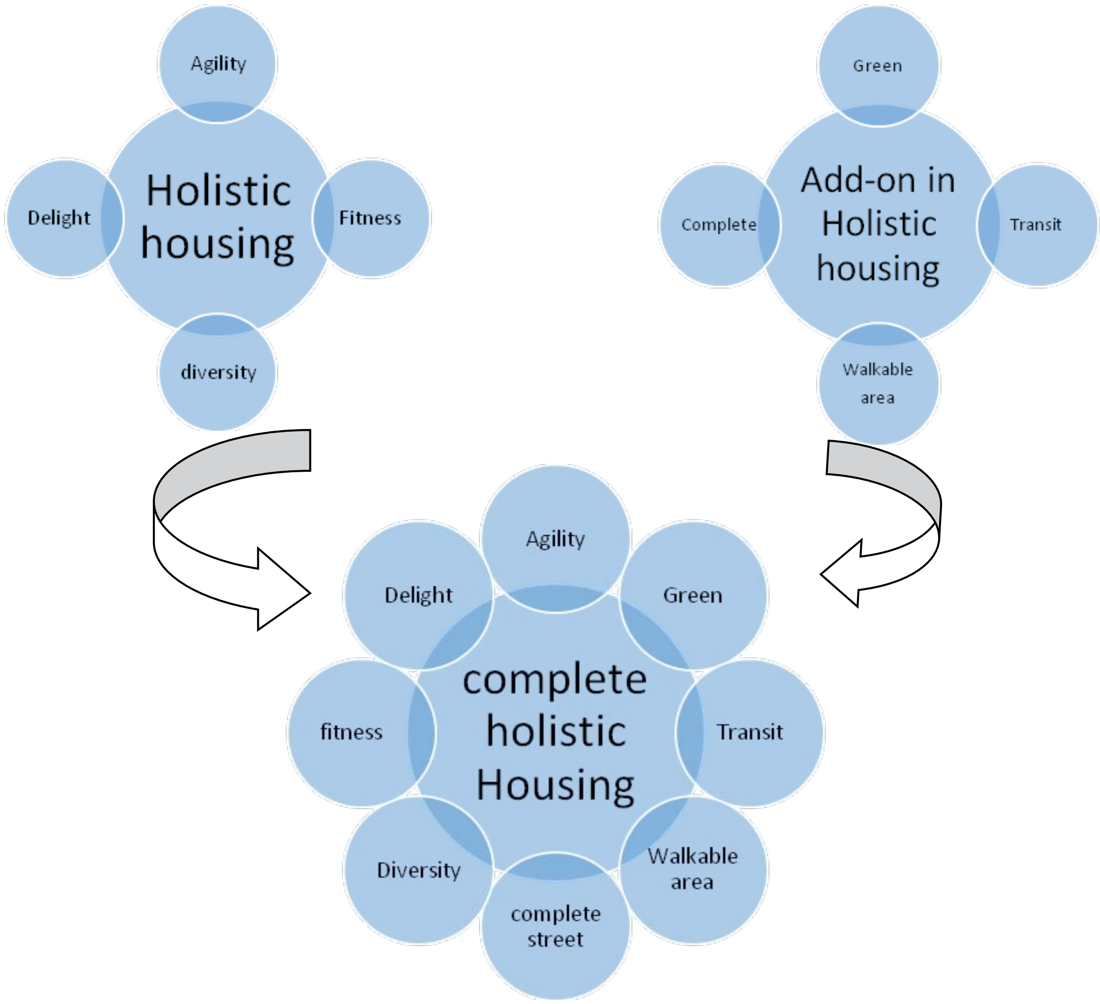

Figure 1: Complete housing comfort as per Sinclair model

affordable" (Friedman, 2012). Transit systems, pedestrian path, asses to market along with efficient housing have an important role in assessing the affordability of living and sustainable of neighborhood (Friedman, 2012). This theory can validate with the person who can invest more with likely to have a more favorable housing condition in contrary to the person who cannot invest more towards housing tend to be less satisfied with their housing environment.

It needs to have an overall balance of social, cultural, environmental, economic, political and other aspects for design sustainable environment in a holistic manner. The urban housing design should be multidimensional aspects: apart from safer, energy strategies, transit facility, etc. Sinclair's framework about the design and planning of housing requires four major interconnected element viz., Agility, Fitness, Diversity, Delight, added with green, transit system, Complete street, walkable area as shown in fig-1.

Further, Kevin Lynch in his book Good City Form, mentioned about critical points in planning viz. vitality, Sense, Fit, Access, Control, Efficiency, and Justice. Sinclairs (2009) highlighted more open systems and added adaptability, durability, constructability and materiality. Sinclair, (2014) feels about improving the model and suggested that for urban housing, designers need to create an environment which are for more fluid, flexible and responsive.

No doubt, effective plans will surely lead to holistic development of the country. To improve the scenario, concerned authorities have to modify their approach towards urban agglomerates. They have to utilise the basic natural resources like air, water, sunlight etc. for proper arrangement of the urban centres. Few suggestions/approaches urban planners should keep in mind are as follows. The wind is a very crucial factor. In addition to soothing effect, it cause a good amount of pressure on building thus disturbing the economy of construction project. Proper study of wind rose diagrams and data provided by IMD will surely be of much help in deciding orientation of buildings which will eventually lead to a retrench in construction cost as well as expenditures made for thermal comfort. Now comes the sun, serving us as a source of light since millennium also controls the settlements in strategic way. Planners generally tend to keep settlements in such a place so as to have optimum effect of sun. But now a days, we are running short of space, so we have to explore ways how to exploit the available land for our benefit. We can cite the example of Project Sunroof by google using which and person can calculate the intensity of sunlight falling on the roof and how much solar electricity can be generated. In India, due to lack of advanced infrastructure in GIS and Remote Sensing, we have become laggards. No doubt the development of indigenous satellite network for subcontinent will surely help in proper planning of resources. While planning use of water resources for urban settlement, the studies on statistical data is a must. The data should not be forged as this leads to false predictions which is a very heinous practice. The absence of proper infrastructure for monitoring water resources has led to the pollution, over exploitation and wastage.

Finally, to make a good urban settlement plan, analyse the data carefully, Put logic and try to see the clear picture and decide what can be fruitful in the long run. Planning should not be for ephemeral periods. In case of disasters, efficient planning can save many lives. Emergency exit plans must be a mandatory part of any planning approach.

References:

1. Fraker, Harrison (2013), Hidden Potential of Sustainable Neighborhoods: Lessons frm Low-carbon Communities. Washington, D.C., Island Press.
2. Friedman, Avi (2007), Sustainable residential Development: Planning and Design for green neighborhoods, New York: McGraw-Hill Professional.
3. Friedman, Avi (2012), Town and Terraced Housing: for affordability and sustainability. London: Routledge.
4. Gehl, Jan (2010), Cities fro people.Washington, D.C.: Island Press.
5. Gehl, Jan (2011), Life between buildings: using public space. Washington, D.C., Island Press.
6. Lynch, Levin (1984), Good city form.Cambridge, MIT Press.
7. Sinclair,BR.,(2005) Comprehension+ Comprehensive: The Environmental Design of Spaces + Places, The 3rd Conference of the Ottawa Colloquium on the Governance of Sustainable Develpement. Ottawa, Canada, Center on Governance of the University of Ottawa.
8. Sinclair, B R., Somayeh M, Ghazaleh S (2012) Agility, Adaptability+ Appropriateness: Conceiving, Crafting & Constructing Architecture of the 21st Century. Enquiry: ARCC Journal of Architectural Research, 9, 1.
9. Sinclair, B. R., Somayeh M., and Kamaran N (2014) Change Exploring Psyschological Sociological Constructs in the Quest for Agile Architecture & Environmental Design, ARCC Conference Repository, 2014.

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International Seminar & Exhibition on “Emerging Building Materials and Construction Technologies”

BMTPC organized an International Seminar on Emerging Building Materials & Construction Technologies on March 21-22, 2016 at New Delhi so as to bring all stakeholders on one platform to share their knowledge and experience.

The International Seminar was inaugurated by Shri M. Venkaiah Naidu, Hon’ble Minister of Housing & Urban Poverty Alleviation, Urban Development and Parliamentary Affairs, Government of India. Besides Academic, R&D Institutions, known experts of the country; agencies involved in bringing technologies from advanced countries also participated with their technical presentation and showcasing of products and system. The participants also include representatives of Govt. agencies, faculty & students of technical institutions. More than 380 delegates participated in the Seminar. On this occasion a publication titled “Emerging Building Materials & Construction Technologies” and Audio-Visual CD “Hands on Training for Masons” were released by Hon’ble Minister.

To coincide with the International Seminar, an Exhibition on Emerging Building Materials and Construction Technologies showcasing various building products and construction technologies was also organised. More than 20 firms/companies displayed their products, technologies and systems.

New Construction Systems for PMAY

Dr. Shailesh Kr. Agrawal, Executive Director &
*J. K. Prasad, S. K. Gupta, and Dalip Kumar**

INTRODUCTION

The Housing at the Centre has always been our present Government's motive which is quite evident from the Hon'ble President of India, in his address to the Joint Session of Parliament on 9th June, 2014 where it was promulgated that "By the time the Nation completes 75 years of its Independence, every family will have a pucca house with water connection, toilet facilities, 24x7 electricity supply and access." 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)" in June 2015 through Ministry of Housing & Urban Poverty Alleviation (HUPA). The mission seeks to address the housing requirement of urban poor including slum dwellers by providing central assistance to implementing agencies through States and UTs for providing houses to all eligible families/ beneficiaries by 2022. Although, demand survey is in progress across states to estimate the actual housing shortage, Nevertheless, a Technical Committee constituted by Ministry of Housing & Urban Poverty Alleviation to assess housing shortage at the beginning of the 12th Plan, has estimated the shortage at 18.78 million in 2012. Against this, about 18 million of shortage is estimated to pertain to EWS and LIG categories. Housing and habitat related services for the urban poor and low income groups are estimated to cost a sum of about Rs.6,00,000 crores which requires proper planning, policy frame work and technical interventions to deal with the subject. Through Housing for All by 2022 mission it is targeted to construct 20 million houses with a span of seven years.

Also, to address the gap in rural housing and in view of Government's commitment to provide "Housing for All" by 2022, the scheme of IAY has been re-structured into Pradhan Mantri Awaas Yojana – Gramin (PMAY-G) w.e.f. 1st April, 2016. Pradhan Mantri Awas Yojana – Gramin will be implemented in rural areas across the country except Delhi and Chandigarh. Under the scheme, government to construct 1 crore pucca (permanent) houses for the rural poor in a span of three years from 2016-17 to 2018-19 with a budget of Rs. 81,975 crore. The cost of unit (house) assistance is to be shared between central and state governments in the ratio 60:40 in plain areas and 90:10 for north-eastern and hilly states. An allowance of Rs. 120,000 in plain areas and Rs. 130,000 in hilly areas will be provided for construction of homes.

This humongous task needs introspection of our current construction practices and study of globally accepted new construction systems so as to introduce best technologies and practices for faster & sustainable, quality & safe construction in different parts of the country. It is high time for construction fraternity to make paradigm shift from orthodox cast in situ concrete construction to mechanized factory made building systems which can bring economy, efficiency & fast delivery.

BMTPC has been promoting alternate cost-effective, environment-friendly, energy-efficient and

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disaster resistant technologies. Recently, BMTPC took an initiative to study/select emerging and alternate cost effective technologies suitable to Indian geo-climatic conditions and advocate these technologies to the State Govt. for implementation in housing projects under various housing schemes of government in different parts of the country.

BMTPC's INITIATIVE

In order to identify & evaluate suitable technologies for mass housing, as a cost effective substitute for conventional system, a framework Based on the information with respect to material and structural details, status of evaluation, actual construction carried out in India or elsewhere and their performance, economic scale of construction, status of transfer of the technology to India, suitability for mass construction in urban areas, durability & speed of construction, cost effectiveness, innovation in technology, ease of working & adaptability in Indian condition, etc., the following broad parameters were considered for evaluation of technology/system:

- Structural stability
- Material specification and its durability
- Green concept
- Joints and connections specially for prefabricated system
- Cost effectiveness of the emerging technologies vis-à-vis conventional construction system (RCC and masonry construction)
- Speed of construction and quality
- Sanitation
- Suitability to Indian climatic and hazard conditions
- Scale of minimum number of houses
- Adoptability of Services.
- Expected life span of the proposed system
- Maintenance scheme for the system
- Resistance of the system against fire, blast, etc.
- Users' feedback and certification, wherever possible.
- Compatibility and adherence of the system to BIS
- Any shortcoming of the system

Based on the broad parameters, the identified technologies/ systems can be broadly classified as follows:

- ❖ Form work systems
- ❖ Precast Concrete Construction Systems
- ❖ Steel Structural Systems
- ❖ Light gauge Steel Structural Systems
- ❖ Precast Sandwich Panel systems

Form Work Systems

Monolithic Concrete Construction Systems

In the monolithic concrete technology, Walls and slabs are cast in one operation in specially designed

light weight form/ moulds in concrete. Concrete is poured in the forms & forms are removed after the setting of concrete takes place, resulting in box like cubical structure of required architectural design. The pre-designed formwork also acts some sort of assembly line production and enables rapid construction of multiple units of repetitive type. These formworks are made from different materials such as aluminium, plastic, steel and composites. Single floor with built up area of about 300 sqm. can be completed in two days using the aluminium formwork system. The technology reduces the cost of repair and maintenance compared to conventional system.

Modular Tunnelform

Tunnel formwork is a mechanized system for cellular structures. It is based on two half shells which are placed together to form a room or cell. Several cells make an apartment. With tunnel forms, walls and slab are cast in a single day. The structure is divided into phases. Each phase consists of a section of the structure that will cast in one day. The formwork is set up for the day's pour in the morning. The reinforcement and services are positioned and concrete is poured in the afternoon. Once reinforcement is placed, concrete for walls and slabs shall be poured in one single operation. The formwork is stripped the early morning and positioned for the subsequent phase.

Coffor Construction System

Coffor is a structural stay-in-place formwork system to build load bearing monolithic structures. It is composed of two filtering grids made of rib lathe reinforced by vertical stiffeners made out of GP sheets. The grids are connected by articulated rebar loops and connectors that fold for cost effective transportation. The panels can eliminate a major part of rebarring and bar bending activity and completely eliminate the shuttering and deshuttering activity for the load bearing wall. The system remains in the construction to reinforce it after the concrete is poured.

Sismo Building Technology

Sismo Building Technology is an insulating shuttering kit for whole building based on a three-dimensional lattice made of galvanized steel wire. The lattice is filled with materials of different nature to serve as formwork. The basic structure of the Sismo building module is steel wire lattice. At the exterior sides of the lattice, infill panels are inserted, which transform the lattice into a closed structure that can be filled with concrete. The type of infill panels used depends on the purpose of the wall: load bearing or not, insulated or otherwise, etc. The steel wire also acts as armature and anchoring for the finished material and it will hold reinforcement bars in place during concrete filling.

Precast Concrete Construction systems

Precast concrete panels using concrete, welded mesh and plates

This System combines a series of modules to create the overall building, this provides complete flexibility in the layout. The structure is designed in splitable transportable modules. These panels are assembled on specially designed steel beds and floor concrete is done linking the panels to the floor reinforcement forming a monolithic structure. This module is moved to various stages to complete the secondary operations and finishing works just like in a car assembly line. Finished module is then transported to site and erected together to form the final structure. It is suited for low to medium rise mass housing projects.

Industrialized 3-s system using cellular light weight concrete slabs & precast columns

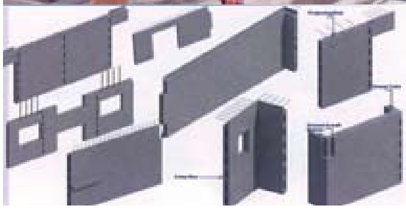
The industrialized total open prefab construction technology is based on factory mass manufactured structural prefab components conforming to norms of IS standards and BIS Certification mark. In this system precast dense concrete hollow column shell of appropriate size are used in combination with precast dense concrete rectangular T Shape/L shape beams and lightweight reinforced autoclaved cellular concrete slabs for floors and roofs. The hollow columns are grouted with appropriate grade of in–situ concrete. All the connections and jointing of various structures are accomplished through in situ concreting along with secured embedded reinforcement of appropriate size, length and configuration to ensure monolithic continuous resilient ductile behavior.

Waffle-Crete Building System

Waffle-Crete Building system consist of factory made large, structural, ribbed panels of reinforced precast concrete, bolted together and the joints between the panels are caulked to form the walls, floor and pitched or flat roofs of buildings. The surface of each panel consist of 51 mm thick slab or skin, stiffened with the ribs around the perimeter and across the panel, giving an overall panel thickness of 152mm or 203 mm.

Prefabricated Large Concrete Panel System

Precast large concrete system is generally a large panel system, modular system or combination



of both. Precast building consists of various precast elements such as walls, slabs, beams, columns, staircases and some customized elements that are standardized and designed for stability, durability and structural integrity of the building. Precast residential building involves design, strategic yard planning, lifting, handling & transportation of precast elements, installation at site, connecting and finishing. The building framing is planned in such a way that maximum number of repetitions of moulds is obtained. These elements are cast in controlled factory conditions. The factory is developed at or near the site which provides an economical solution in terms of storage and transportation.

Pre-stressed precast prefab technology using hollow core slab, beams, columns, solid walls, stairs, etc.

Pre-stressed precast RCC 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 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.

Steel Structural Systems

Factory Made Fast Track Modular Building System using Concrete, Steel Structure and Polystyrene Core

Factory Made Fast Track Modular Building construction is a structural steel frame system manufactured and fabricated in a controlled factory environment and shipped to a prepared building site for installation. The system based on steel structure with different walling components is designed according to relevant Indian / International standards to withstand various forces. About 70% of the work is done in the factory with minimal usage of concrete which enables it to deliver the building within a few days of work at site. The steel-modules pre-fitted with flooring, ceiling tiles, electrical and plumbing fittings are transported to the site for installation. Once all the components are assembled and erected at site, concreting is done on the factory made 3-D Expanded Polystyrene (EPS) panel walls making it a monolithic structure.

Speed Floor

Speed floor is a suspended concrete flooring system using a roll formed steel joist as an integral part of the final concrete and steel composite floor. The Speed Floor system essentially is a hybrid concrete/steel tee-beam in one direction and an integrated continuous one-way slab in other direction. The joists of different depths are manufactured from pre-galvanized high tensile steel in a one pass roll former, where it is roll formed, punched, pressed and slotted in a fully computerized machine.

Light gauge Steel Structural Systems

Light Gauge Steel Framed Structure Using Cold Formed Steel Sections

Light Gauge Steel Framed Structure is based on factory made galvanized light gauge steel components produced by the cold forming method assembled as panels at site. The basic building elements of light gauge steel framing are cold formed sections which can be prefabricated on site using various methods of construction. Light Gauge Steel Framed Structure is typically ideal for one to three storey high buildings, especially in residential homes, apartments and commercial buildings. Light Gauge Steel Framed Structure can be combined with composite steel/concrete deck resting on light steel framing stud walls. Construction phases of steel buildings resemble the phases of conventional reinforced concrete buildings.

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

Light Gauge Steel Framed Structure with Infill Concrete Panels (LGSFS-ICP) Technology comprises of factory made Light Gauge Steel Framed Structure (LGSFS), light weight concrete and precast panels. The LGS frame is a "C" cross-section with built in notch, dimpling, slots, service holes etc. produced by computerized roll forming machine. These frames shall be assembled using metal screws to form into LGSF wall and roof structures of a building. Provisions for doors, windows, ventilators and other cutouts as required shall be incorporated in the LGSFS.

Precast Sandwich Panel systems

Expanded Polystyrene Core Panel System

The panel Building system is a load bearing wall construction. 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 expanded polystyrene core panel (EPS). High resistance steel meshes composed of bars having dia. 2.5 to 5 mm. are made in factory. 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 for 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 / m3. Once the panels are installed, they are anchored and finished with the application of concrete by shortcreting on both of their sides.

GFRG/ Rapid wall Building System technology

Glass Fibre Reinforced Gypsum (GFRG)/ Rapid wall is a building panel product, made essentially of gypsum plaster, reinforced with glass fibres. GFRG panels are presently manufactured to a thickness of 124 mm under carefully controlled conditions to a length of 12 m and a height of 3 m. The panel can be cut to required size. Although its main application is in the construction of walls, it can also be used in floor and roof slabs in combination with reinforced concrete. The panel contains cavities that may be filled with concrete and reinforced with steel bars to impart additional strength and provide ductility. GFRG panels can also be used advantageously as infills (non-load bearing) in combination with RCC framed columns and beams (conventional framed construction of multi-storey buildings) without any restriction on the number of storeys. Also, GFRG panels with embedded micro-beams and RCC screed (acting as T-beams) can be used as floor/roof slabs.

ROAD AHEAD

BMTPC has identified, evaluated and certified construction systems which can replace conventional typical RCC framed construction. These systems are suitable for mass housing and have an advantage over conventional construction systems in terms of speed, safety, life-cycle cost and quality. However, in order to successfully mainstream and transfer these systems in the field, the following areas require immediate attention:

a) Standards, specifications, schedule of rates and design & construction manuals

b) Demonstration construction to instill confidence amongst masses

c) Build capacities of professionals i.e. engineers and architects in the area

d) Skill training of manpower in emerging technologies

e) Development of contractors who can execute the projects

f) Cost economics

BMTPC has been working on all the above areas and a few states have already adopted few emerging technologies suiting to their geo-climatic conditions for their housing projects.

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Smart City – A Holistic Perspective

*S.B. Dangayach**

Some of the dictionary meanings of the word "smart" are as under:

"Socially elegant, sophisticated and fashionable"

"Very good at learning or thinking about things"

"Showing intelligence or good judgment"

The symbiotic relationship between cities and information technology began in the ancient world. Nearly six thousand years ago, the first markets, temples and palaces arose amid the irrigated fields of the Middle East and served as physical hubs for social networks devoted to commerce, worship and government. As wealth and culture flourished, writing was invented to keep tabs on all of the transactions, rituals and rulings. It was the world's first information technology.

In more recent eras, each time human settlements have grown larger, advances in information technology have kept pace to manage their ever-expanding complexity. During the nineteenth century, industrialization kicked this evolutionary process into high fear. New York, London and other great industrial cities boomed on a steady diet of steam power and electricity. But this urban expansion was not driven only by new machines that amplified our physical might, but also by inventions that multiplied our ability to process information and communicate quickly over great distances. As Henry Estabrook, the Republican orator (and attorney for Western Union) bombastically declared in a speech honoring Charles Minot, who pioneered the use of telegraph in railroad operations in 1851. "The railroad and the telegraph are the Siamese twins of Commerce, born at the same period time, developed side by side, united by necessity".

The telegraph revolutionized the management of big industrial enterprises. But it also transformed the administration of city government. Police departments were among the earlier adopters, using the tool to coordinate security over growing jurisdictions. Innovations flowed from government to industry as well – the electromechanical tabulators invented to tally the massive 1890 census were soon put to use by corporations to track the vital signs of continent-spanning enterprises. By enabling business to flourish and municipalities to govern more effectively, these technologies removed critical obstacles to the growth of cities. By 1910, historian Herbert Casson could declare matter-of-factly what was clear to all about yet another technology. "No invention has been more timely than the telephone". It arrived at the exact period when it was needed for organization of great cities and the unification of nations.

Massive growth in ICT is an extension of intimate relationship of man with communication. Rapid advances in this field give us an opportunity to think of superior solutions through application development and deployment involving all the stakeholders.

Smart city is currently a buzzword. It definition is evolving and therefore in different contexts meaning of the term smart city goes on changing.

Common understanding of a smart activity, operation, device

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or entity is that a stakeholder gets more out of less. In other words, the output for given input is higher in smart option than in normal option. In the context of a city, there are several products, services and solutions that are a part of habitat, which can be improved. The basic elements of urban agglomerate or city revolve around the following:

- Land
- Housing
- Water
- Wastewater
- Sold waste
- Energy
- Communications
- Roads
- Transport
- Environment

In addition to the above, social infrastructure needs are again a part of a city and inter alia covers the following:

- Education facilities
- Skilling facilities
- Healthcare facilities
- Cultural and religious facilities
- Entertainment

The above infrastructures have to support and sustain the following:

- Economic activities like jobs and enterprises
- Sustainable environment'
- Safety and security of citizens
- Good governance

In the modern context, technologies are rapidly improving and evolving. Using Information and Communications Technology (ICT), a whole lot of products, services and solutions can be made more efficient on all counts. Thus, in a smart city, use of ICT in an optimal manner is also considered necessary in many situations. Like any other technology, ICT is enabling tool for bringing about superior resource efficiency, waste reduction, better environment and better health of the people of city.

Smart City history in foreign countries:

Smart city as a concept is recent in India. Due to amorphous meaning and interpretation, it has come to signify different things to different people. A new smart city is indeed a very expensive proposition and hence very few new smart cities have come up in the world so far.

Various people connected with smart city movement have realized that smart interventions can be applied to an area or a service or a cluster in the existing cities and thus there are attempts to make select portion of city smart in a given domain. Examples...

New smart city: Songdo in South Korea

Old cities: Amsterdam, London, New York, Bogota

In Songdo ICT players like Cisco, Google, Microsoft, Samsung etc. have collaborated to create a smart city, result of which are not yet found satisfactory.

In places like Bogota, Bus Rapid

Source: http://gradestack.com/blogs/smart-cities-all-you-need-to-know/

Transport has been used as a better alternative to private transport whereas in Amsterdam special efforts are made to promote walkergand cycling as an alternative to conventional transportation.

Smart City Concept in India

Government of India thought of creating 100 new smart cities in the beginning of their term in the year 2014. Realizing the scope for making the current cities also smart, Government of India thought of extending the concept of smart city to several urban areas across the country. A visit to the website of the Ministry of Urban Development shows that government is in the process of lending a comprehensive shape to the smart city concept. At present, the website focuses on smart city contest that is to be run by 98 cities selected for the purpose.

The onus for submitting proposals is now on the city administration or urban local body administration (municipal corporations or urban local bodes). Necessary knowledge with these bodies is inadequate. Government of India, therefore, has invited proposals from consultants and have shortlisted them after due evaluation and diligence. List of such consultants is available on the website.

Urban bodies have to now decide on proposals for smart city in the selected area and field with the help of these consultants. For examples:

- Varanasi has a problem of waste management. A proposal can be worked out for solid waste management and liquid waste management in Varanasi.
- Mumbai has a problem of slum clusters. It can possibly work out a proposal for a proper habitat for the slum dwellers while utilizing the land efficiently.
- Water supply for 24 x 7 is considered a smarter way in many parts of the world. Cities like Nagpur has demonstrated that this can be a win-win. Some cities can therefore look at 24 7 x water supply.
- Public health in some areas of Delhi is indeed poor. Using ICT solution as well as public health measures, several outbreaks such as dengue, malaria and chikungunya can be reduced.

All the proposals have to clearly show outlay, method of securing funds, proper management, benefits, costs and sustainability. Thus, smart city proposals have to shown to be even financially sustainable in the given period of time.

Conclusion

Smart city concept revolves around efficient use of resources, technologies, tools and solutions for enhancing quality and performance of urban services, reduction of cost, reduction of resource consumption, engagement of people and above all happiness of people. Smart city concept has to be sustainable and feasible in medium to long term as constant demand of viability gap funding or subsidy can cause more damage and harm to national development. As efficiency and smartness are more of less synonymous, this concept can be extended to towns or villages or habitats of any kind.

A mechanism for periodical review of the smart city project against the stated objectives will be essential. Our urban local bodies are financially not sound nor do they have a proper financing system in place. A thorough project appraisal and review will be necessary to avoid wastage of all kinds of resources in implementation of such projects.

Smart city will have to eventually show that "less is more" in all sense.

William Shakespeare wrote *"What is the city but the people"*. It is therefore obvious that people have to be at the centre of the whole movement. They have to be a part of the complete process of converting ordinary existence into smart living. Assimilation and application of knowledge by them holds the key to success.

(The views expressed in this article are personal)

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Demonstration Housing Project
at Saraswathi Nagar, Venkatachalam Mandal, SPSR Nellore, AP

BMTPC has identified, evaluated and certified 16 new construction systems for mass housing which facilitate faster delivery of quality, sustainable and safe houses. BMTPC has initiated construction of model demonstration housing projects in Andhra Pradesh, Odisha, Telangana, Bihar, Tamil Nadu & Uttar Pradesh, etc. so as to spread awareness and disseminate new emerging systems across India.

In the process, BMTPC has constructed 36 Demonstration Houses using GFRG panel technology and a Community Centre building using alternate technologies like flyash blocks, filler slab, etc. at Saraswathi Nagar, Chowtapalem Village, Venkatachalam Mandal, SPS Nellore, Andhra Pradesh. The Demonstration Housing Project was designed by IIT Madras who has certified GFRG technology for mass housing.

Shri M.Venkaiah Naidu, Hon'ble Minister of Housing & Urban Poverty Alleviation, Urban Development and Information & Broadcasting, Government of India inaugurated the Demonstration Housing and Community Building Project on September 3, 2016 constructed by BMTPC in collaboration with IIT Chennai, FRBL Kochi and APSHCL, AP.

The project has evinced interests amongst construction fraternity and the project has already been visited by professionals, entrepreneurs and developers.

SALIENT FEATURES OF THE DEMONSTRATION HOUSES USING GFRG TECHNOLOGY

- No. of houses : 36 (G+1)
- Carpet area of each unit : 30 Sq.mts.
- Each Unit consist of : Living room, Bedroom, Kitchen, Bath, WC and Balcony
- Houses includes Earthquake Resistant Features.

TECHNOLOGIES USED

Foundation

- RCC Column footing with M-25 concrete

Walling

- GFRG Panel filled with M20 concrete

Roof/Floor

- GFRG Panel Slab for floor& roof

Doors/Windows

- Wooden Door & Aluminum Window Frames
- Flush door Shutter
- PVC door and frames in toilet
- Glazed aluminum windows

Flooring & Finishing

- Ceremic tile flooring
- Interlocking pavers block at entrance lobby
- Oil bound distemper on internal surface
- Exterior walls with weather proof paint

Staircase

- GFRG Panel with polished cuddapa stone as tread and riser

SALIENT FEATURES OF THE COMMUNITY CENTRE USING ALTERNATE TECHNOLOGIES

BMTPC, in continuation of its efforts to demonstrate cost effective and disaster resistant technologies, constructed Community Building having an area of 6900 sq.ft. using green technologies like flyash bricks, filler slabs, etc. The Community Building consists of a multi-purpose hall, kitchen/pantry area, office space and utility area.

TECHNOLOGIES USED

Foundation

- RCC Column footing with grade beams using M-25 concrete

Walling

- 200 mm thick walls using Fly ash blocks

Roof/Floor

- Filler slab using earthen pots
- RCC Sloping roof over the courtyard and entrance lobby using designer tiles as cladding

Doors/Windows

- Aluminium Door & Window Frames
- Glazed aluminum door shutter
- PVC door and frames in toilet
- Glazed aluminum windows

Flooring & Finishing

- Vitrified tiles flooring
- Interlocking pavers block in entrance lobby
- Oil bound distemper on internal plastered surface
- Exterior walls with water proofing cement paint

Infrastructure:

- Boundary wall of Fly-ash brick
- Interlocking paver tiles on pathways and internal roads
- Underground Water Tank
- Septic tank for solid waste management
- Landscaped inner court

National Workshop on "Utilization Of Construction & Demolition (C&D) Waste in Construction of Dwelling Units & Related Infrastructures

BMTPC has prepared the Guidelines for Utilization of Construction & Demolition (C&D) Waste in Construction of Dwelling Units & related Infrastructures in association with C-FARM, New Delhi. Utilization of Construction and Demolition waste in construction activities is a burning topic. Recently Ministry of Environment Forest and Climatic Change, Govt. of India has brought out C&D Waste Management Rule 2016 defining the waste, duties of waste generator, duties of local authorities, service providers and Pollution Control Boards, criteria for site selection for storage and processing or recycling facilities for construction and demolition waste etc.

In many industrialized countries, C&D waste is being recycled and used for housing and infrastructure. In India also, some of the state governments have taken steps to process and use C&D waste in construction. In Delhi and Gujarat, plants have been set up to process the C&D waste for gainful utilization. It is required to set up such facilities in other parts of the country also.

The Guidelines covers International Scenario of use of C&D waste Indian Scenario of availability & generation of C&D waste, potential of use of C&D waste in building sector with suggestion for specific uses and a Road Map for Gainful utilization of C&D waste in housing sector.

In order to sensitize and create awareness about the important points of the Guidelines amongst different stakeholders, a National Workshop was organised on September 23, 2016 at New Delhi. The Workshop was inaugurated by Dr. N.Chatterjee, Secretary, Ministry of Housing & Urban Poverty Alleviation.

About 150 delegates from Municipal Corporation, Pollution Control Board, Technical Institution, Construction Industry and C&D waste Processors & Equipment Suppliers participated in the workshop.

Suitability of Prefabricated Reinforced Cement Concrete Construction for Mass Housing in India

*Debashis Sanyal **

Shortage of housing

With reference to technical group report on Urban Housing shortage (2012-2017) by MOHUPA Govt. of India, "there is a housing shortage of 18.78 Million housing units by 2022 considering the demographic increase and urbanization" (Kundu A. 2012). It is experienced that the Building industry has always exhibited inertia to development as compared to other industries. Any innovation in material, technology or management techniques have always reached the construction industry in the end. Other industries have always-developed new solutions to their problems whereas problems in construction industry accepting and adopting technology from other industries solve. The building industry in India changed little in the years after the Independence. It is riddled with all types of inefficient practices both in construction and management. Experience has not taught us much and the mistakes are repeated time after time. There has been no significant addition of the technology or materials used. Scarce materials have been wastefully used with utter disregard to their conservation and judicious use. Industrialization can be looked upon as a means to overcome the plethora of problems faced by the present building industry.

Affordable housing

Housing that is decent-quality and affordable (generally defined as consuming less than 30% of a family's income) enables families to better enjoy a variety of life outcomes, such as family stability, good health, employment, education and recreation. Decent and affordable housing also contributes to the improved physical, economic, environmental and social health—the sustainability—of communities (Millennial Housing Commission 2002). These impacts are especially important for lower income households and other underserved populations. It has been also observed that generally Govt. based accommodation offered by various development agencies often do not match with the affordability of the stakeholders in India. Mass Housing is very much needed for proper site management and economy in numbers. Generally different Development agencies like housing boards launch such projects, but it is experienced that in India such projects runs for years and runs into costly overruns. This is largely due to use of conventional construction techniques and mismanagement at site. Private builders and developers in India seldom undertake mass housing projects. Still to overcome shortage of Housing in India, particularly in EWS and LIG sectors (which comprises 56% of total), mass housing is a necessity.

Advantages of off-site modular technology

Time Saving: The overall construction schedule for modular homes is compressed because of site work and home construction (in factory) can happen simultaneously. The major building trades involved are organized, operating together under supervision. Conventional site construction often experience delays as a result of labour force problems of availability, coordination etc. and unpredict-

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able weather. Standardized design and construction processes allow modular construction 30% quicker than Conventional site construction (Kaufmann Michelle 2009). Industrialized housing factory nearly eliminates the uncertainties of construction scheduling that often plague traditional building projects, such as delays and damage due to weather. Further as modular off site housing reaches site 90% complete, they significantly reduce the on-site construction process and disruption to neighbors.

Reduced Waste: In general over estimating, ordering and delivering more than required quantity of building materials on building site results in lots of wastage of nascent building materials. The problem of dispensing them off site is also significantly increased due to this. Construction waste is considerably reduced in the modular factory. Precision in building manufacturing process reduces the amount of materials used, and the remaining scraps can be easily stored at the factory for reuse or recycling. 50% to 75% waste can be saved compared to on-site building (Kaufmann Michelle, 2009). Theft and vandalism can also be controlled this way. Reduction of wastage of construction materials will bring in economy also.

Quality Control: Since modular off site housing are manufactured in a controlled environment, better quality control can be achieved. Quality is also increased in case of assembly-line construction. It is a fact that team of trained/skilled craftsmen/construction workers will produce significantly better quality of housing than Conventional on-site construction in India which is a large country.

Stronger: Industrialized housing can meet all local, national/ international building codes and can exceed them. Structural quality is ensured and sturdier in a modular home than Conventional on-site construction. Further, due to assembly line production with modern tools the necessity of precision in construction and finishing can be easily achieved. Desired exemplary horizontal or verticalness (plumb lines) can be easily maintained in factory which will effectively reduce the chances of faulty joining lines and building defects, etc.

Less use of Fossil fuel: A significant amount of fossil fuel is used to transport labor and materials to sites for conventionally built homes daily and that too over a longer period of time. Further house delivery logistics can reduce the truck traffic on roads and factory construction will also reduce commuting labors/ workforce over longer distances for 7-8 months (typical on-site construction time in India). The delivery of labor and materials to sites for conventionally built homes are often more unpredictable like weather.

Sustainability: Reduction of waste, use of sustainable designs and eco-friendly materials can make these homes more sustainable than conventional ones. These factors sometimes are lost between custom-built housing colonies, where every house is designed differently and constructed one-at-a-time.

Technology & Materials – Urgent Need for Improvement

Traditional burnt clay bricks still continue to be the primary raw material for housing activity all over India, but soil for bricks is sourced from fertile top soil from agricultural fields. Further, Baking of bricks consumes fossil fuel, i.e. coal and it emits unhealthy smoke and carbon dioxide into the atmosphere. It should be noted that the land wasted in the production of current annual requirement of 170 billion bricks deprives the country of food production that could feed 30 Lakh Indians for the whole year. Moreover, production of these bricks consumes around 24 million tonnes of coal and the process emits 61.3 million tonnes of CO2 into the atmosphere. It is therefore imperative that we must look for and develop alternative materials, which are energy efficient and more environment–friendly. Fly Ash Clay bricks, Fly Ash lime Sand bricks are some of the alternatives being promoted by CBRI, NTPC, Fly Ash Mission, but with limited success. Fly Ash based Autoclaved Aerated Concrete (AAC) blocks, produced in big plants or more efficient and economical alternative of site produced Cellular Lightweight Concrete (CLC) blocks are gaining increased usage. The latter produced in an environment–friendly process need least intrinsic energy, offer superior thermal efficiency and lower water absorption than clay bricks, need lower raw material inputs and make productive use of fly ash – a waste industrial output. This seems to be one of the ideal futuristic materials.

Even on the technology front, we continue to depend on manpower intensive traditional construction practices, which are slow and highly dependent on skilled labor input - a category already scarce in availability. Therefore, in order to be able to meet the huge housing shortage, we need to adopt partially or fully mechanized methodologies, which primarily need some unskilled labour inputs. Large scale application must be encouraged for semi-mechanized and mechanized systems like monolithic concrete/CLC construction using large area wall-, slab- forms or room sized forms or tunnel forms, with appropriate thermal insulation for external walls. These in-situ technologies are highly effective for mass scale application in earth-quake and tsunami prone conditions in India. These would provide faster, durable, economical dwellings deploying limited unskilled inputs. Use of prefabrication technology or ready-made building components in traditional constructions needs to be urgently encouraged. This can however be feasible, only if the establishments, producing and marketing such components are subject to similar labour laws and taxation structure as applicable to manufacture of clay bricks.

The proposed alternative technologies, which offer safe, durable, energy efficient, economical and environment–friendly green dwellings to our countrymen, are recommended to be encouraged for wide scale application. Concrete based technologies which have potential for mass housing applications identified by BMTPC are [Agrawal, Shailesh Kr. 2016]:-

1. **Monolithic Concrete Construction:-** All shear Walls are constructed in monolithic manner with slabs using modular formwork system of aluminium, steel, plastic or composite. Faster, speedier construction possible with advantage of need of very little external finishing. This is suitable for large housing projects, where repetition of formwork of 50 times is possible.
2. **Precast Prefabricated concrete construction:-** Precast/ prestressed concrete contribute to sustainable design. Versatile, durable, factory produced with trained personnel. These are manufactured under strict quality control measures, with minimum wastes. The precast panels or beams/columns can be quickly erected on site. This system has long term economic benefits, lower maintenance and overall operating cost.

Comparison of Building Materials for LIG housing

While deciding the materials suitability for LIG housing, longitivity and strength plays an important role as these house may need once in a life time opportunity for having a own shelter above their heads. However a comparison is made and given in Table-1 [Sanyal, D. & Bhargava R.K. 2014].

Due to faster development of cement industry in India, RCC is readily available for house construction in every part of urban India. There is plenty relevant skilled labour available. The mixing of fly ash/ slag dust into (20 to 30% of) raw materials for making cement, makes it somewhat environment friendly, (since fly ash/ slag dust are both air polluting agents). Most of the cement manufacturers in India have adopted this measure for economical reasons. Further ready-mix concrete is also now started penetrating the urban market. This makes it convenient for mass housing construction. The equipments necessary for precast RCC construction is similar to precast railway sleeper manufacturing facility. The fireproof quality of concrete also advocates more usage in housing sector. Precast RCC Construction if constructed properly will last for 60 years or more and maintenance free. Except excessive rainfall Precast construction can be an all weather construction technique in composite climate which covers largest part of India. A reduction of up to 80% of actual in-situ construction period is possible by prefabrication [Indian Concrete Institute, 2016].

Different Alternatives of Precast Construction System

Tunnel form system & Precast Component system are generally

Table-1: Comparison of Building Materials for LIG housing

Characteristics of building materials	R.C. Concrete	Alternative Timber products (Ply wood, etc.)	Other Low cost / recycled/ non-timber materials (Gypsum board, etc.)
More eco-friendliness	3	2	1
More Fireproof	1	3	2
More Waterproof	1	3	2
More Strength	1	2	3
More Economical	3	2	1
More Weatherproof	1	2	3
Requires Less Maintenance	1	2	3
Availability near site	1	2	3
Total Scores	**12**	**18**	**18**

Scores are 1: Most Suitable. 2: More Suitable. 3: Less Suitable.

experimented and practiced in India. Tunnel form system is, casting 2 walls and roof unit together forming a tunnel like form, whereas 2 vertical wall units of 3 storey heights can be joined together. In Precast Component System all individual column, beam etc. will be casted separately and joined together in site. This two systems can be developed by making on-site production shed also. One of other feasible alternative is Box system. In Box system whole unit can be manufactured beforehand in factory and shipped to site. Though this alternative is heavily dependent on transportation logistics.

Adoption of Precast Technology

Looking to the vast needs of India's shortage of Affordable housing, Precast RCC construction can be advantageous. Other developments in Concrete technology like lightweight concrete, sandwich panels can be also considered. As long as faster construction rate and quality of construction is maintained, these can prove really beneficial to India's mission of "Shelter for all".

Reference:

1. Kaufmann Michelle 2009, Remick Catherene, Prefab green, pp70-71.
2. Millennial Housing Commission Report May 2002, Washington DC.
3. Agrawal, Shailesh Kr. 2016, International Seminar on Emerging Building Materials and Construction Technologies, BMTPC, New Delhi.
4. Kundu, A., Sept. 2012, Report of the Technical Group on Urban Housing Shortage (2012-17), New Delhi; Ministry of Housing and Urban Poverty Alleviation.
5. Sanyal, D. & Bhargava R.K. 2014, Identifying Various Building Materials suitable for Industrialised Mass Housing in India, ABACUS (Monsoon) Vol.9, 2, ISSN 0973-8339, pp12-19.
6. Indian Concrete Institute 2016, Handbook on Precast Concrete for buildings, ICI-TC/02-01, pp4.

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

BMTPC organizes capacity building and training programmes on regular basis. The purpose of these programmes is to enhance the capacity of Engineers & Architects at ULB & State level in the area of "Quality Control and Good Construction Practices" in housing projects and to introduce emerging technologies for construction of houses which may be useful for mass housing projects in the States.

In this series, a Capacity Building Programme on Good Construction Practices including Emerging Technologies for Housing were organised at Jaipur, Rajasthan from October 8-9, 2015, Bhubaneswar, Odisha from December 18, 2015 and Gangtok, Sikkim from March 1-2, 2016. The expert faculty made presentations on Planning & Design, Good Construction Practices and Quality Assurance, Earthquake Resistant Design.

Around 60 to 65 participants from housing development agencies and State Governments participated in each programme.

Pre-cast Light Weight Large Wall and Roof Panels for Mass Housing using Expanded Polystyrene


*J. Prabakar** *J.D.R.Joseph ***

In general, pre-cast, pre-stressed building components comprising thin concrete sections are not commonly recommended or used as seismic shear walls due to non ductile behavior particularly the connections between the sandwich wall panels and the foundation joint failures. In these aspects, it is necessary to solve the issue to have pre-cast light weight large wall and roof panels particularly to address the seismic resistant building and the joint / connections failures. . In view of this, it is importance and necessary to provide people with housing units that are affordable. Preliminary studies carried out indicate that there is wider scope for using light-weight precast concrete structural panels in the construction of affordable housing units. The panels are sandwich type comprising of two high strength concrete Wythes separated by an inner lightweight core. Due to the use of light weight inner core material, the consumption of concrete is low and most structurally efficient. It's extremely light in weight and is easy to handle, transport and erect. The panels are assembled on the site edge to edge to form an enclosure and the joints between the wall to wall and roof to wall is connected through connectors. The system provides satisfactory thermal and acoustic insulation for the constructed facility. Besides structural soundness, the use of waste material in large quantities is also involved which adds to eco-friendliness of the system. A (G+1) building constructed using light weight panels tested for seismic loading effect and loadings of seismic zone-5 was applied and the building performed excellently. The entire system is light in weight, durable, and resistant to forces caused by disaster such as earthquake.

Advantages of Light Weight Large Panel Prefabricated Buildings

The lightweight prefabricated building made up of EPS wall panel has several advantages than other building systems. It is seismically safe and affordable and provides personal, social, and economic benefits. Prefab housing, re-anchors the homeless in the community and mobilizes those traumatized by a disaster and assumes importance in a post-disaster situation. Light weight EPS panels are known for their low density and good thermal insulation. Other advantages include reduction in dead load, speedy construction and easy handling. Composite concrete panel is lighter than the normal concrete panel by 45 to 60%. The reduced weight of reinforced composite panels makes it highly preferable for structures in seismic zones because of the reduced dynamic actions. The advantages of light weight large panel prefabricated buildings are listed below;

- EPS is an excellent material for construction of housing because of its low thermal conductivity, moderate compressive strength, and excellent shock absorption.
- Low density and good thermal insulation.
- Simplicity of construction as well as ease of expansion for future development.
- Concrete wastage is reduced to a greater extent as it is factory made.
- EPS panel is rigid and easy to

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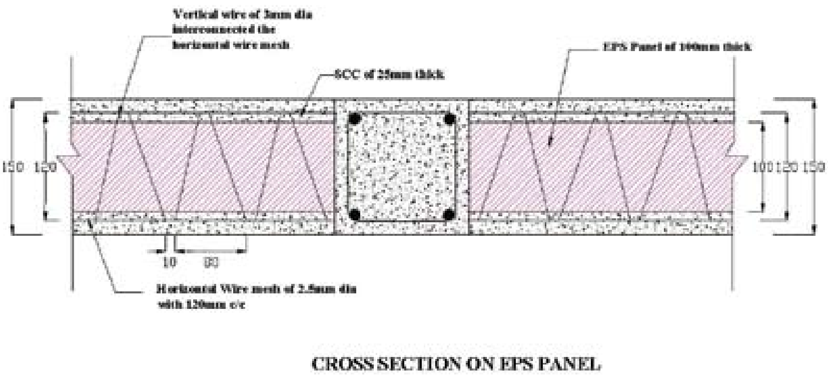

Fig.1 Typical Cross Sectional Details of Sandwich EPS Panel

handle.

- Formwork arrangements are simple and can be used repetitively.
- Better quality can be assured.
- It is excellent in seismic prone zones.

Details of Sandwich EPS Panel

Typical sandwich EPS panel along with rib beam is shown in Fig.1. The panel consists of 100 mm thick core made in Expanded Polystyrene (EPS) which is held in position by a three dimensional welded wire space frame. The space frame consists of welded wire fabric of 100 square millimeter welded mesh pattern of longitudinal and transverse wires of 3 mm thickness made of galvanized high tensile steel on both sides. To complete the space frame galvanized high tensile steel wires of 2.5 mm thickness are pierced completely through the EPS and welded to each of the outer wire mesh to form a truss pattern at every 100 mm centre to centre. Concealed longitudinal RC beams of 100 mm width and 100 mm depth were provided on either side of the panel by removing the EPS to a width of 100 mm on either side. The beam consists of 4 nos. of 12 mm diameter bars and a 10 mm diameter rebar at the middle of the panel on either side. The Wythes are 25 mm thick made of M 40 self-compacting concrete. Typical cross section of Sandwich panel with EPS is shown in Fig.1.

Casting Methodology of Sandwich Panels

A steel mould has been fabricated to cast light weight panels and the specimens had 100 mm thick EPS panel with GI wire mesh of size 100mm x 100mm on both surfaces of the EPS panel. Shear connectors made of same material of the wire mesh connected both the wire meshes. 25 mm thick Wythes of M40 grade concrete were provided on both the surfaces. The sequence of casting sandwich panel by pouring SCC (Self Compacting Concrete) is shown in Fig.2. SSC poured into the mould to get 25 mm thick concrete uniform and then EPS panel is placed and top the EPS again SCC is poured to a thickness of 25 mm.

Light Weight Panel under Static Flexural Test

The test set-up used for carrying out static flexural test on the panels is shown in Fig.3. The panel was simply supported over two steel pedestals. Hinge condition was provided at one end of the RC panel and roller support was provided at the other end. The effective span of the panel was 2700 mm with middle 900 mm kept under constant bending moment. A hydraulic jack of 1000 kN capacity was used to apply the load at mid-span and equally distributed line loads at 900 mm from the supports. Thus, panels were subjected to two points loading. The instrumentation provided consists of primarily the measurements of strains and deflection on the panels at various locations. The cracks formed were also marked at every load stages. Lead wires from the electrical strain gauges fixed to the reinforcement were connected to

Fig.2 Casting Sequence of Sandwich Panel

the strain recording instrument to record the strain. Electrical strain gauges were fixed on the surface of the panel to measure top compression strains. At every loading stage, cracks appearing on the surfaces were monitored. The panels were loaded up to ultimate failure. The test arrangement of the panel for flexural loading is shown in Fig.3.

Fig. 3 Flexural Test Set-Up

The panel failed at an ultimate load of 76.5 kN under two points loading and the maximum bending moment computed is 33.75 kNm. Thus at failure, the equivalent uniformly distributed load on the panel is 37.04 kN/m^2 (3704 kg/m2). The ultimate load computed from reinforced concrete theory worked out to 75 kN. The first crack appeared at the bottom side of the panel at a load of 18 kN. The central deflection at this load is 2.5 mm and the maximum deflection of the panel at failure load is 250 mm.

The ultimate load carrying capacity of the panel is 37.04 kN/m2. The behaviour of the panel can be considered as acceptable. The service live loads expected on a floor slab of a commercial building is approximately 4 kN/m^2. Thus, from the test it is seen that the panels can be used as floor panels in cases where higher live loads are expected. The load and deformation value of panels under flexural loading is shown in Fig.4

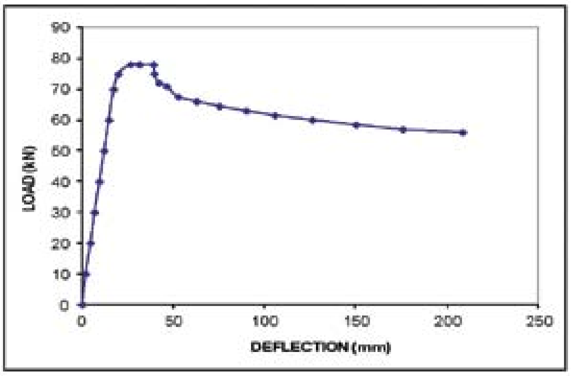

Fig.4 Load Vs Deflection Curve of the Panel under Flexural Test

Light Weight Panel under Axial Compression Test

The panel had a length of 2500 mm, width of 1200 mm and thickness of 150 mm. Concealed reinforced concrete columns of 100 mm width, 100 mm depth and 2500 mm long were provided at both the edges of the panel after removing EPS to a width of 100 mm. The reinforcement provided consisted of four nos. of 12 mm diameter TMT bars in each column. A 12 mm diameter bar was provided at the centre of the panel on either side and connected together using a 6mm diameter ring shaped rod at 500 mm centers. At the two extreme ends of the panels (loading edges) reinforced concrete beams of 150 mm width x 100 mm depth and 1.2 m long were provided. These beams would help in transferring uniform load to the panel. Two 100 t jacks were used to apply the load uniformly along the panel. Test setup of the panel for axial compression is shown in Fig.5.

Fig. 5 Light Weight Panels under Axial Compression

In the axial compression test, the panel failed at a load of 1800 kN. The ultimate load carrying capacity of the panel was computed as the sum total of the load carried by the concrete of the two concealed columns, load carried by the reinforcement provided in the columns and load carried by the concrete wythe of 25 mm thickness on both the faces and found to be equal to 1880 kN. Load Vs. deflection of the panel under axial compression is shown in Fig.6.

Seismic Performance Evaluation of Prefabricated Building Constructed using Lightweight Panels

A (G+1) single bay prefabricated building, with plan area of 3550 mm x 3550 mm and storey height of 3000 mm, made with lightweight wall and roof panels was assembled and rigidly mounted on the 4m x 4m shake table at CSIR-SERC and subjected to realistic earthquake motions (Fig.7). Spectrum compatible time history was applied in a progressively increasing manner and the response of the structure was studied. The design spectra composed of a band of frequencies specified by the Indian code of practice IS-1893 for earthquake resistant design of structures founded on medium stiff soil is made use of to derive the input displacement time history. There is “no-damage” response of the structure and the absence of any cracks or permanent deformations of the structure was observed. This shows that the structure has withstood the maximum earthquake loads successfully. This study clearly indicates that the prefabricated light weight wall panel building can be effectively used as seismic resistant building. The strain observed in this building is well within linear limits and never reached the yield strain. G+1 building constructed using the developed panels tested on the shake table withstood PGA up to 0.5 g without any damage.

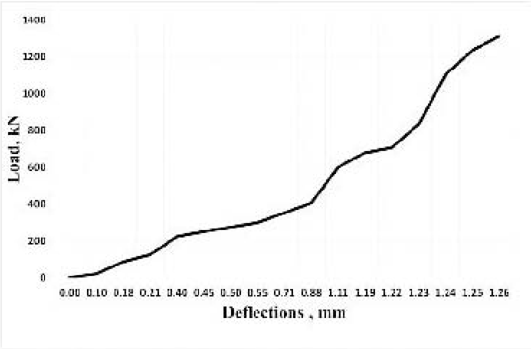

Fig.6 Load Vs Deflection Curve of the Panel under Axial Compression

Experimental Building with Light Weight Wall and Roof Panels using EPS

Based on the Seismic Performance Evaluation of Prefabricated Building with EPS Panel, it is evident that these panels can be used for construction of seismic resistant building. In order to bring confident amongst the user, an experimental demonstration building construction was undertaken using this technology. The building using light weight EPS panels is constructed at CSIR-CLRI Campus, Chennai. The execution of experimental building was carried out by construction RCC frame such as columns and roof beams. The EPS panels were placed over the roof beam for casting roof slab. Each EPS panel was reinforced with 12 mm of 3 Nos. at 750 mm intervals. The panels were joined by overlapping mesh as well as by tying 12 mm rod laterally at every 400 mm intervals. The EPS panels were properly tied in roof beam with dowel bars. Concrete of 40 mm thick was placed over the EPS panels place on the roof beam. For walls, the EPS panels were placed in between the RCC framed structure and the EPS panels are properly tied into the RCC members around it by inserting 12 mm rods to a depth of 120 mm with lock fixing. The details of construction methods using EPS panels are shown in Fig.8.

Fig.7 A (G+1) Prefabricated Building assembled on Shake Table for Seismic Test

(a) Building with RCC plinth beam and columns with doweled bars

(b) EPS Panels Over Roof Beams for Slab

(c) EPS Panels introduced with Steel Reinforcement

(d) Electrical Conduit Pipes Provided at Roof bottom of the EPS Panel

(e) Placing of Concrete Over EPS panels for Roof Slabs

(f) EPS panels in Wall and Window Sunshade Areas

(g) Connection Between EPS Panels by Providing L-Hook

(h) EPS Panels in Wall

Fig.8 Crèche Building at CLRI with Light Weight Panels both on Walls and Roofs

Experimental Demo Building with Prefab Large Walls and Roof Panels using EPS at CSIR-SERC

Prefab pre-cast large light weight wall and roof panels using EPS were used to construct a demo building in CSIR-SERC campus. Prefab large wall panels of size 3.55 m x 3.0 m with door 2 Nos. and without door openings 2 Nos., Wall Panels of size 3.25 m x 3.0 m with windows opening 4 Nos. and roof Panels of size 3.55 m x 3.55 m 2 Nos. All the panels were cast with a overall thickness of 150 mm. Construction sequence details are given in Fig.9.

Construction of four class rooms at KV-CLRI. EPS panels was also taken up using EPS panels. These panels were fixed in-between the framed structure and tied with dowel bars provided. These panels are acting as nonstructural members. Fig.10 shows the use light weight panels in construction of four class rooms at KV-CLRI .

Important features unique to the development

- The developed panels when used in building results in two third weight reduction compared to the conventional ones.

Prefab Large wall and Roof Panels in Building

EPS roof Panel for Connecting two Prefab Units

Window Lintel / Sunshade Using EPS panel

EPS Panel at Portico

Skirt Concrete with Weld mesh on Roof Top

Finished View of Demo Building

Fig.9 Construction Sequence of Demo Building with Prefab Wall and Roof Panels using EPS

Fig.10 KV CLRI School Building with Light Weight Panels using EPS

- Sandwich panels have low thermal conductivity, moderate compressive strength and excellent shock absorption ability.
- The lightweight panels cast using self-compacting concrete resulted in faster casting and better quality control.
- Amenability for prefabrication

Concluding Remarks

- Technology developed to cast the top and bottom skins in single casting – considerable reduction in the panel production time.
- A prototype G+1 building constructed using the developed panels tested on the shake table withstood PGA up to 0.5g without any damage.
- Meeting mass housing demand through speedy and quality construction
- Leads to pollution free construction
- Wastage of materials minimized compared to the conventional construction practices

Acknowledgements

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References

1. PCI Committee, ' Precast Concrete Sandwich Wall Panels: State of the Art of Precast/ Pre-stressed Sandwich Wall Panels", PCI Journal-Pre-cast Pre-stressed Concrete Institute , Vol.42, Issue 2,pp. 91-133, March/April 1997.
2. Flores-Johnson E.A., and Li Q.M, 'Structural Behaviour of Composite Sandwich Panels with Plain and Fiber Reinforced Foamed Concrete Cores and Corrugated Steel Faces' , Composite Structures, Vol. 94, Issue 5, pp.1555-1563, April 2012.
3. Amir F., and Sharaf T., (2010) ' Flexural Performance of Sandwich Panels comprising Polyurethane Core and GFRP skin and ribs of various configurations', Composite Structures, Vol.92, pp.2927-2935, November 2010.
4. Stephen Pessiki, Alexander Mlynarczyk, 'Experimental Evaluation of the Composite Behaviour of Precast Sandwich Wall Panels', PCI Journal , Vol.48, Issue 2, pp.54-71, March/April 2003.
5. Thomas D.Bush and Zhiqi Wu, (1998) 'Flexural Analysis of Prestressed Concrete Sandwich Panels with Truss Connectors, PCI Journal, Vol.43, Issue 5, pp.76-86, September/October 1998.
6. Benayoune, A., Abdul Samad, A.A.,Trikha,D.N.,Abang Ali, A.A and Ellina,S.H.M ' Flexural Behaviour of Precast Concrete Sandwich Composite Panel-Experimental and Theoretical Investigations, Construction and Building Materials, Vol.22, No.4, pp.580-592, April 2008.
7. Salmon David C., Amin Einea, Maher K. Tadros and Todd D. Culp, 'Full Scale Testing of Precast Concrete Sandwich Panels, ACI Structural Journal, V. 94, No. 4, pp. 354-362, 2008.
8. IS 1893 (Pert I) 2002, 'Indian standard criteria for earthquake resistant design of structures' General Provisions and Buildings (Fifth Revision), Bureau of Indian Standards, New Delhi.
9. Annie Peter J, J.Prabakar and Nagesh R Iyer., 'Precast Lightweight Large Panel Wall and Roof Elements for Seismic Resistant Building', Proceeding of the International UKIERI Concrete Congress , Jalandhar, India, 5-8 March 2013., pp.612-624.

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Sustainable Materials for Roofing System

*Dr. J.S. Chauhan**

Introduction

Roof over the head is one of the fundamental needs of a human being. Even birds, animals run in search of shelter at night or at the time of rain or natural calamities etc. It is very unfortunate that a large part of the population in Metropolitan cities has no roof over their heads and the living of human beings on the pavements, open spaces etc. creates social problems. It is roughly estimated that about 25—30% of urban population in metropolitan cities like Delhi, Mumbai, Madras, Calcutta etc. is living in slums and squatter settlements. This is increasing due to migration of rural population to urban cities in search of employment and attraction of city life, fast natural increase in population etc.

In a number of cities efforts have been made to improve the human living condition of the slums, houses-sites have been allotted and resettlement colonies have been established. But at the same time the high cost of construction is a great haindrance in fulfilling the desire of living in a pucca house by this economically weaker section of society. There has been a further rise in the prices of raw materials like timber, cement, steel etc. which means that housing is going to be costlier than ever before.

Roof may be defined as a covering provided over the top of a building with a view to keep out rain, snow, sun and wind and to protect the building from the adverse effects of these elements. A roof basically consists of roof covering materials supported on structural elements resting at the top of the building. The structural elements may be trusses, portals, flat slabs, shells, domes or space frames whereas the covering materials may be thatch, wooden shingle, tiles, slates, A.C. sheets, GI sheets etc. The choice of the type of roof for a building should be made considering the climatic conditions, local availability of materials, skilled labour and equipment, aesthetics and cost of construction. A well planned roof should be structurally sound and strong enough to carry the anticipated loads safely. It should be durable and protective against the adverse effects or rain, snow, sun, wind etc. It should be leak-proof and provide resistance against heat and sound. The roofs may be broadly classified into pitched or sloped roof and flat or terraced roof. Pitched roofs are used in coastal areas or other areas where the rain fall is heavy or in hilly areas where there is snowfall. Flat roofs are provided in areas where snow and rainfall is scanty. Other types of roofs like domes, shells, folded plates etc. are provided to meet the functional as well as aesthetic requirements of buildings.

Pitched roofs may be of different types such as lean-to-roof, coupled roof, collar roof, scissors roof or roofs supported on king-post roof truss, queen post roof truss, composite roof truss etc., depending upon their shapes and are constructed mainly with timber or steel sections. Flat roofs could be of R.C.C., R.B., R.B.C., Madras terrace etc.

Due to steep rise in cost of construction and scarcity of critical materials like cement, steel, timber, bricks, etc., cost effective roofing systems are required in

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buildings. As the roofing components forms 25% of the cost of construction of a building, a saving in the cost of roofing system will affect the overall savings in the cost of the building to a considerable extent. It is, therefore, necessary to evolve and adopt innovative methods of planning, design and construction of roofing systems. In this thesis work low cost techniques particularly for roofing of Residential Buildings have been briefly discussed and an effort has been made to compare the costs of different roofing systems.

Factors for selection of material

The materials required for construction of roofs depend upon a number of factors such as :

— type of roofing such as sloping or flat

— form and shape of roof

— structural design of roof

— dimensions of the space to be covered

— climatic requirements

— functional characteristics

— durability of constructions

— availability of materials and skills (locally)

— Cost economy etc.

Materials for Sloping Roof

Bamboo or timber roof frame with covering of thatch or palmyrah leaves, reeds.

The thatch or leaves is a material which gets decayed and catches fire quickly. It also blows up due to high pressure of air. To increase the life, thatch can be given preservative treatment prepared by mixing 64 kg. solution of bitumen and kerosene oil and wax (100:200:1) with one cubic metre of earth mixed with Bhusa.

Bamboo or timber frame with clay tiles, slates, etc.

Clay tiles or slates are brittle and the timber frame may also decay. CBRI has developed good quality tiles which increase the life of roof and improved the function of roof. The use of cement and steel can be avoided by making the roof with the clay tiles.

Asbestos or G.I. or aluminium corrugated sheet roofing.

These roofs are light in weight and economical in cost. But the disadvantages of such roofs are that these get heated quickly. Asbestos sheets are brittle and GI sheets get rusted in humid areas.

Cement-coir-corrugated sheets roofing

The roof has been developed by CBRI. The defects like brittleness or rusting have been eliminated in this type of roofing. This type of roofing does not get heated quickly. Use of steel is completely avoided and coir which is a waste product is properly utilized.

Asphaltic Corrugated sheets roofing

Asphaltic corrugated sheets are manufactured from waste materials like scrap paper, bagases, jute waste, coconut fibre, etc. These sheets have good thermal insulation properties and are water proof, flexible and light in weight. These are not attacked by fungi or vermin. They are not susceptible to corrosion and leakage. These are relatively safe against fire and are not brittle like asbestos sheets roofing. In this type of roofing use of cement and steel is practically nil except fixtures. This type of roofing should be used in the areas where the temperature does not exceed 40°C.

Materials for Flat Roof

Flat roofs with timber rafter, wooden flats and mud covering

The timber can be given preservative treatment to improve its life. Secondary species of timber may also be used for reducing down the cost. Mud covering may also be finished with a coat of water-repellent mud plaster to withstand heavy rains, etc.

Flat roofs with timber rafters and stone slab covering

Good quality of stone duly chiselled and well dressed improves the workability and life of roof. The timber rafter can also be given treatment with preservatives to prevent it from decay, insects, etc.

Brick or stone arch or dome

For arch or dome work, good quality bricks and stone should be selected to avoid any chance of efflorescence or other defects in the structure.

Brick jack arch roof with steel section

Bricks should be of good quality and steel should not be exposed to moisture. Steel structures should be properly painted in case they are exposed to atmosphere.

Reinforced brick flat roof

The life span of such type of roof is small compared to R.C.C. roof. If the top of the roof is not properly water proof, the steel reinforcement of the roofs gets rusted due to moisture, due to seepage of water. Therefore, the roof should be properly treated with water proofing compound.

Reinforced brick panel roofing

The brick panels are cast in small size according to requirement and laid over R.C.C. joists. The construction of this type of roofing is less time consuming. 15 percent saving in cement and steel is achieved by adoption of brick panel roofing.

Stone slab roofing

In the areas like Madhya Pradesh, Rajasthan, where stone is available in abundance, stone slabs are used for roofing. In plain slab roofing, the stone slabs of size 1.5 to 3.6m length and 0.27m to 0.6m width are used according to the size of span. The stone slabs are directly supported over the walls and no middle support or joist is used for roofing.

In other types of stone slab roofing, small slabs of size 1.0m x 0.6m are placed over the wooden or RCC joists and a layer of lime terracing is done over the slab roofing.

Reinforced cement concrete slab roof

Such roofs are durable and longer lasting, but the cost is high compared to other types of roofing.

New Materials and Products

Polymer Composites

These are produced using polymers in addition to one or more of the traditional ingredients, namely, cement, fine and coarse aggregates. Addition of polymers to concrete products considerably improves the compressive strength and resistance to wear and tear.

Polymer composites are produced mainly by three different methods.

i) Polymer impregnated concrete

In this process, precast products are manufactured in traditional methods using cement composites. After the product is hardened, air from the voids in it, is evacuated and a monomer is injected under pressure. Sometimes the product may be soaked in the monomer for its effective diffusion through concrete in case of surface polymerisation. The product is then subjected to polymerisation. Polymerisation can be initiated either by radiation or heat treatment. The commonly used monomers in the former method are methly - methacrylate (MMA), styrene, and polyesterstyrene. Ether benzoyl peroxide, or Azobisisobutyronitrite, or hydrogen peroxide is used as catalyst in the heat treatment method. Compressive strengths of 280 MPa have been achieved in Italy, using MMA, high silica cement and crushed basalt aggregate.

ii) Polymer cement concretes

These are polymer modified cement composities and are obtained by mixing polymers with the ingredients of ordinary concrete. They are produced using either latices, such as, natural rubber, styrene-butadiene and acrylic polymers or prepolymer modifiers, such as, furfuryl alcohol, furfural acetol, diglycidyl. Increased impermeability and reduced water absorption capacity are the main advantages of these products.

iii) Polymer concrete

Cement is used as a binder in cement concrete. In the same way, a monomer or resin is added to bind preheated aggregates consisting of coarse, fine, ultrafine and other waste products such as, glass and saw dust. The commonly used binders are styrene, methylmethacrylate, polyesters, and epoxies.

Sulphur Impregnated Concrete

Sulphur, sand, and coarse aggregate are the ingredients of this concrete. Molten sulphur is added to the preheated aggregates in a mixer. The hot mix is immediately transferred into the moulds to fill them completely. The products manufactured with sulphur concrete need no curing and the moulds can be stripped immediately as the sulphur solidifies rapidly under normal temperatures. One of the major advantages of these products is that they can be remoulded and concrete can be reused with minimum or no wastage. These products have very low absorption and less permeability.

Strengths upto 44 MPa have been reported, when 30% of sulphur, 50% of sand, and 20% of coarse aggregate are mixed. These are, therefore, versatile for use as precast slab elements of canal and tunnel linings.

Fibre Reinforced Concrete (FRC)

The concept of reinforcing brittle materials with fibres is very ancient. As early as 2500 B.C., asbestos fibres had been used to improve the tensile and flexural strength of ceramics in Finland. Horse hair was reported to have been used in plaster to increase its tensile strength. Even straw and other vegetable fibres were used in the past to reinforce the sun baked bricks. Thin fibres of short lengths introduced into brittle materials serve as crack arresting mechanisms making the material ductile to a certain degree.

Thin fibres made of several materials such as steel, glass, asbestos, graphite, nylon, polyester, polyethelene, polypropelene, rayon, kelvar, Aramid, wollastonite, basalt, bamboo, cotton, coir, sisal and banana, have been tried out to improve the structural properties of concrete. Properties and applications of FRC made using some of these materials are discussed in detail in this report.

Steel Fibre Reinforced Concrete (SFRC)

SFRC is a composite material having fibres as the additional ingredient, dispersed uniformly at random in small percentages, i.e. between 0.3% to 2.5% by volume in plain concrete. SFRC products are manufactured by adding steel fibres to the ingredients of concrete in the mixer and by transferring the green concrete into moulds. The product is then compacted and cured by the conventional methods. Segregation, or balling is one of the problems encountered during mixing and compacting SFRC. This should be avoided for uniform distribution of the fibres. The energy required for mixing, conveying, placing and finishing of SFRC is slightly higher. Use of pan mixer and fibre dispenser to assist in better mixing and to reduce the formation of fibre balls is essential. Additional fines, and limiting maximum size of aggregates to 20 mm, cement contents of 350 kg/m³ to 550 kg/m³ are normally needed.

Steel fibres are added to concrete to improve the structural properties particularly, tensile and flexural strength.

Glass Fibre Reinforced Cement (GFRC)

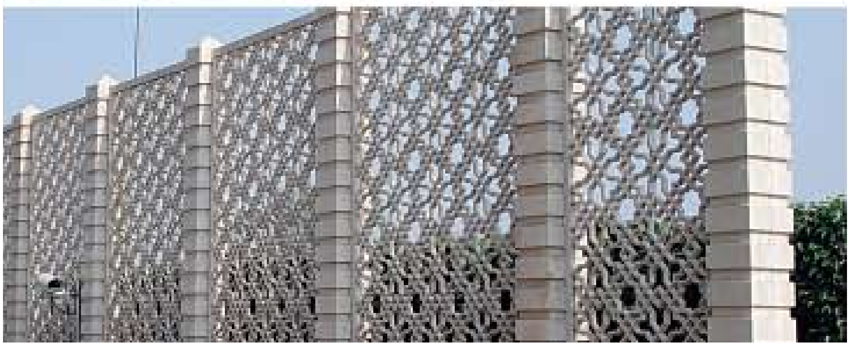
Glass fibres are used to reinforce cement and concrete. Glass fibre reinforced cement (GFRC) comprises hydration products of cement, or cement plus sand, and the glass fibres.

Glass fibres of 10 mm to 50 mm in length and a few microns in diameter can be added upto 5% by weight and premixed with cement and water in a pan or a paddle mixer. Small quanties of lubricating admixtures, such as, polyethylene oxide or methyl cellulose may be added into the mix. The resulting mix may be sprayed, or cast into the moulds. The products can also be produced either by extrusion or by injection-moulded process. In some of the processes, rovings can be chopped in situ and sprayed simultaneously with a slurry of suitable consistancy on to a mould for production. This is very effective and convenient for casting shell roofs and sheets.

Use of glass fibres in concrete is very limited because they suffer severe damage and loss of strength due to abrasion and impact forces generated during movement of aggregates in mixer.

Asbestos Fibre

Asbestos is a naturally available mineral fibre which has been successfully combined with Portland cement paste so as to form asbestos cement. Asbestos cement has been widely used for fibre reinforced composite. Asbestos cement products contain about 8% to 16% asbestos fibre which imparts flexural strength to asbestos board about 3 to 4 times of that of unreinforced matrix. Asbestos cement has high thermal insulation, high mechanical strength, and high chemical resistance; but are brittle with low impact strength. Asbestos products, such as, corrugated roofing sheets, pipes, tanks are well known. All over the world, there is great demand for a suitable sub-



stitute for asbestos fibre due to a disease called “Asbestosis” associated with the asbestos fibre.

Concrete Reinforced with Organic Fibres

Organic fibres include vegetable fibres, such as, sisal, bamboo, coir, cotton, and banana, and synthetics, such as, nylon, polypropylene. Investigations made by British Research Station in the U.K., on the use of sisal fibres gave disappointing results due to high water absorption by the fibres. Recent studies on cement mortar reinforced with some natural fibres of the above family showed encouraging results. Synthetic fibres of high purity are now available in many places in the world. Nylon in the form of cut monofilaments were recommended for the blast resistant buildings in U.S.A. However, nylon was found to be more expensive than polypropylene and hence, fibrillated polypropylene twine was recommended for use in concrete.

Ferrocement

The concept of ferrocement dates back to the ancient constructions built in India using mud walls reinforced with woven bamboo mats and reeds. Chinese have extended this to roof construction using burnt lime composites with bamboo pole reinforcement. The present form of ferrocement consisting of cement mortar and thin steel meshes was originally developed in France for boat building in the first half of the nineteenth century.

Since then many countries in the world showed continued interest in the ferrocement constructions. The journal of the structural Engineering, India, published a special issue in January 1975 on the developments in ferrocement. In 1976, the Asian Institute of Technology, Bangkok, established the International Ferrocement Information Centre and the Journal of Ferrocement is regularly published from this centre to develop and disseminate the technology in the ferrocement held in Italy in July 1981 dealt several aspects of ferrocement construction.

Ferrocement composite comprises rich cement mortar matrix of ten to sixty millimeters thickness, in which are embedded one or more layers of very thin wire mesh and a skeletal reinforcement consisting of either weld mesh or mild steel bars. The matrix is typically rich in cement - cement/sand ratio of 1:1.5 or 1:2. Use of 1:3 cement mortar has also been reported. Portland cement, with or without pozzolanas, is generally used for ferrocement. Plastixizers and other admixtures may also be added to improve the workability. Chromium trioxide can be added to prevent galvaniccorrsion of steel in ferrocement.

Water requirement of mortar, which is an important factor that governs strength and workability of mortar, primarily depends upon the maximum grain size, the fineness modulus, and the grading composition of sand. Sands with maximum particle sizes of 2.4 mm and 1.2 mm with optimum grading are recommended for ferrocement mixes. Use of fine sand in ferrocement is not recommended.

As already stated, the reinforcement used in ferrocement is of two types, viz. skeletal steel and wire mesh. When used, the former comprises relatively large diameter (about 3 mm to 8 mm) steel rods spaced typically at 70 mm to 100 mm. It may be tied reinforcement or welded wire fabric. The wire mesh consists of galvanised wire of diameter less than one millimeter, (chicken wire mesh, hexagonal or square type) formed by welding, twisting or weaving. Specific mesh types include woven or interlocking mesh, woven cloth, welded mesh in a rectangular pattern with or without diagonals. Expanded metal or without diagonals. Expanded metal lath has also been tried out for fibre reinforced products.

Applications of Ferrocement

Ferrocement consists of very high percentage of well distributed and continuously running steel reinforcement, and hence, their behaviour is nearly the same as steel plates. As discussed earlier, its cracking resistance, ductility, flexibility, impact and fatigue resistance are higher than concrete. In addition, impermeability of ferrocement products is far superior to that of the ordinary reinforced products. Ferrocement combines easy mould ability of concrete to any desired shape, and lightness, tenacity and toughness of steel plates. Hence it is becoming a popular structural composite to manufacture many precast products, such as, water tanks, silos and bins, biogas holders, pipes, boats, different types of roof and floor units, kiosks, and service core units.

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HFNRP Partition Sheets for Housing at the Centre: A revolutionary solution



V.A.Nagarajan K.P.Vinod Kumar** B.G.Bavithran****

Introduction

India is still a developing country and hence urbanisation is indispensable. People move in to big cities for their livelihoods and many of them cannot afford to buy their own homes. Owning a house has been an eternal dream, even for the middle class people living in India. Also, land cost and land area in the overcrowded cities of India are other major deterrents in the urban areas for house construction. Providing ample facilities to the expanded areas of cities such as power and water facilities are the other difficulties faced by the local administration. Consequently, it is imperative for the cities to grow vertically in terms of multi-storeyed apartments.

Normal concrete multi-storeyed building construction involves high cost and takes much time for the completion. As the number of floors in the multi-storeyed apartment's increases, the overall weight is increased, which is not desirable and unsafe. During natural calamities such as earthquake, downfall of such large buildings results in high fatalities. In order to reduce the cost and win such difficulties, low cost and less weight Fiber Reinforced Plastics (FRP) can be used as indoor partition material in multi-storeys construction [Paul Wambua et al 2003].

Fishnet is made using nylon fibre and woven in a grid-like structure. Monofilament and multifilament fishnet are generally used for fishing and the latter is composed of many small filaments twisted together. Nylon is a plastic material, which is tough, possess high tensile strength, elasticity, lustre and highly resistant to abrasion and chemicals [Clara Ceppaa et al 2012, Siddharth Das Gupta et al 1996]. These are discarded as wastes and thrown away as wastes along the shores [Central Pollution Control Board, 2012].

Hybrid fishnet reinforced plastic (HFNRP) composites are developed with the discarded fishnet, glass fiber and polyester for indoor partition applications in our laboratory. The manufactured composite materials are tested for its mechanical and other properties. These low cost building partition sheets, which is being developed is a potential material for the building of affordable and safe homes for millions of people, who dreams for owning a home in cities.

Materials used:

Raw material such as glass fiber of grade 300 g/m^2. Discarded nylon fishnet of 8 mm mesh size were collected from the coastal area of Kanyakumari District, washed thoroughly with water to remove dirt, subsequently were dried and stored for composite manufacturing. Unsaturated polyester (Grade: SBA2303-Isothalic) was used as the matrix material. Methyl Ethyl Ketone Peroxide (MEKP) was used as the catalyst. Cobalt naphthenate was used as the accelerator.

Mechanical properties of fishnet nylon and glass fiber

Density of the glass fiber and discarded fishnet are 2.5 g/cm^3 and 1.15 g/cm^3 respectively. Elongation at break of glass fiber and discarded fishnet are 4.5 % and 40 % respectively. Young modulus of glass fiber and discarded fishnet are 60-68 GPa and 3.1 GPa respectively.

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Composite Sample Preparation

HFNRP were prepared using discarded fishnet, glass fiber ad polyester matrix. Curing of composites was done using Methyl Ethyl Ketone Peroxide (MEKP) and cobalt naphthenate (accelerator), all those were of AR grade chemicals. The manufacturing is done by the hand lay-up method. The types composites developed are given in figure 1.

- HFNRP 1 consists of two glass fibers and one fishnet sandwiched.
- HFNRP 2 consists of two glass fibers and three fishnets sandwiched.
- HFNRP 3 consists of two glass fibers and five fishnets sandwiched.
- HFNRP 4 consists of two glass fibers and seven fishnets sandwiched.

The thickness of composites HFNRP-1, HFNRP-2, HFNRP-3 and HFNRP-4 measured with screw gauge are 2.07, 2.09, 2.11 and 2.15 mm respectively.

A model of the HFNRP composite developed is given below in figure 2.

Mechanical Tests

Various mechanical tests conducted such as Tensile Strength, Flexural Strength and Impact Strength are given in table 1. All the experiments were reproduced three times for consistency.

The tensile test was conducted as per the ASTM D 3039 specifications for which the composite specimens were cut to required dimensions using saw. The test results for tensile strengths of HFNRP sheets are studied. It is seen that the tensile strength of the HFNRP composite increases with increase in fiber content. The glass fiber has more tensile strength than nylon fiber, which is reflected in the composites [F.T. Wallenberger, 1999]. Here, the stress and the strain of the composite sheets are taken into consideration and the fact is that the partition sheets does not imply to tensile load. The tensile strength of the HFNRP tends to increase with the increase in fishnet layers. But when the number of layers of fishnets exceed more than three, the increase is less.

Glass fiber	Glass fiber	Glass fiber	Glass fiber
Fishnet	Fishnet	Fishnet	Fishnet
Glass fiber	Fishnet	Fishnet	Fishnet
	Fishnet	Fishnet	Fishnet
	Glass fiber	Fishnet	Fishnet
		Fishnet	Fishnet
		Glass fiber	Fishnet
			Fishnet
			Glass fiber
HFNRP-1	HFNRP-2	HFNRP-3	HFNRP-4

Figure 1 Different Hybrid Fish Net Reinforced Composite Plastics (HFNRP) fabricated

Figure 2 Model of HFNRP composite

The flexural tests were performed according to ASTM D 790 using Universal Testing Machine at a cross head speed of 1.4 mm/min. Test specimens were made to 191×13 mm. The flexural strengths also show similar type of results, as the increase in value is very less in percentage as the number of fishnets layer increases above three. The flexural strength of nylon is comparable to glass fibers [Jacob John et al, 2001]. From this observation, the composite with three fishnets possess maximum flexural property when compared to the other three.

Impact tests were carried out in accordance with ASTM D 256. Fishnet nylon material has more elastic property. The impact energy values of different composites recorded during the impact tests. Fishnet nylon material has good elastic property [M.L. Tate et al, 1996]. It is observed that glass fiber is more brittle than nylon fiber (soft) [D.J. Lin et al, 2006] and flexible. It shows that the resistance to impact loading of composite material improves with increase in fishnet contents. The suitability of a composite for a specific application should therefore be determined not only by usual design parameters, but by its impact or energy

Table 1. Comparison of Mechanical Properties

S.No.	Test	Unit	HFNRP 1	HFNRP 2	HFNRP 3	HFNRP 4
1.	Tensile	MPa	70.0	74.4	74.6	75.0
2.	Flexural	MPa	148.0	270.0	276.2	269.0
3.	Impact	kJ/m^2	43.8	63.1	65.0	68.7

absorbing properties. It is obvious that glass fiber is more brittle than nylon fiber, which reflects the fact that HFNRP 2 have better impact property than the others.

Flammability

Flammability of the HFNRP composites were evaluated using the horizontal flame test and the vertical flame test.

Horizontal flame test: Flammability horizontal evaluations of composites were performed by adopting the standard procedure, ASTM D 635. Horizontal burning test was conducted by holding the specimen horizontally and a flame was introduced to one end of the specimen. The time taken for the flame to reach from first reference mark (25mm from one end) to the second reference mark (100mm from the same end) was noted. The burning rate of the composites was calculated by V=60L/t, where V is the burning rate in mm/min, L is the burned length and t is the time of burning. It is obvious from the results that more glass fiber incorporated composites have better flammability resistance than more fishnet incorporated composites. But the variation is not significant for all the four composites.

Vertical flame test: Flammability vertical evaluations of composites were performed by adopting the standard procedure UL-94. None of the samples confirmed to this test as the specimens burned up to the clamp. However, fire retardant polyurethane coating shall be applied over these composite surfaces to reduce the flammability, which can be used as partition sheets in multi-storeyed apartments.

Conclusion

Four different types of composite panels were prepared with fishnet nylon fiber and glass fiber as reinforcement material individually and in combinations along with polyester matrix. Various mechanical and fire properties were examined for the composites. The results showed that hybrid composite material made with two layers of glass fibers and three layers of nylon fishnet has good properties than other composites. Therefore, HFNRP – 2 composite can be used as an alternate, less weight partition sheet material in multi-storeyed apartments at the centre, where weight plays a major role in construction.

Acknowledgement:

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References

1. Clara Ceppaa and Gian Paolo Marinoa. Food-pack waste systemic management. Alternative ways to reuse materials and to develop new business, products and local markets, Procedia Environmental Sciences 2012; 16: 616 – 623.
2. Jacob John, Shivaputrappa A. Gangadhar and Ila Shah, Flexural strength of heat-polymerized polymethyl methacrylate denture resin reinforced with glass, aramid, or nylon fibers, The Journal of Prosthetic Dentistry, 2001; 8 (4): 424–427.
3. Lin DJ, Chang CL, Lee CK and Cheng LP. Fine structure and crystallinity of porous Nylon 66 membranes prepared by phase inversion in the water/formic acid/Nylon 66 system. European Polymer Journal 2006; 42: 356-367.
4. Material on Plastic Waste Management, Central Pollution Control Board, June 2012, Delhi-110032.
5. Paul Wambua, Jan Ivens and Ignaas Verpoest. Natural fibres: can they replace glass in fibre reinforced plastics. Composites Science and Technology 2003; 63: 1259–1264.
6. Siddharth Das Gupta, Willis B. Hammond and William A. Goddard III. Journal of the American Chemical Society 1996; 118, 12291-12301.
7. Tate M.L., Kamath Y.K., Wesson S.P. and Ruetsch S.B. Surface Energetics of Nylon 66 Fibers. Journal of Colloid and Interface Science 1996; 177: 579-588
8. Wallenberger F.T., Silica Glass Fibers, in Advanced Inorganic Fibers Processes, Structures, Properties, Applications, F.T. Wallenberger, Ed., Kluwer Academic Publishers 1999; 129–168.

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Earthquake Hazard Zoning Maps and Atlases

Shri M.Venkaiah Naidu, Hon'ble Minister of Housing & Urban Poverty Alleviation, Urban Development and Information & Broadcasting, Government of India and Shri Rao Inderjit Singh, Hon'ble Minister of State for Urban Development and Housing & Urban Poverty Alleviation released the Earthquake Hazard Zoning Maps and Atlases brought out by NDMA and BMTPC on September 20, 2016 at New Delhi.

NDMA with the technical assistance of BMTPC have prepared the Earthquake Hazard Zoning maps of India as a whole, every State and UT of the country and even each District, taking the details upto the sub-district namely, Tehsil, Talukas, Blocks, etc. This information can be used by every citizen of the country by looking at the District Hazard Zoning Map to know in which intensity zone his/her village is and then to approach the knowledgeable authorities for guidance about his/her safety from a future earthquake occurrence in the area.

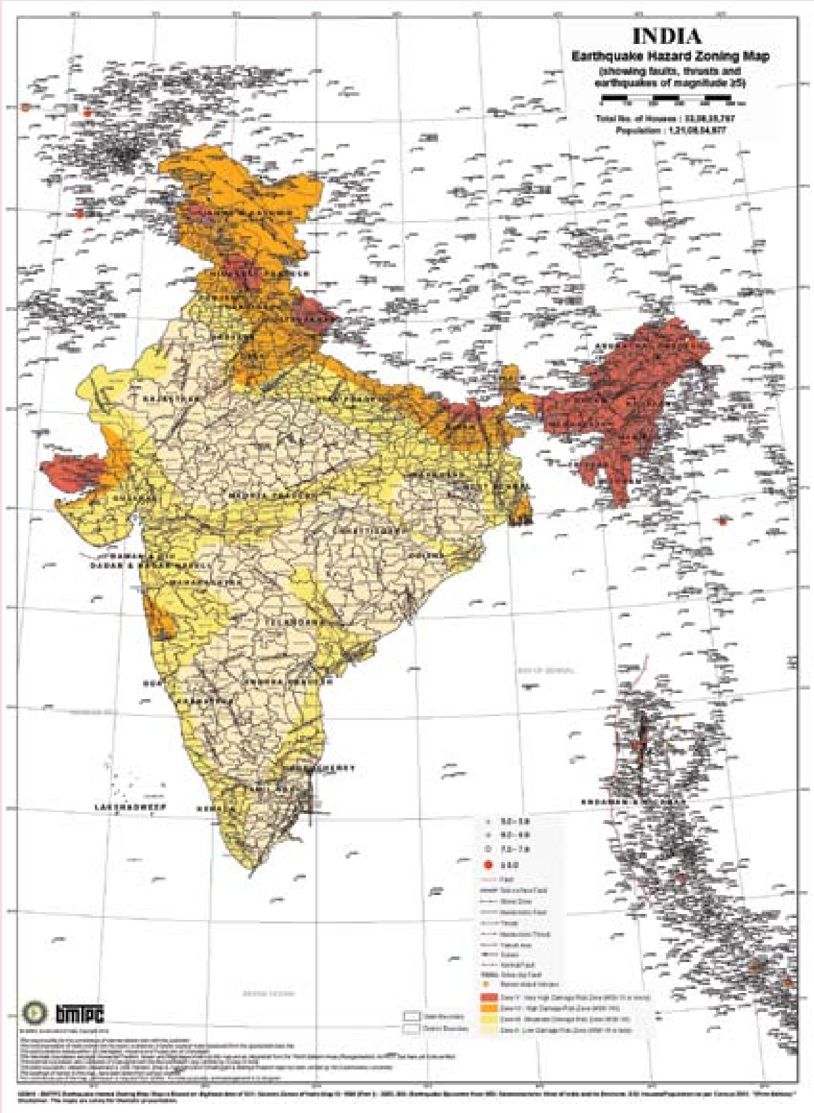
The updated Earthquake Hazard Maps and Atlases has the following components:

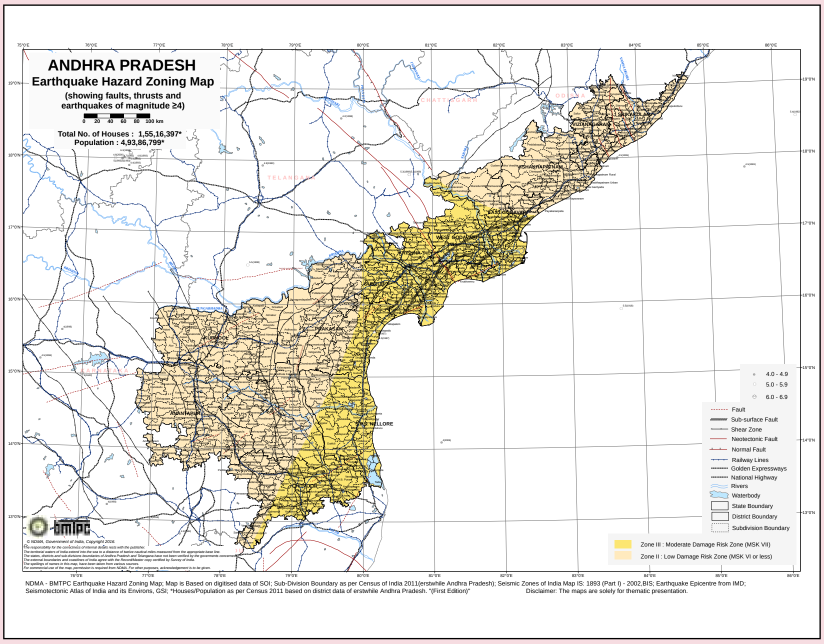
- Earthquake Hazard Zoning Maps for India
- Earthquake Hazard Zoning Maps for 36 States/UTs
- Earthquake Hazard Zoning Maps for all Districts
- Earthquake Hazard Zoning Atlas of India
- Earthquake Hazard Zoning Atlases for 36 States/UTs

The updated Earthquake Hazard Zoning Maps are based on Seismic zones as per IS 1893 (Part1) – 2002, District Boundary as per 2012 Survey of India data, Sub-division Boundary as per Census of India 2011 data, Epicentres of earthquakes of 4.0 and above as per IMD data, Seismo Tectonic details as per Seismotectonic Atlas of India of GSI. The additional features in the maps are Housing Data and Population data (Census 2011), Railway Lines, Golden Expressway & National Highway, Rivers & Waterbody.

Usefulness of Earthquake Hazard Zoning Atlas and Maps

- All major stakeholder groups i.e. leaders and policy makers, urban planners, engineers and architects, disaster management professionals, and people at large will benefit from the earthquake hazard knowledge incorporated in the maps.
- These outputs will also be useful for Code Committees, architects and engineers, insurance agencies, people involved in land use planning, and, in various aspects of public and financial policies dealing with disaster mitigation and emergency planning and management.





Role of Aerodynamics of tall buildings in making cities Safe, Resilient and Sustainable


*Dr. S.Selvi Rajan** *Dr. P.Harikrishna***

Introduction

The approach of 'Housing at the Centre' as defined by UN Habitat, is used to shift the focus from simply building houses to a holistic framework where housing is orchestrated with national and urban development in a way that benefits all people, which is aptly applicable for the Smart Cities Mission initiated by Government of India (Ref.: http://unhabitat.org/housing-at-the-centre-of-the-new-urban-agenda/). Some of the smart cities proposed by the Government are located along the coast line are exposed to severe cyclone hazard. The design of tall buildings in those cities requires special design guidelines. CSIR-Structural Engineering Research Centre has been conducting post-cyclone damage survey on buildings and structures since 1970. Wind loads on such buildings and structures need to be assessed scientifically for ensuring their safety and sustainability. This exercise would also help in achieving the resilience of the society in general. Development of rational design guidelines for tall buildings require following considerations:

- Aerodynamic modification to the structures having many reentrant corners
- Aerodynamic optimization for economical design
- Group effects amongst cluster of buildings
- Aerodynamic data to improve the design of buildings
- Occupancy comfort for tall flexible buildings
- Serviceability aspects for effective functional performance
- Pedestrian comfort in a colony where channelized flow exists

Boundary layer wind tunnel (BLWT) experiments have been employed successfully for the past five decades to generate the design aerodynamic data required to address the above issues. These experiments help in assessing the wind loads and their effects on tall buildings in urban environment. The built-up terrain effects including atmospheric boundary layer effects and topography effects can be reliably simulated in the boundary layer wind tunnel. The aerodynamic parameters required for the design of tall building depend on mainly the shape in plan and elevation, the geometric proportions and the angle of wind incidence.

Wind Tunnel Facility at CSIR-SERC

The boundary layer wind tunnel facility available at CSIR-SERC is an open-circuit, blower type wind tunnel. The total length of the tunnel is 52m. It is possible to generate a wind speed of 0.5 m/s to 55 m/s with the help of an axial fan. The power of the fan-motor is 600 HP (as shown in fig 5.1). An inlet diffuser is provided, followed by a settling chamber with screens and honey combs to channel the approach flow and to control the whirls into a laminar flow. The flow is furtherpassed through a contraction (1:5) zone. After the contraction zone, stream of air with uniform flow characteristics are achieved at beginning of the test section. The size of the test section is 18m (L) X 2.5m (W) X 1.8m (H) as shown in Fig. 1. Such a long test section is preferred to achieve

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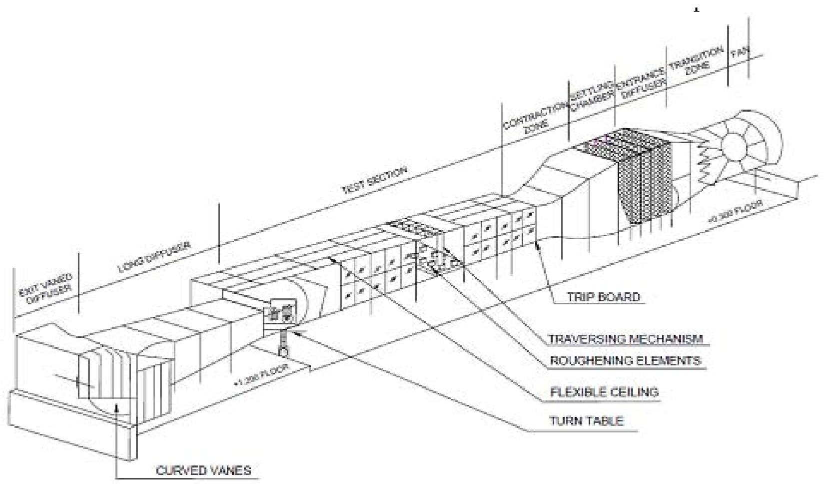

Fig.1 Isometric view of boundary layer wind tunnel at CSIR-SERC

(a) Set-back

(b) Tapered

Fig. 3 Models of Tall Building with Non-Prismatic Shapes in Wind Tunnel

natural development of a boundary layer. A flexible ceiling arrangement is provided to achieve zero longitudinal pressure gradients. In the test section, a trip board at U/S end followed by, roughness boards with roughness blocks are provided as the vortex generators. With this setup, a boundary layer depth as high as about 1.2 m can be satisfactorily generated at the downstream side of test section at which instrumented models are placed on a turn table.

Wind Tunnel Studies to Evaluate Aerodynamic Coefficients of Tall Buildings

Tall buildings with regular plan shape:

The aerodynamic characteristics of tall buildings with regular plan shapes like rectangular/square are observed to be mainly dependent on plan ratio and aspect ratio. It is observed from wind tunnel experiments (Fig. 2) that beyond an aspect ratio of 1:7 the drag coefficient values are invariant.

Fig. 2 Model of a Tall Building with Square Plan Shape in Wind Tunnel

Tall buildings with irregular plan shape:

Compared to tall buildings with regular plan shape, for buildings with irregular plan shape the mean drag coefficients are less and mean lift coefficients are higher. The mean torsion coefficients were observed to be almost same for buildings with regular and irregular plan shape.

Tall buildings with non-prismatic shape:

For tall buildings with non-prismatic shape, wind tunnel studies (Fig. 3) revealed that mean local drag coefficient values vary along the height as against nearly constant value for prismatic shaped buildings. The values of Strouhal number are comparable to those of prismatic shaped buildings.

Tall buildings with corner-cuts:

Compared to tall buildings without corner-cuts, for buildings with corner cuts (Fig. 4), the mean drag coefficient values are less. Further, the optimization of height over which corner cut need to be provided has partial benefit in reducing a few overall force coefficients.

Tall buildings with curved plan shapes:

As against circular buildings for which the mean drag coefficient is uniform, for buildings with elliptical plan shape (Fig. 5), the drag co-

Fig. 4 Model of a Tall Building with Corner-Cut in Wind Tunnel

Fig. 5 Model of a Tall Building with Elliptic Plan Shape in Wind Tunnel

efficient varies linearly with angle of wind incidence.

Tall buildings with twisted shape:

Compared to regular rectangular tall buildings, for rectangular building with twisted shape (Fig. 6) the mean drag and lift force coefficient are invariant with angle of wind incidence and the maximum values of the coefficients are less.

Group effects between tall buildings:

The studies on influence of orientation of three identical tall buildings with many recessions in plan (Fig. 7) with juxta positions with specific c/c spacing on the interference effect indicated that mean force coefficients are observed to be significantly increased for buildings plans parallel to each compared to building plans rotated by 45 degree.

Fig. 6 Model of a Tall Rectangular Twisted Building in Wind Tunnel

Fig. 7 Models of Group of Tall Buildings in Wind Tunnel

Summary - Importance of Wind Tunnel Stuidies for Urban Development

Tall buildings in urban environment are in general surrounded by other buildings due to which these buildings are prone to wind induced group effects, either shielding or enhancement. Boundary Layer Wind Tunnel is being successfully serving as a research and design tool in the assessment of such wind loads. The aerodynamic loads on tall buildings can be effectively reduced, with aerodynamic modifications to conventional shapes such as corner-cut, set-back, taper, twist, etc. This article brings out the role of aerodynamics of tall buildings in making cities safe, resilient and sustainable.

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Indo-Norwegian Training Programme on Nonlinear Analysis and Performance Based Design of Multistorey Buildings

The Council organized a Indo-Norwegian Training Programme on Nonlinear Analysis and Performance Based Design of Multistorey Buildings from December 3-5, 2015 at New Delhi in collaboration with Indian Institute of Technology, Roorkee, Royal Norwegian Embassy to India and NORSAR, Norway.

The programme was inaugurated by Dr. Nandita Chatterjee, Secretary, Ministry of Housing & Urban Poverty Alleviation. During the Inaugural Session, the participants were addressed by Dr. Shailesh Kr.Agrawal, Executive Director, BMTPC, Mr. Arild Oksnevad, Counsellor, Royal Norwegian Embassy to India, New Delhi, Dr. Dominik Lang, Senior Advisor & Project Manager, NORSAR, Norway and Dr. Yogendra Singh, Professor, Department of Earthquake Engineering, IIT Roorkee. The course was specifically targeted to Structural and Geotechnical Engineers, Practitioners, Designers in public and private sectors. The programme was attended by 70 participants from various parts of the country. It was fourth programme of the series organised in a span of two years.

Ferro-Cement as a Cost Effective Alternate Building Material – A Participatory Approach

*Dr. Sumana Gupta**

Introduction

The use of ferro-cement is observed in modern buildings as a flexible building material to achieve different shapes or forms. Ferro-cement finds wide application as a cost-effective building material in different states of India. Although, ferro -cement is not a new technology it is sparsely used as a building material in the state of West Bengal. Auroville Building Research Centre at Pondicherry has carried out extensive research on ferro-cement and has demonstrated it through different structures within their campus and surrounding. Wide applications of ferro-cement as a low cost building material is observed in this decade in the states of Kerela, Gujarat, Bihar and north eastern states of India. The West Tripura Rural Development center is also carrying out ferro-cement construction extensively. In Nadia district of West Bengal, 'Sankalpa' is the only organization that has initiated production and use of ferro-cement doors and windows, tanks for aqua culture.

Definition of ferro-cement as reported by American Concrete Institute Committee 549, 1988 is "Ferro-cement is a form of reinforced concrete using closely spaced multiple layers of mesh and/or small diameter rods completely infiltrated with, or encapsulated in, mortar. The most common type of reinforcement is steel mesh. Other materials such as selected organic, natural or synthetic fibers may be combined with metallic mesh." Moreover, in ferro-cement there is partial elimination of formwork material due to self shaping. When a ferro-cement sheet is mechanically overloaded, it tends to folding instead of cracking or rupturing. The wire framework holds the pieces together. A ferro-cement construction has only 10 to 25 percent of the weight of a comparable construction made of bricks resulting in considerable cost reduction. It is 10 to 30 mm in thickness. Ferro-cement is used as an alternative low cost building material and it is beneficial for construction in cyclone prone and earthquake prone areas because of its thin section that allows sway and remains integrated with the reinforcing mesh. Hence this composite material can take any profile because it is thin unlike heavy concrete sections. The advantages of this material are: it is cost effective; light in weight, hence can be used for low cost housing. When building units are prototyped then the construction time is also saved and modular construction can be carried out.

The Midnapore district of West Bengal receives heavy rainfall and cyclonic weather because of its geographic location. The village houses are severely affected by rainfall which damages the temporary roofs, walls and floors. Presently, the Kuccha housings are being converted to pucca houses through financial support from Indira Awas Yojna. Objective of this paper is to introduce ferro-cement as an alternative low cost building material to the villages of Midnapore through a participatory process where the mason is adequately trained regarding the construction technology and he himself makes the unit. A mason was selected who agreed to contribute his land to build the unit with this alternate building material on his own and learn the process

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of manufacturing the units and process of assembling. In return he owns the unit and it is left for demonstration for the village and neighbouring villages. The government fund which is distributed to the rural community to build up their housing units can be alternatively made of this material which is cost effective and safe under the prevalent cyclonic weather conditions of coastal West Bengal.

Literatures published by the Auroville Earth Institute (Baetens, 2004) and several video demonstrations prepared by the West Tripura Rural Development Centre and Auroville Earth Centre were shown to the mason.Various literatures (Sakthivel and Jagannathan, 2012; Girija et. al., 2014; Daniel et. Al., 2010; Clarke, 2010) were also studied which carried out the different structural tests with ferrocement. A mix of 1:2:2 by weight of cement, fine sand and zero chips was adopted similar to ferrocement wall panel units prepared in Tripura. Seven day and 28 day cube test for compressive strength test was also performed and was found satisfactory. The wall panels are designed in such a fashion that it had the provision to receive insulation within the cavity.

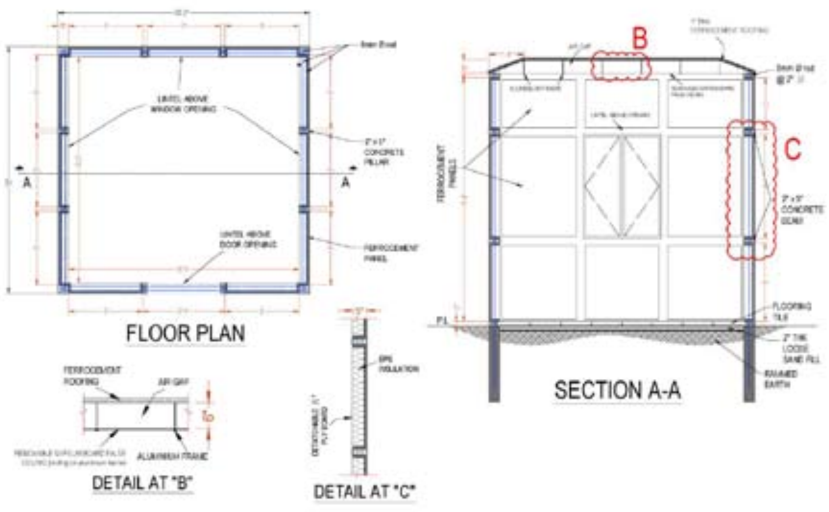

Figure 1 Showing plan and sectional details of the unit

The process of making the wall panel and laying the units

Initially a plan with details (Figure1) was prepared and a ferrocement panel dimension was appropriately chosen to make the reusable mould. Refer Figure 2a to 2c which shows how the reinforcements were placed, bound and the chicken wire mesh was placed in two layers. The framework was then placed in the wooden mould made for the purpose following the plan. The concrete mix was then cast and shuttering was removed after 24 hours and then cured keeping it in the same place for seven days (Figure3). Panels dimensions were appropriate to fit into the brick foundation (Figure 4). Four pillars were constructed at the corners to hold the structure. Intermediate concrete supports of 50mmx125mm were also grouted into the foundation as seen in Figure 5a. Horizontal ties of 50mmx125mm ran all through like a band lintel after placing each layer of wall panel (Figure 5b). Door and window opening was left open and the horizontal ties running above the openings were strengthened with additional tensile members (Figure 6). The top layer was continuous and the panel height was less compared to the lower two layers. Panels were cast accordingly to fit the required dimensions.

The process of laying the roof

The roof of the unit was cast in its place with centering and was cured for 28 days. It was found to be labor intensive compared to the sole unit to be cast. However, in case of mass production, separate casting is recommended. A ferrocement shell was constructed with two layers of chicken wire mesh. A layer was initially laid along with the reinforcement and tied with wires at intermittent points. The wires were left long and vertical and a thin layer of concrete mix was cast.The second layer of mesh was immediately spread and tied to the main reinforcement followed by second layer of concrete mix. Neat cement finish with damp proofing chemical was laid as the finish layer. Figures 7 (a,b), 8(a,b), 9(a,b) illustrate the stages.

External plastering and internal ceiling plastering of the entire unit was later carried out along with flooring. Door and window of PVC were fixed in position as seen in Figure 11a and 11b.The building was finished with appropriate painting as seen in Figure 13(a,b).

Thermal treatment

The drawback of ferro-cement while using as a building material is the thin section which do not act as sufficient buffer to the day time solar radiation. The day time temperature during summer months varries between 37-42^{o}C. Considering the higher thermal

Figure2(a,b,c) Making of the framework by the mason

Figure 3. Casting of the wall panel

Figure 4. Placing the panel at corner

Figure 5(a,b)Reinforcement for Vertical and Horizontal band between each layer

Figure6(a,b) Door and window opening and its spanning by integrated lintelwith horizontal band

Figure 7(a,b) The continuous top layer and roof shuttering

Figure 8(a,b) Rod binding and casting the roof

Figure9(a,b) Laying the second layer of wire mesh

Figure 10(a,b) Casting the top layer

Figure 11(a, b) View of door and window as fixed to the unit

Figure 12(a,b) Plywood covering over thermocol set within the panels and false ceiling on roof

Figure 13 (a, b) showing the finished unit both external and internal

conductivity (0.8) of concrete and very low thickness of the ferro-cement wall panels and the roof cover, the internal comfort condition was additionally taken care To achieve a desirable comfort level experiment with locally available low cost thermal insulation materials like grass board and hay was carried out by changing the insulation opening the plyboard cover on top. The values were also compared with the readings obtained in the mud houses with thatched roof, asbestos roof and tin roof. The ferro-cement wall panels were finally covered with ply boards and expanded polystyrene (commercially available as thermocol) as infill to provide thermal insulation as shown in Figure 12a and 12b. Gypsum board false ceiling was used, however, grass board could be used to reduce further cost. A study on rice husk boards (Bhatti and Shaikh, 2011) explores the thermal conductivity of rice husk as 0.035 and suggests its use as an alternative low cost insulating material. Locally available low cost material like rice husk boards could have been alternatively used. The other advantage of such board is it takes care of the waste of the rice industry. Architectural detailing of the wall panel unit to accept thermal cushions was also considered. However, rice husk boards could not be used as an experimental material because it is not manufactured locally, raw material for it is abundantly available and with the promotion of ferro-cement, rice husk boards can also be locally manufactured.

Summary of Cost

The target cost of the entire construction was one lakh INR. Considering it to be the sole unit the estimate had a little deviation, however once this can be promoted to a mass scale production the cost is expected to go down considerably.

Table 1: Expenditure under each Head

Heads	Cost in INR
Expenditure towards materials	71,892
Expenditure towards labour	26,930
Expenditure towards travel by the author for regular instruction	5,570
Total	**1,04,392**

The time required for the construction was 3 months by one single labourer and one helper. Use of multiple moulds can make the manufacturing process even faster.

Conclusion

The specific objectives of the paper to transfer the knowledge of use of alternative building material and its construction technology were achieved through execution of the unit. Training the mason to prepare the individual panels using proper reinforcing grid, winding it with the chicken wire mesh; using the right concrete mix and further setting up the livable unit as a life demonstration to other village households were successfully carried out. Insulating the unit using different material was also carried out along with electrical points. Transfer of technology and skill development through the training was achieved so that they can build their new houses or extensions using the same technology.

Response of the local people was also notable. The mason is also made aware of its construction procedure, cost effectiveness and advantages to promote ferro-cement construction under different schemes. If ferro-cement wall unit and roof units are produced in a mass scale, the cost and time of construction will reduce. Locally available materials can be appropriately used for insulation purposes. Local awareness, understanding and the practise of using ferro-cement will make it more popular.

References:

1. Baetens T., (2004), Manufacturing and Specifications of Prefabricated Ferrocement Roof Channels, Auroville Building Centre – Ferrocement roof channels.
2. Baetens T., (2004), Manufacturing and Specifications of Prefabricated Ferrocement Doors, Auroville Building Centre – Ferrocement Roof channels.
3. Bhatti K.Q., Shaikh M.S., Light weight insulating material prepared from rice husk, Journal of Environmental Sciene and Engineering, Vol 5, 2011, 882-885.
4. Clarke R. P., (2010), Study of full-scale elements of a ferrocement roof system for Caribbean application, Construction and Building Materials, Vol. 24, 221–229.
5. Daniel B. R., Jorge E. Hurtado and Lluis P., (2010), Experimental and analytical research on seismic vulnerability of low-cost ferro-cement dwelling houses, Structure and Infrastructure Engineering, Vol. 6, Nos. 1–2, 55–62.
6. Girija S., Shivkumar P., Lakshmikandhan K.N., Ravichandran R., Karthikeyan B.,Novel, (2014), Ferro-cement Lightweight Panels, International Journal of Applied Engineering Research, Vol. 9, 18, 4645-4657.
7. Sakthivel P.B, and Jagannathan A, "Fiber Reinforced Ferrocement - A Review Study", Proc. 2nd Int. Conf. on Advances in Mechanical, Manufacturing and Building Sciences (ICAMB-2012), SMBS, VIT University, Vellore, India, 09 January 2012 (a), pp.1172-1177.

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Earthquake Safety of Housing in India

*Prof. C.V.R.Murty**

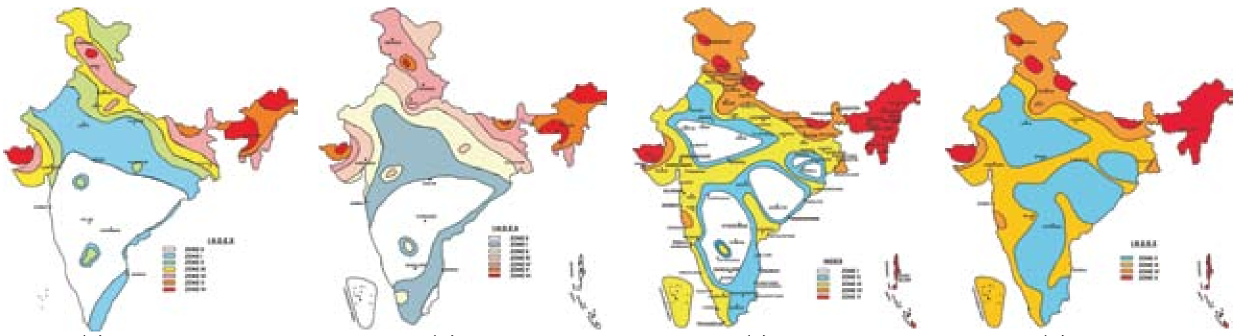
Introduction

In India, most house construction is done by individual homeowners themselves, and in many cases by masons acting as "self-styled" contractors; often, all this is without the involvement of an engineer or architect. Consequently, the expected knowledge base for planning and design is not available to make these houses earthquake resistant, and therefore the level of risk associated with such construction is not known. In the last two decades, a number of earthquakes in the country have caused significant loss to life and property. A large part of this loss is attributed to the type of housing typologies in practice in the country. For example, the relatively smaller size 1993 M6.4 Killari (Maharashtra, India) earthquake alone caused about 8,000 deaths; this colossal loss of life is attributed directly to collapse of houses built with random rubble stone masonry walls in mud mortar topped with heavy wood plant and joist roof overlaid with about 600mm of mud that collapsed on the occupants causing death and injuries.

Seismic Hazard in India

The varying geology and seismotectonics at different locations in the country implies that the likelihood of damaging earthquakes at different locations is quite different. Thus, a seismic zone map is required to provide a guideline to the level of earthquake shaking expected in different regions. The seismic zone maps are revised from time to time (Figure 1.1) as more understanding is gained on the geology, the seismotectonics and the seismic activity in the country (Murty, 2005). The Indian Standards provided the first seismic zone map in 1962, which was later revised in 1966. The first seismic zone map [IS:1893, 1962] of Independent India had seven seismic zones, namely O, I, II, III, IV, V, and VI; O was considered non-seismic zone (Figure 1.1a). The second map [IS:1893, 1966] only shifted the margins between these zones while maintaining the broad features (Figure 1.1b).

Based on levels of intensities sustained during damaging



(a) (b) (c) (d)

Figure 1.1: Indian Seismic zone maps since 1962: (a) 1962 edition, (b) 1966 edition, (c) 1984 version, and (d) 2002 edition (Redrawn based on IS:1893-1962, 1966, 1984 and 2002).

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earthquakes in the interim period in regions considered to be low seismic areas (*e.g.,* 1967 Koyna and 1969 Bhadrachalam Earthquakes), the 1984 version of the zone map [IS:1893, 1984] subdivided India into five zones – I, II, III, IV and V (Figure 1.1c), by merging areas under erstwhile zone O with that of zone I, and of zone VI to that of zone V (Table 1.1). Also, significant changes were made in the peninsular region along the western and eastern coastal margins, where these 1967 and 1969 earthquakes occurred. The maximum Modified Mercalli (MM) intensity of seismic shaking expected in the resulting five zones were V or less, VI, VII, VIII, and IX and higher, respectively. Parts of Himalayan boundary in the north and northeast, and the Kachchh area in the west were classified as zone V.

Table 1.1: Seismic zones in each revision of Indian Code – increased perception of seismic threat

Year of Release of Zone Maps			
1962	**1966**	**1984**	**2002**
0	0	I	II
I	I		
II	II	II	
III	III	III	III
IV	IV	VI	IV
V	V	V	V
VI	VI		

Public uproar following the 1993 Killari (Maharashtra, Central India) earthquake that occurred in the erstwhile seismic zone I, with about 8,000 fatalities, again raised questions on the validity of the seismic zone map in peninsular India. The 2001 Bhuj earthquake in the most severe seismic zone V of the country caused about 13,805 fatalities. These two events in particular compelled the Bureau of Indian Standards to revise the seismic zone map again in 2002 (Figure 1.1d); the current map has only four seismic zones – II, III, IV and V [IS:1893, 2002]. The areas falling in seismic zone I in the 1970 version of the map are merged with those of seismic zone II. Also, the seismic zone map in the peninsular region has been modified. Chennai (formerly Madras) is now included in seismic zone III as against in zone II in the 1970 version of the map. This 2002 seismic zone map is likely to be modified as more information emerges on seismic hazard of the regions.

Fatalities Versus Economic Setback

In countries (like India), where seismic design is not practiced in general, each earthquake is expected to cause both large fatalities and huge economic setbacks. For instance, the M7.7 Bhuj earthquake in 2001 resulted in 13,805 deaths, over 167,000 injured, 215,255 houses collapsed and 928,369 houses damaged [Murty *et al*, 2005]. The economic setback is slated at US$5 billion [Jain *et al*, 2002]. Urbanization in India is rising at an alarming rate, but the safety of the built environment is not commensurate with the prevalent seismic hazard. And, with time, the disasters will only get bigger because effectively very few earthquake-resistant constructions are being built across the country even today. Moreover, with accelerated urbanization, more and more vulnerable and disaster prone areas are witnessing widespread building activities, thus increasing the targets for future natural disasters. On the other hand, in countries where structural design has matured with formal processes in place, the losses are more in terms of contents of buildings than in collapse of buildings or loss of life. For instance, in Australia [UWA, 2007], even small events caused major economic set back, *e.g.,* the M5.6 Newcastle (NSW) earthquake of 28 December 1989 killed 13, but affected Aus$1.5 billion economic setback, and the M5.4 Ellalong (NSW) earthquake of 8 August 1994 resulted in Aus$40 million setback. With increasing urbanization and lifestyle changes, the finishes (non-structural elements) are becoming increasingly expensive. But such countries (with appropriate systems in place) are very few across the world. Majority of countries, including India, fall into the former category.

Housing in India

India became independent in 1947 and is home today to about 1.2 billon people. India is a seismically active country. But, even though construction standards exist in India, mechanisms are not in place even today to ensure their compliance. Even worse is the fact that earthquake safety issues are not taught in undergraduate civil engineering or architecture courses until 2003; even after 2003, only the few government colleges in one of the states (namely Gujarat that experienced a major earthquake in 2001) mandated the inclusion of earthquake resistant design and construction in the curriculum.

Added to this is the fact that the urban areas in India are growing at an alarming pace. The cities and towns are magnets for millions of citizens from rural India, and becoming attracting reservoirs of skills and engines for the productivity & economic growth of the country. By 2020, the urban areas are expected to account for 40%

of the population and to contribute 70% of the GDP of the nation. Further, the already acute shortage of housing, with more than 25 million units to be built, is further enhanced by the housing losses caused by the natural calamities. With water supply, sanitation and other urban infrastructure becoming scarce, legal and institutional reforms have not kept pace with the population explosion. Regulations to control land use, occupancy and ownership are in place in some cities, but there is no political will to implement them. They do not exist at all in many non-urban or semi-urban areas. With this as the backdrop, the real estate boom underway in the nation happens at a time where there are insufficient checks on quality of built environment coming up.

About 96.5% of India's construction is of non-engineered type with little or no engineering input, and the rest is made largely of reinforced concrete frame systems. Even this ~3.5% of so called *engineered* structures showed high vulnerability to earthquake shaking during the past two decades in the country. Unfortunately, the number of practicing professionals formally trained in earthquake safety related subjects is small, and a number of projects are being implemented without sufficient expertise in earthquake-resistant design and construction. Standards exist for earthquake-resistant design of structures, but are not used in most building projects, because of lack of understanding amongst designers on the one hand and of lack of perception of risk on the other. Even the available standards have a number of loopholes that designers exploit to reduce cost of construction. These strategies result in different levels of safety built into buildings. The local governments have insufficient checks on technical quality, because municipal offices not equipped to monitor technical quality; many of them do not have civil engineers to scrutinize the building designs. With no system in place for ensuring conformation, there is an indiscriminate issue of permits to construct based only on architectural considerations.

Seismic Risk of Indian Housing Stock

The existence of seismic faults in peninsular India (Figure 1.2) and the consequent seismic threat has been articulated in the Indian Seismic Code IS:1893 since the early 1960s. The 1.2 billion population of India lives (Figure 1.3) in over 25,000,000 houses built on soil

Figure 1.2: Seismic faults in India (*Source: GSI, 2003*)

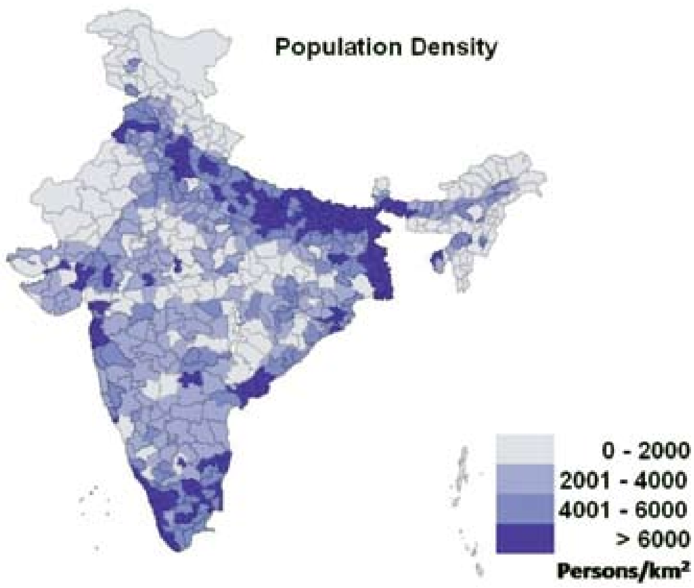

Figure 1.3: District-wise population density (Number of persons/km^2)
(Source: CoI, 2011)

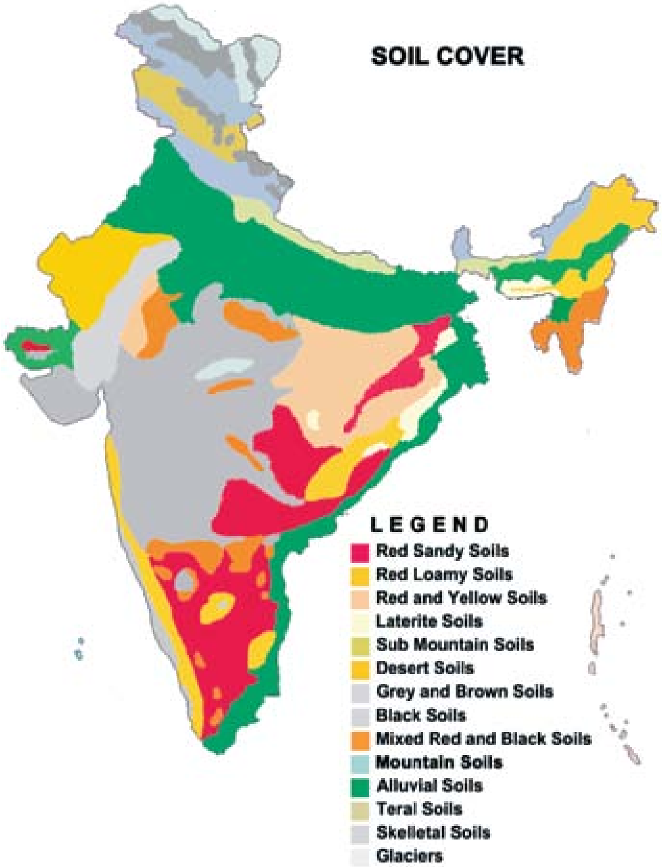

Figure 1.4: Soil cover (*Source: GSI, 2003*)

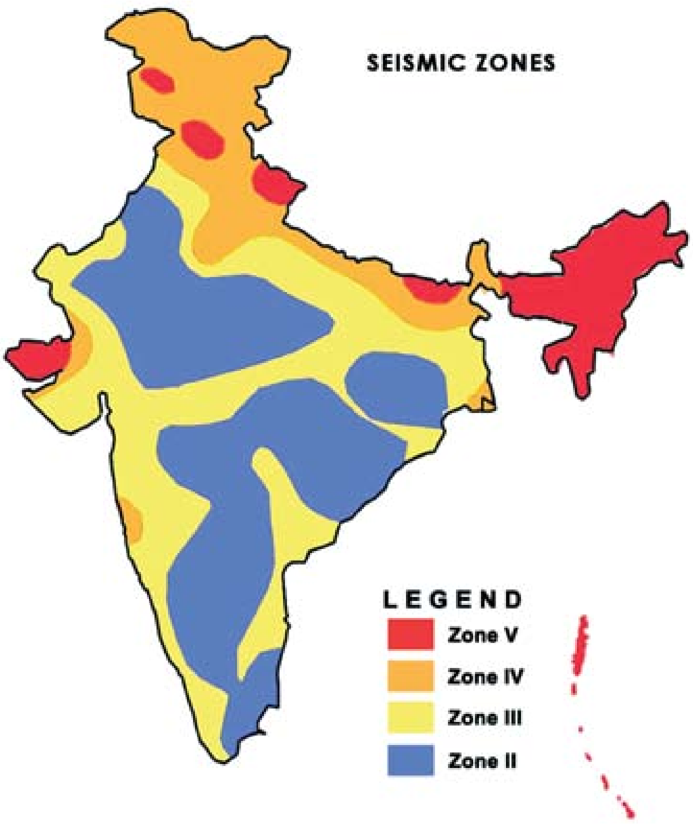

Figure 1.5: Seismic zone map (*Source: IS1893(1)-2004*)

cover that varies across the country (Figure 1.4). As mentioned earlier, about 60% of land area is under the threat of moderate to severe seismic shaking as per the Seismic Zone Map of India (Figure 1.5). The seismic hazard and prevalence of large housing stock in seismic areas (Figure 1.6) makes a significant part of housing in India at risk to earthquake damage and loss (Figure 1.7). Of these determinants of risk of the Indian population to seismic shaking across the country, the vulnerability of Indian house construction strategies should be kept low to reduce the risk of such damage and loss.

Another pointer that gives deep insights into the safety of housing in India is the choice of material used in the construction of houses across the country. Table 1.2 shows the summary statistics of the material for wall construction in rural areas, urban areas and entire country [CoI, 1991; 2001; 2011]. The cumulative dominant materials of choice by 2011 are: (1) mud and un-burnt brick (about 22%), (2) burnt brick (about 48%); and (3) Stone (about 14%). These three materials together account for 84% of houses in the country. This is in great contrast with the emphasis of the civil engineering and architectural education imparted across India. On the one hand, the housing construction materials listed above are reflected in only 3% of the courses taught to the undergraduate students. In particular, the course on masonry is almost extinct in the curriculum across the engineering colleges in the country. On the other hand, 97% of the curriculum is addressing the small minority of 3.6% of reinforced concrete houses in the country.

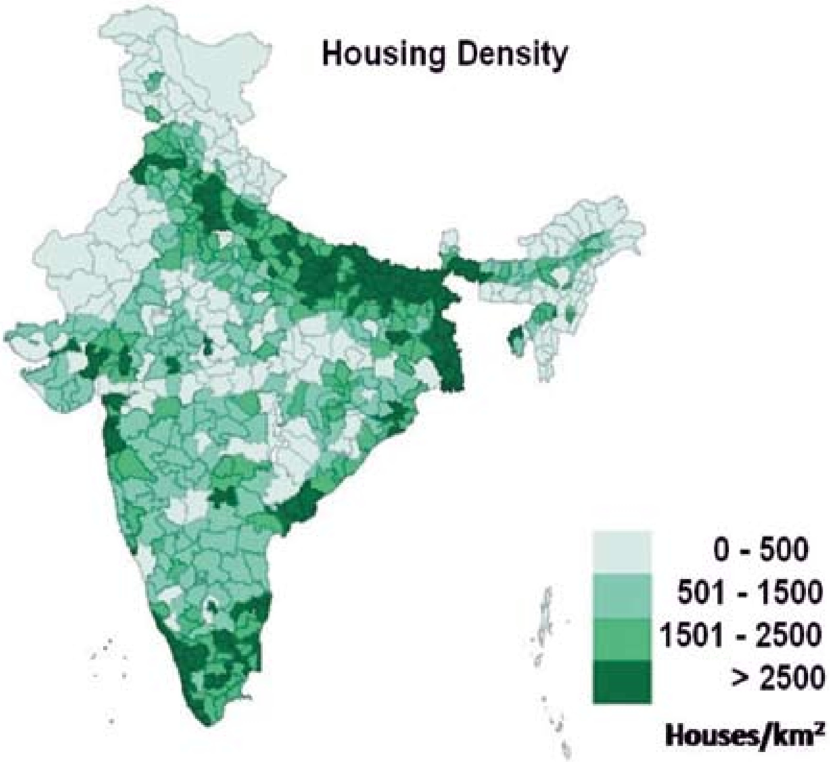

Figure 1.6: District-wise housing density (Number of Houses/km^2) (*Source: CoI, 2011*)

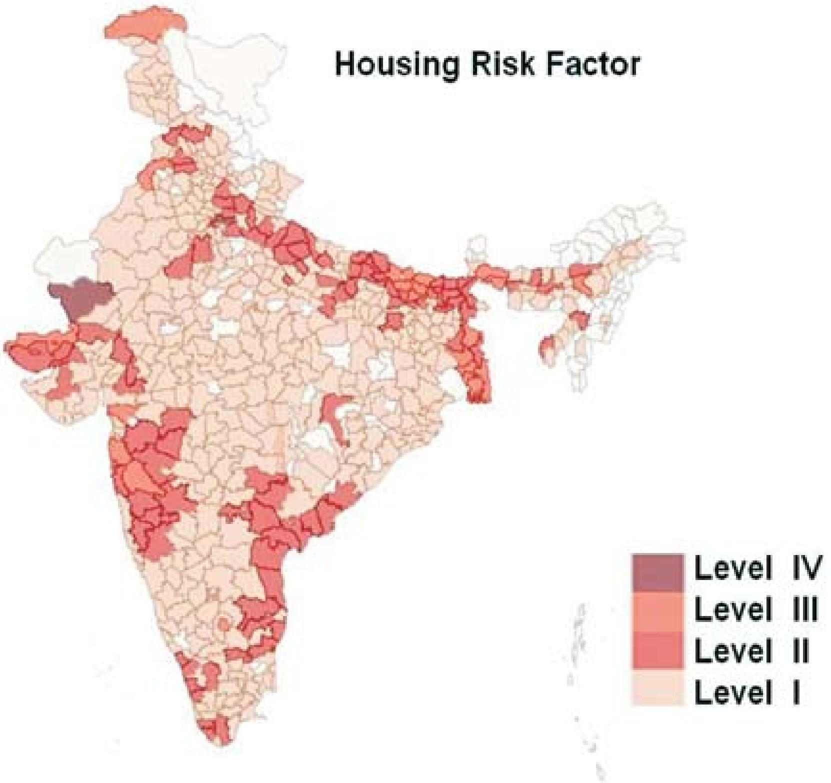

Figure 1.7: District-wise seismic risk factor (Seismic Zone Factor Z of the seismic zone multiplied by Number of Houses/km^2 for each District of India)

Recognizing the above skewed situation, there is need to develop clear understanding of this vulnerability of the building stock in the country, towards (1) identifying measures that can retrofit the existing building stock to earthquake-resistant standard, (2) ensuring that new houses constructed are not vulnerable, and (3) making systemic changes (as part of *capacity building* and *preparedness* initiatives of disaster management) towards mitigating impending earthquake disasters. Hence, a systematic methodology is required for

(a) Documenting Housing Typologies in the Moderate-Severe Seismic Zones of India, with a view to (i) understanding the extent of loss that is expected in each existing housing type, and (ii) developing guidelines for all new constructions; and

(b) Retrofitting the vulnerable housing stock in the Moderate-Severe Seismic Zones of India.

Table 1.2: 1991-2001-2011 India summary of choice of wall material in house construction (*Source*: CoI, 1991, 2001, 2011)

S.No.	*Wall Material*	*Number of Houses (Census **1991**)*					
		India		*Rural*	*%*	*Urban*	*%*
1	**MUD, UNBURNT BRICKS**	74,810,594	**41.3**	67,218,236	47.0	5,422,316	10.9
2	**BURNT BRICK**	68,897,374	**33.6**	36,646,602	25.6	32,250,772	64.5
3	**STONE**	21,703,991	**10.6**	17,284,400	12.1	4,419,591	8.8
4	Grass, Thatch, Bamboo, ...	19,588,428	9.6	17,056,489	11.9	2,531,939	5.1
5	**CONCRETE**	3,956,540	**1.9**	1,155,760	0.8	2,800,780	5.6
6	Wood	2,866,393	1.4	1,795,840	1.3	1,070,553	2.1
7	GI, Metal, Asbestos sheets	1,016,866	0.5	251,910	0.2	764,956	1.5
8	Ekra	254,908	0.1	201,039	0.1	53,869	0.1
9	Others	2,042,549	1.0	1,376,176	1.0	666,373	1.3
	GRAND TOTAL	**195,137,643**	**100**	142,986,452	**73.3**	49,981,149	**26.7**

S.No.	*Wall Material*	*Number of Houses (Census **2001**)*					
		India	*%*	*Rural*	*%*	*Urban*	*%*
1	**MUD, UNBURNT BRICK**	73,799,162	**29.6**	65,807,212	37.1	7,991,950	11.2
2	**BURNT BRICK**	111,891,629	**44.9**	62,515,919	35.3	49,175,710	68.7
3	**STONE**	25,481,817	**10.2**	20,347,899	11.5	5,133,918	7.2
4	Grass, Thatch, Bamboo, ...	**24,737,121**	9.9	22,162,932	12.5	2,574,189	3.6
5	**CONCRETE**	**6,540,338**	**2.6**	2,253,979	1.3	4,286,359	6.0
6	Wood	3,196,992	1.3	2,363,200	1.3	833,792	1.2
7	GI, Metal, Asbestos sheets	1,998,678	0.8	776,677	0.4	1,122,001	1.6
8	Plastic, Polythene	721,776	0.3	477,498	0.3	244,278	0.3
9	Others	728,356	0.3	532,197	0.3	196,159	0.3
	GRAND TOTAL	**249,095,869**	**100**	177,237,513	**71.3**	71,558,356	**28.7**

S.No.	*Wall Material*	*Number of Houses (Census **2011**)*					
		India	*%*	*Rural*	*%*	*Urban*	*%*
1	**MUD, UNBURNT BRICK**	66,449,827	**21.8**	58,330,614	28.2	8,119,213	8.3
2	**BURNT BRICK**	146,545,805	**48.1**	83,618,436	40.5	62,927,369	64.0
3	**STONE**	43,482,932	**14.3**	28685790	13.9	14797142	15.1
4	Grass, Thatch, Bamboo, ...	28,947,594	9.5	26,417,331	12.8	2,530,263	2.6
5	**CONCRETE**	**10,983,679**	**3.6**	3,699,096	1.8	7,284,583	7.4
6	Wood	2,781,271	0.9	2,132,342	1.0	648,929	0.7
7	GI, Metal, Asbestos sheets	2,331,869	0.8	1,269,359	0.6	1,062,510	1.1
8	Plastic, Polythene	1,097,831	0.4	762,256	0.4	335,575	0.3
9	Others	2,261,640	0.7	1,648,466	0.8	613,174	0.6
	GRAND TOTAL	**304,882,448**	**100**	206,563,690	**67.8**	98,318,758	**32.2**

Cyclone Shelter – Urban Sustainable Development

*Gajjala Ramesh Babu** *M. Keerthana***

Introduction

Peninsular India has a long coastline, which provides plethora of advantages to the country in the form of providing livelihood to people, being a viable source of renewable energy and acting as a hub for trading, to name a few among many. There is a natural tendency for urbanisation to take place around such geographical locations which nurture development. However, one of the major disadvantages of having such a long coastline is its increased vulnerability to tropical cyclones, which cause extensive damage to life and property. India, located in Asia-Pacific region, is battered by frequent tropical cyclones. Even recently, two very severe cyclonic storms ('PHAILIN' with a gust wind speed of 220 kmph in 2013 and 'HUDHUD' with a gust wind speed of 204 kmph in 2014) crossed the east coast of India.

Some of the proposed smart cities announced by Government of India under National Mission of Smart Cities are located on the coast and are vulnerable to cyclones. This is evident from the extensive damage suffered in Visakhapatnam, of the infrastructure like roof cladding of airport, glazing of commercial buildings, industrial structures, transmission line/communication towers etc., during recent 'HUDHUD' cyclone. Such urbanisation is one of the major reasons for sustained global warming. There is a need to view urbanisation and its impact on the environment in an interactive mode. This has resulted in increased sea surface temperatures, which will have implications in the form of higher probability of occurrence of extreme wind events/natural disasters. It has become necessary to design the human settlements against natural disasters like cyclones, which is one of the key aspects of the urban sustainable development. Government of India is also emphasizing the necessity to adopt disaster resistant technologies and designs for housing under the National Mission for Urban Housing / Smart Cities.

Thanks to the technological intervention and modelling capabilities, due to which loss of lives are brought under control through advanced early warning systems by the meteorological department, though the damage to property is unavoidable. The number of houses/buildings/other infrastructures damaged is still significant and is observed to be directly related to the intensity of the cyclone. The losses during the event of cyclone has been observed to account for 2% of the country's Gross Domestic Product (GDP) and about 12% of Central government revenue [1].

Urban planning practices have so far been by and large limited to cities, with lesser focus on the rural areas. A developing country like India can prosper only by means of a sustainable urbanisation that caters to the needs of both rural and urban areas. This precisely is the theme "Housing at the Centre" of the World Habitat Day this year.

Improvements to Low-Rise Dwellings against Cyclone

The eastern coast of India has high vulnerability to cyclones. It houses thousands of human settlements/communities involved in (and not limited to) fishing, pearl

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farming, salt production, etc. In earlier times, the dwelling units were mostly non-engineered and semi-engineered, subjected to extensive damage in the event of cyclone. Low-rise buildings in urban environment on the coast or in a complex topography or in low-lying areas are also susceptible to the fury of cyclone. CSIR-Structural Engineering Research Centre (CSIR-SERC) has contributed towards improving the performance of such dwellings against the cyclone by providing simpler guidelines [2] to:

(i) Enhance the strength of existing dwellings and their structural connections through simple techniques and finer detailing,

(ii) Construct new dwellings with the conventional and locally available materials through simplified construction/design practices.

The aforementioned guidelines have been prepared in the form of posters with illustrations in English and the vernacular languages of the east coast regions and circulated among the local people for adoption in their housing schemes. The same has been made available in the form of IS code 15498-2004, "Guidelines for improving the cyclonic resistance of low rise houses and other buildings/structures" [3].

Cyclone Shelter – Need and Design Aspects

The guidelines provided by CSIR-SERC for low-rise dwellings have helped in a big way to reduce the damage caused to such structures. The average coastal population density is 432 persons per sq. km as against 256 persons for the entire country [4]. Giving due importance to the lives of people in densely populated coastal regions and the safety of those living in non-engineered and semi-engineered dwellings (not satisfying the codal provisions), they need to be evacuated from their existing dwellings and accommodated in "cyclone shelter" (Fig. 1; Fig. 2). Cyclone shelter is a specialised multi-purpose community structure designed to combat the increased loading due cyclones and the associated storm surge. CSIR-SERC designed cyclone shelters for German Red cross society with special provisions. The innovativeness of structural design includes:

(i) Selection of suitable aerodynamic shape to resist cyclonic wind forces more effectively,

(ii) Provision of stilt, and sloping ground to satisfy the functional requirements against storm surges and

(iii) Selection of appropriate design wind speed based on risk analysis of cyclonic wind speeds carried out at CSIR-SERC.

There are about 203 cyclone shelters in the state of Odisha, including 65 constructed by Indian Red Cross Society [5], about 50 in the state of West Bengal [1], about 460 in the state of Andhra Pradesh [7]. At the stage of planning and design, the number of cyclone shelters to be constructed is governed by the density of population living in dwellings mentioned earlier that could probably be subjected to damage and the local topography. In certain situations, people living in engineered construction (that may not be subjected to structural damage during cyclones) also seek shelter in these structures, as such structures are subjected to damage

Fig. 1 Side view of Cyclone Shelter Designed by CSIR-SERC in Odisha (Photo: 2012) http://www.osdma.org

Fig. 2 Front view of Cyclone Shelter Designed by CSIR-SERC in Odisha http://www.indianredcross.org/rts/cyclone-shelters-provide-safety-to-hundreds.pdf

due to storm surge. The problems of contaminated water, damage to drainage lines, non-availability of food supplies, etc, are also faced by people living in engineered structures. In such scenarios, cyclone shelters provide safety to the occupants during times of havoc.

Cyclone shelters are one of the nodal points where relief materials will be made available by Government will be made available, till the normal life is restored. Hence, the approach roads to cyclone shelters needs to be given due importance in the sustainable urban planning. The access roads to cyclone shelter must be functional for transporting people and relief and rescue materials during cyclones. Specific designs of cyclone shelters with cattle mounding to accommodate cattle have also been designed and constructed.

The cyclone shelters must be designed with materials and methods such that the maintenance costs involved are less. In regions which are prone to multi-hazard such as cyclone and earthquake, the cyclone shelter should be designed to resist the earthquake forces. During normal times, cyclone shelters are used as community shelters for housing schools, health camps, election booths, etc. However, they have been identified to be more suitable for schools, thereby providing better schooling infrastructure. Hence, the appropriate development authorities can plan new schools in form of cyclone shelters, in a two-fold beneficial mode. Realizing the need and importance of cyclone shelters, Government of India in association with State Governments, has initiated construction of many cyclone shelters along the coastal regions. Even recently, Prime Minister has accorded approval for construction of six cyclone shelters at an estimated cost of Rs. 8.23 crore - two in Kozhikode, one in Kannur district of Kerala and three in Lakshadweep through the National Disaster Management Authority (NDMA) [8].

CSIR-SERC, based on its R&D expertise has conducted wind tunnel experiments towards evaluation of design wind pressure coefficients and improving the design of cyclone shelter (Fig. 3). Though the stilted configuration offers protection against storm surge, it is perilous in attracting high loads in the bottom and top slabs. The effect of stilted configuration on the wind load has been systematically studied in the wind tunnel by simulating cyclonic wind characteristics (Fig. 4). Efforts are underway to bring out a code of practice for the design of cyclone shelters against cyclonic winds.

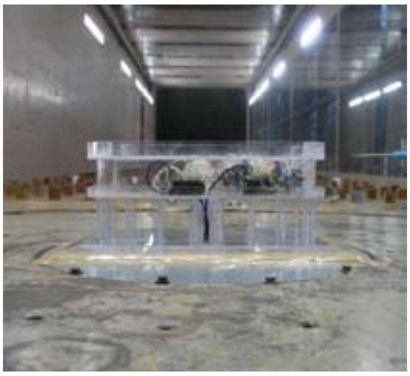

Fig. 3 View of cyclone shelter model in the wind tunnel

Fig. 4 Cyclone shelter subjected to simulated cyclone wind in wind tunnel

Summary

The role of cyclone shelters in urban sustainable development in coastal areas has been discussed. It can be seen that cyclone shelter is one of the important infrastructure in cyclone prone regions, and a component of the theme "Housing at Centre" for urban development. Proper planning and design of cyclone shelters is a vital disaster risk reduction measure for a sustainable built environment. In continuation to the contribution towards cyclone shelter, CSIR-SERC is continuously engaged in cyclone wind monitoring along the Indian coast to evaluate the cyclone wind characteristics for the structural damage mitigation. Such studies on the characteristics of cyclonic winds which are associated with high wind speeds and increased turbulence intensities will aid in the design of buildings/structures against extreme winds, to make them disaster resilient or build the housing infrastructure better. Research at CSIR-SERC is in progress towards scientific and rational methods of vulnerability assessment of cyclone prone coastal regions using cloud computing.

References

1. http://ncrmp.gov.in/
2. http://www.ndma.gov.in/images/cyclones/Recommended_Practices_CSIRSERC_NDMA.pdf
3. IS 15498: 2004, "Guidelines for improving the cyclonic resistance of low rise houses and other buildings/structures", New Delhi, India.
4. "Management of Cyclones" (2008), National Disaster Management Guidelines, NDMA.
5. http://www.osdma.org
6. http://www.ndma.gov.in/en/
7. https://www.pmnrf.gov.in/

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‘Housing for All’: Planning and Design Interface

*Dr. Uttam K Roy**

Introduction

After few decades from now will our urban historians mark the present decade (2011-20) as decade of housing for all? Or as decade of Smart city or Swachh Bharat? Or as digital India or start up India? Only future can answer this question. But we are entering in a new paradigm of global mandate through Habitat-III, with the slogan ‘Housing at the centre’ (UN Habitat, 2016) and with maximum and renewed hope in India to win a mammoth challenge of housing shortage, a known and old problem. To transform from a state of enthusiasm to a time bound performance we must try to strengthen our effort. It is a great opportunity to sharpen our tools before we plunge into post Habitat-III era to take up our remaining works for the mission. For last thirty years there have been phenomenal changes in policies related to land, finance and housing operations. Due to those reforms we now have a housing market with higher readiness to respond to the need of all economic groups including lower income groups (LIG) and economically weaker section (EWS) with or without govt support. Government of India under the leadership of Honourable Prime Minister Shri Narendra Modi has adopted an ambitious vision and mission to eliminate all existing housing shortages and achieve housing for all by the year 2022. The Pradhan Mantry Awas Yojona (PMAY) along with a Technology Sub-mission (TSM) has targeted the housing shortage in a new approach which was hitherto non-existing. To realize this goal we need continuous refinement and synchronisation of our action at all levels. Housing and land is a state subject as per the constitution of India. There is enormous scope for each state to reciprocate with initiative of government of India by creating larger canvas of plan and strategic actions for our cities and regions even beyond the scope of central schemes. Fortunately there are couples of state governments who have come up with excellent set of state level housing policies so far following the National Urban Housing and Habitat Policy 2007. A model state housing policy framework has been floated to enable others to adopt. The next level action will be required at the level of cities to make specific plan and strategies to estimate the future housing demand and map the possible resources (including PMAY) and implementation. Moreover a robust framework for design interface will be essential for the systemic change in the technology as envisaged in TSM. Here a discussion on such planning and design interfaces is considered as very important and essential prerequisite for a housing mission and therefore presented. For doing this, a short review of the present context will be required and is provided in the next section.

Revisiting the context for HFA mission

Urban population of India is already increased from 285.3 million in 2001 to 377 million in 2011, and expected to reach 410 million in 2015, 468 million in 2020 and 533 million in 2025 as per the projection based on the historical growth pattern of our population (1901-2001). The housing gap in India during 2001 was at 24.48 million (NUHHP). The gap in urban areas was found to be higher by almost 5% than the rural areas. Technical Group-12 on estimation of housing

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shortage commissioned by Ministry of Housing and Urban Poverty Alleviation (MOHUPA) estimated urban housing shortage as 18.78 million in 2012. Around 56% of the shortage was observed among the EWS households (household average annual income up to Rs. 1 lakh) and approximately 40% among the LIG households (household average annual income of Rs. 1 lakh to Rs. 2 lakhs). Further, Indian Housing market is characterised for its severe mismatch of supply and demand for respective income groups. EWS and LIG constitutes 96% (56+40) of total Housing Need where as market supply caters only around 15% (calculated in-house) for these groups in total.

The first concrete step taken by the government to govern the housing sector was the formulation of National Housing Policy (NHP) and National Housing Bank (NHB) in 1988. Through this initiative, the government attempted to tackle two of the stated issues – regulatory framework and financing, respectively. The NHP laid the foundation of housing policy in India and was modified or upgraded in future as a response to more identified issues. This resulted in the amendment of NHP in 1994 and formulation of National Habitat and Housing Policy (NHHP) in 1998. While evolving as a 'facilitator' of housing development, the approach towards the constituent policy parameters also underwent transformation.

The post liberalization policies and reforms in housing and land markets enabled private players in delivery of housing to all including LIG and EWS. Meanwhile joint ventures (with private and public) gained popularity in creating such housing stock by adopting cross subsidies in large or medium sized projects. Several developers started delivering market driven affordable housing units for low income families. In spite of all, the housing supply to low income people has been inadequate in comparison to the huge demand. Till the year 2000 the delivery of low income housing revolved around the subsidy or cross subsidy based policy undertaken by the central, state governments of para-statal bodies and also in very few cases public private partnership (PPP) companies.

Box-1: Various enabling approaches in affordable housing

1. Joint Venture: Cross subsidy based approach encourages joint venture companies with private developers
2. Land Reform: Legal and policy reforms like Repeal of Urban Land Ceiling and Regulation Act, Amendment of Land Acquisition Act etc towards making land available.
3. Reservation: Reservation of dwelling units and land for EWS and LIG in the privately developed housing projects.
4. Preventive: Preventive actions like streamlining rental housing by enabling private developers, and amending Rent Control Act
5. Demand Side intervention: Demand side intervention enabling people through interest subsidy.

After the year 2000 when several private players came up to cater for the housing for low and mid income category without any subsidy on market price, this whole situation started changing. This was due to various urban reforms took place along with JnNURM (2004-12) and Rajiv Awas Yojona (RAY ,2010-14). Various enabling approaches were tried to revive the housing market for whole some coverage (Box-1). Policy changes in streamlining availability of housing land and housing finance made it possible for international investment in large chunks of urban land and more housing supply. It is expected that the demand for affordable housing is likely to rise from 25 mn households to more than 38 mn households by 2030. This will be on the back of an increase in urban population to 590 mn by 2030 with more than 91 mn being from the middle class segment (MGI).

The trend of developing market driven housing unit for the mass is a mentionable improvement in India in recent times though the quantity is not sufficient yet in comparison to need. Further, recent legal and financial reforms by the government of India like interest subsidy scheme, reservation for Lower Income Group (LIG) and Economically Weaker Section (EWS) in private housing, tax exemption for affordable housing, has laid opportunity to various private players. They include investors, developers, micro-finance companies, suppliers of building materials etc. Concurrently PMAY incorporated the magic power of private partnership along with a combination of demand side and supply side interventions.

However, till now, the investments are limited to site-specific housing projects involving mainly onsite and traditional construction methods resulting slower and insufficient housing supply general. With this enabling land and financial market which is suitable to private developers, many such developers started exploring new technology options to deliver mass housing in less time to capture the time value. TSM as a sub set of PMAY is timely envisaged to cater to this need of the market in an organised manner. At this point we will discuss the planning and design interfaces required for the PMAY and TSM.

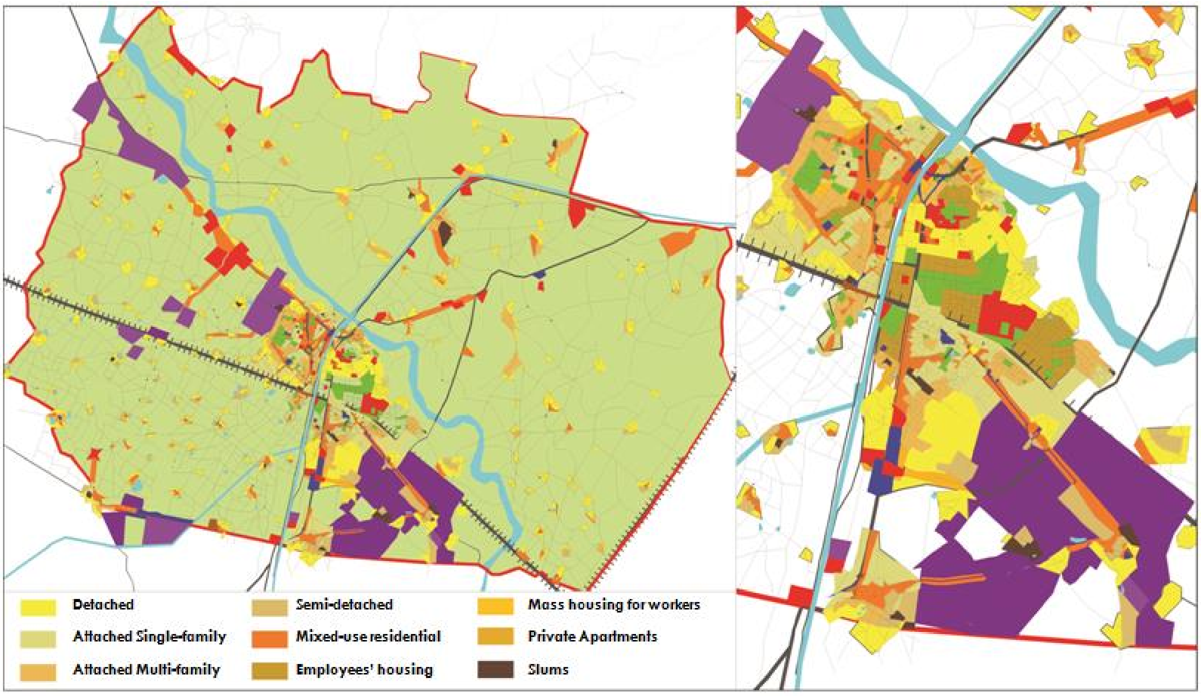
City Planning interface of HFA mission

After about two and a half decades of 74th Constitutional Amendment Act, Indian cities have inherited first generation of city planning exercise as city development Plan (CDP) during 2004-12 in Jawaharlal Nehru National Urban Renewal Mission (JnNURM) period. With the right mixing of reforms and policy at the central and state we are now in a position to scale up such planning action at the next level. CDP being a first generation planning discourse in Indian cities, it mostly covered the comprehensive linkage of funding schemes with the city infrastructure requirements. In term of creation of future land and a direction, based on the projection and growth trend, could not be covered. For a futuristic plan for provision of housing for all in a city, such an exercise to develop a

Box-2: Spectrum of housing Types in a City

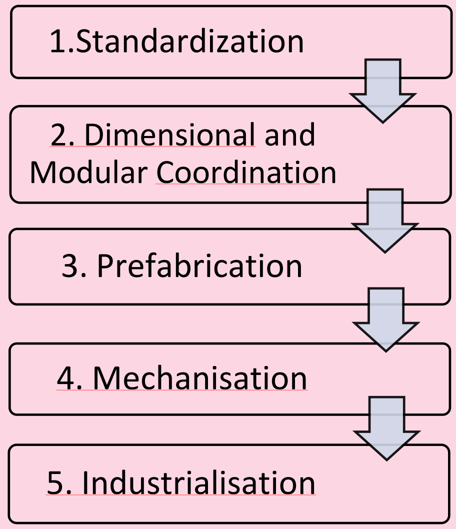
Origin	Housing Typology
Organic	Old city/walled city housing
	Urban village
	Traditional Housing
	Private plotted houses
Formal	Private developers housing
	Cooperative housing
	Employees housing
	Public developers housing
	Planned Private plotted housing
	Rental housing
	Joint ventures companies housing
Informal	Illegal /unauthorized houses
	slum and squatter
	Temporary stay of pavement dwellers

Box 3: An example of mapping of housing typologies at the sub-regional level: Case of Roorkee



comprehensive housing strategy for projected population will be required. In absence of such strategy documents, city authorities are unable to come out of a 'scheme driven' action to a 'holistic action' which will satisfy all possible typologies of housing, not only the slums. Unless we create developed urban land for future housing of various categories we will fail to prevent future slum formation. Following several land related reforms creation of land bank for future housing is possible with minimal effort. Every city is different and so is the predominant housing supply in each city even if those are in same geographical location. Are our city authorities aware about the future demand of different categories of housing typologies? Has anybody estimated or projected such demand? Are our city authorities aware about the available land and technology options for each category of housing? Therefore the strategic exercise for provisioning future land and housing is very crucial to avail the maximum benefit of present schemes, reforms and housing markets.

A typical city housing strategy formulation has several stages. First it takes the account of existing situation of all housing typologies (Box-2), stocks, condition, shortage and issues. In this second stage, it projects the future demand of each housing typology based on the trend in housing growth and population projection. Third, it estimates the land and finance required for each typology for future and identifies such pockets of development in the overall framework of CDP or master plan. After several iterations it decides the final allocation and location of future housing, land and finance. It also incentivises the new technology under TSM to get a quicker delivery. Set of strategies and plan of action need to be integrated with the current schemes and programmes (like PMAY etc). It may be noted that a housing strategy must address physical, financial and control mechanism of all housing types as applicable and shown in Box-2.

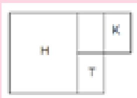
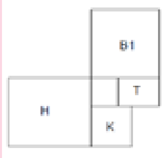
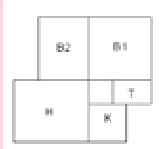
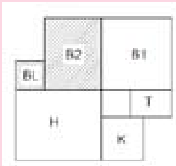
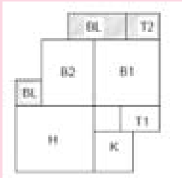


Box 4: Stages of IBS

Another very crucial aspect of city housing strategy is the planning area delineation. It has been seen that housing development has been greatly influenced by connectivity, land use and land value. Again higher land value zone extends beyond the city boundary to the sub regional level. Intelligent developers and investors build housing complexes on those lands for quick profit. Such housing development ends up with urban sprawls with no or minimal offsite infrastructures. To address such problems, the only solution to prevent the sprawl is to extend the planning boundary for making future housing strategy on the basis of land value and land use patterns at the sub regional level. The exercise needs integration of several thematic mapping in different layer to identify suitable hot spots for investments. Thus land value capture is essential task in a housing planning exercise. The Box-3 shows typical housing typology maps of city of Roorkee where a similar academic exercise had been undertaken.

Design Interface of HFA Mission

HFA mission will deliver houses in two channels in terms of construction systems. One, the houses built through tradition construction methods. Second, houses delivered through an industrialised mode using innovative and new technologies for which a TSM has been envisaged for the first time in the independent India. For the former case, design of housing will be largely dealt with the implementing agencies (municipal corporation, development authorities) where ministry (MOHUPA) provides broad guidelines and boundary conditions of unit areas, cost etc. Here the consultant designer will develop units or layouts based on the requirements and geo climatic context. However since this process is much time taking as second method where faster delivery is being envisaged through mass housing construction using factory made components

Box-5: Illustration of Space standards for LIG housing unit (taken from Roy & Roy, 2016)			
Activity spaces	1HK STARTER UNIT (21 sqm/225 sft)	1 BHK COMFORT UNIT (28sqm/300 sft)	1+ BHK ASPIRANT UNIT (35sqm/375 sft)
Hall	YES	YES	YES
Bed Room 1	Attachable	YES	YES
Bed Room 2	---	Attachable	YES
Kitchen	PARTLY	YES	YES
Toilet/WC 1	YES	YES	YES
Toilet/WC 2	---	---	Attachable
Verandah	Attachable	Attachable	YES
Basic unit configuratin	(21 sqm/225 sft) 	(28sqm/300 sft) 	(35sqm/375 sft) 
Expansion possibility	 30sqm/320 sft	 37.4sqm/400 sft	 40sqm/430 sft

with innovative and green technology in TSM under PMAY. TSM will also facilitate preparation and adoption of layout designs and building plans suitable for various geo-climatic zones & will assist States/ Cities in deploying disaster resistant and environment friendly technologies (MOHUPA, 2015). The Sub-mission will coordinate with various regulatory and administrative bodies for mainstreaming and up scaling the deployment of modern construction technologies and material in place of conventional construction.

Therefore a systemic change in technology and delivery of housing from an onsite mode to industrialised mode is expected to achieve speed. In order to achieve four distinct objectives in the TSM, i.e. contextual design, speedier technology, environment friendly and resiliency, it is required to follow a technology development path, called Industrialised Building Systems (IBS) which other countries followed earlier. An illustration explaining simplified stages of IBS is shown in Box-4 (adopted from Sarja, 1998 & Warjawski 1999). It shows that the standardization is the essential and unavoidable stage followed by dimensional and modular coordination to achieve the systemic change in the technology. The first two stages (1 & 2) essentially deal with the architectural language where as the next stages (3 & 4) deal with the delivery of that design through faster mode of construction (Box-4).

However design interface for India will not be similar with the same in other western countries as the technology development path is different. It is mentioned by various authors like Jain (2007), Chattopadhyay (2008), Adalakha & Puri (2008), Roy et al (2008) & Roy & Roy (2009, 2016) that for India, mass production of housing by component based partial prefabricated/industrialised building system (IBS) will be suitable to combat with incremental housing shortage. India is a vast country with wide variation in its topography, living patterns and socio economic conditions. The concept of industrialization of housing in India should be decentralized and not the western model of organized centralization. With its diversity India should adopt prefabrication by the masses rather than massive prefabrication (Jain 2007). Therefore for India a set of design package and system with the capacity of mixing onsite and offsite activities will be suitable.

A standardisation of design follows systematic stages involving the market trend, geo climatic pretext, prevailing codes, structural requirement specific to the technology selected etc. considering the diversity of the country, a single standard of design will not work as seen in earlier experiences. Therefore a systematic investment in knowledge and time is required specially by the research and development institutes with support by the ministry. Even within the same geo-climatic zone, the standardisation will have plenty of options for people based on differential affordability. There should be adequate scope for upward improvement of housing units from a basic starter unit to aspirant units in terms of activity area and specification. Such flexibility to integrate economic progress of people is essential in any sort of standardisation practice. An example of such space standards for low income group people in the hot humid geo-

Box 6: Actions by major stakeholders in TSM			
Stages	ACTIONS BY Government	R&D Institutes	Industry
PROCESS-I: Policy & Legal Readiness	• Continue reforms • Facilitate land sharing • Continue 100 % FDI • Empowerment	• Policy inputs • Set up research/design labs • Industry collaboration	• Purchase land • Reach foreign funds • Encourage innovation
PROCESS-II: Knowledge Development	• Identify institutes • Facilitating/Validation • Set up regional HUBs • Multi-criteria assessment • Facilitate planning and design	• Technology mapping • Technology Development • Planning & Design modules/components • Simulation and users test • Prototyping & testing • Develop codes and protocol • Manual and Guidelines	• Market feedback • Collaborative research
PROCESS-III: Implementation and Transfer	• Quality roads development • Connect the prospective investors • Set up factory in PPP	• Knowledge support • Capacity building • Advisory and consultancy • Codes and standards •	• Setup factory • Construct and delivery • Quality checks/ Feedback • Comply regulations

climatic region has been developed at the IIT Roorkee and illustrated for reference (Roy & Roy, 2016) in Box 5. The standard designs are usually calibrated through various parameters and must have possibility of expansion to accommodate the incrementality nature of house building in India.

Conclusion: Agenda for action

The task required for achieving housing for all by 2022 is gigantic. Very special role and action is expected to play and deliver for the government, industry and research institutes. MOUHPA has already started collaboration with IITs and NITs for new technology development with designs and prototyping which seems appropriate. A further strengthening of research documentation, standardisation and prototyping of modules will be required with a rigorous testing before starting production of building components. Three levels of actions are required for a systemic change of the housing delivery. 1) Policy & legal, 2) knowledge development, 3) Implementation and transfer. Indicative actions for each stake holders are shown in Box 6. Apart from the broad roles and actions spelt out above we need to summarise the major and immediate action required for the HFA mission before we conclude.

Technology specific design package specific to geo-climatic region followed by investment plan is to be developed. A comprehensive strategy for industry inclusion is the need for the day for HFA mission. International and national collaboration for manufacturing of new building components may be required. Digital India and make in India scheme should be integrated suitably. Government can act as facilitator to select few such industries with time tested relevant credentials and expertise for the first phase. Land can be mobilised accordingly. It appears that not more than 3-4 new technologies will be appropriate to start with in a phased manner. Further, working group report may be prepared concurrently in possible interface of labour and HR, work schedules. Linking state specific requirement with the ongoing research at the institutes is required. A model framework for formulating city housing strategy as discussed in this article must be prepared and floated by ministry. Incentives to the states and cities to cater different need for housing including rental housing, old age housing, working person's hostel and innovative night shelters may be given.

A brief account of indicative planning and design interface and actions thereby of PMAY & TSM is presented here. I am quite hopeful that the current decade can be made a decade of housing for India provided we put our concerted effort. It is the time to research, reflect and innovate. It is the opportunity to take our country people out of homeless situation within 2022. It is possible.

Acknowledgement

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References

1. MOHUPA, Government of India, Ministry of Housing and Urban Poverty Alleviation, National Urban Housing and Habitat Policy, 2007, National Housing and Habitat Policy 1998
2. MOHUPA, Government of India, Ministry of Housing and Urban Poverty Alleviation, India National Report for Habitat III, 2016
3. UN Habitat, Zero draft for New Urban Agenda, Habitat-III, 2016
4. Sarja A, Open and industrialised building, International Council for Building Research, E FN Spoon, London, 1998
5. Warszawski. A. Industrialized and automated building system. E & FN Spon: Technion-Israel Institute of Technology, 1999.
6. Womack, J., Jones, D., & Roos, D. (1990). "The machine that changed the world– The story of Lean Production". Harper Perennial, New York, USA.
7. Gibb, A. G. F. (2001). "Standardization and pre-assembly – distinguishing myth from reality using case study research" Construction Management and Economics (2001) 19, 307–315.
8. Roy U K, Roy M, Saha S: Mass-Industrialized Housing to Combat Consistent Housing Shortage in Developing Countries: Towards an Appropriate System for India; XXXVI IAHS World Congress on Housing, Kolkata, India, 2008
9. Jain, A. K: Building Systems for Housing: Journal of Indian Institute of Architects, vol-72, issue-11, Nov-2007
10. Chattopadhyay S (p-151): New Essays on Inclusive Housing: Macmillan India Ltd, 2008
11. Adalakha, P K, Puri, H C, Prefabrication Building Methodologies for Low Cost Housing, IE (I) Journal, 2003
12. Roy U K, Roy, M; Saha, S: Space Standardisation for Dimensional Coordination of a MIG Housing Unit Based on Market Trend in India: Journal of Institution of Engineers (now Springer), 2009
13. Roy U K, Roy, M: Space Standardisation for Low Income Housing units in India: international Journal of Housing Market and Analysis (Emerald), 2016

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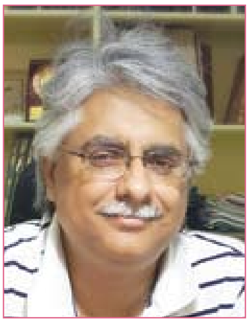
Bamboo Toilet Constructed during Training Programmes in NE Region

Methodology for estimating Embodied Energy in Construction Industry



*Dr. P.S. Chani** *Dr. E. Rajasekar*** *Anil Kumar K****

Abstract

Estimation of embodied energy of a building is an elaborate and complex process. Industry needs a quick way to estimate embodied energy for taking better decisions. This paper demonstrates a methodology developed by the authors at IIT Roorkee to calculate embodied energy in a simpler and quicker way. Existing databases give embodied energy of various materials. In this method calculations can be done on the basis of Bill of Quantities (BOQ). The advantage of this method is in its ability to use the same quantity measuring technique followed in cost estimation and tendering process. This methodology is made possible by a database of 'Schedule of Energy Rates' developed by the authors.

Introduction

Construction sector in India makes a vital contribution to its socio-economic development by providing housing and infrastructure. It is growing rapidly with a projected annual economic growth rate of about 8%, which by implication, makes it a major consumer of energy. The current energy consumption for manufacturing building materials, i.e., their embodied energy[1], is 2500 x 10^9 MJ annually. This figure is expected to rise to 5000 x 10^9 MJ by 2020 AD. Furthermore, the construction sector is responsible for 21% CO_2[2] emissions per annum.

In this situation, there is a necessity of reducing energy consumption in the construction industry. This necessity leads to a question of what are the major consumers of energy in the construction industry. Energy consumed by buildings can be split into two stages. One is energy consumed till materials arrive to site (i.e. embodied energy cost EEC) and the other is operational energy cost (OEC).

Importance Of Considering Embodied Energy

The Embodied Energy forms a sizable component of total emissions. Various sources have published certain percentages. This is shown in Fig 1[3]. This is also reinforced by a pilot study done for the 'Scientist Apartments' of the Central Building Research Institute (C.B.R.I.), Roorkee, in 1995, indicated that the ratio of EEC: OEC was 1:84, i.e. the apartment would have to be operated for nearly 84 years to match up to the energy embodied in them during construction[4]. This shows the importance to be given to reduce Embodied Energy. The pilot study mentioned above highlights that embodied energy of building materials forms a sizeable component of the overall energy consumption during a building's life cycle.

Methodology For EEC Estimation

Embodied energy of a proposed building can be estimated by computing the material requirements of the project, multiplying each material content with its corresponding embodied energy value and by summation, obtaining the total EEC. The drawback with this method is that the material requirements are not directly available, but have to be obtained from the Bill of Quantities (BOQ) of the project. A more efficient methodology would be to use the

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Country	Author	Relationship between embodied and operational emissions in different buildings and infrastructure
UK	Lee & White (2008)	Embodied energy is 3-35% of 100 year life-cycle energy demand
	Yohanis & Norton(2002)	Embodied energy is 67% of operational energy over a 25year period
	Eaton &Amaton (2005)	Embodied carbon is 37-43% of 60 year life-cycle carbon
	Smith (2008)	Up to 80% of life-cycle carbon emission is embodied carbon
	CIBSE (2010)	Embodied carbon is 42-68% of 60 year life-cycle carbon
US & Canada	Engin& Francis (2010)	Embodied energy is 11-50% of 60 year life-cycle carbon emissions
	Webster (2004)	Embodied energy is 2-22% of 50 year life-cycle energy demand
	Athena (2007)	Embodied energy is 9-12% of 60 year life-cycle energy demand
	Build Carbon Neutral (2007)	Embodied energy is 13-18% of 66 year life-cycle energy demand
Australia	CSIRO (2006)	Over 10% of 100 year life-cycle energy demand is embodied carbon
Sweden	Thormark (2002)	Embodied emission is 45% of 50 years life-cycle emissions
Israel	Huberman &Pearlmutter (2008)	Embodied emission is 60% of 50 years life span
Key:	Emissions: Embodied / Operational	

Figure 1: Embodied energy vs operational energy emissions

BOQ directly for estimating the embodied energy.

This paper highlights such a methodology in which the embodied energy of a building can be directly computed from its BOQ, by prescribing energy values for the individual items of work. These values are termed as Embodied Energy Rates (EER). At IIT Roorkee, the authors have developed a 'Schedule of Energy Rates' which runs parallel to the 'Schedule of Rates'. The column for rates in the BOQ is substituted with the EER of the respective items of work.

$$EEC = Quantity_{BOQ} \times EER \quad \text{-----------}\mathbf{1}$$

(EEC – Embodied Energy Cost)

($Quantity_{BOQ}$ – Quantity as per BOQ)

(EER – Embodied Energy Rates)

Each Item of work has say n materials in it. Per unit item of work each of the component materials are in particular quantity. Multiplying the components quantity with its EEV value and summing them up gives EER value of that item of work.

$$EER = (q_1 \times EEV_1) + (q_2 \times EEV_2) + (q_3 \times EEV_3) + \_\_\_\_\_\_\_\_\_\_ + (q_n \times EEV_n) \text{ ----------} \quad \mathbf{2}$$

(q – Quantity of material within unit *item of work*)

(EEV – Embodied Energy Value of unit Quantity of Material)

Sample Demonstration

This methodology has been applied to estimate the embodied energy of 15 single and double storied dwellings, a residential model typical to semi-urban towns like Roorkee.

Table 1A shows the EEV values of materials used in the sample study. Table 1B presents the calculation of EER from EEV. Table 2 presents a sample sheet, showing the application of EER to estimate EEC_T of Project1.

Analysis of EEC

Energy shares of the sub-works have been analysed through the breakups of the EEC_T, presented in Table 2, shows the percentage shares including 2.5% of transportation energy values of each (also refer Figure 1).

The breakups clearly show that masonry work is the single largest contributor to the EEC_T. Similarly, RCC work is the second largest contributor followed by concrete work, finishing and flooring in that order. The combined share of masonry and RCC work is about 78-82% in the EEC_T. Similarly, the presence of steel increases the energy cost of RCC work substantially. It is seen that steel makes a contribution of about 8.5-15.5% to the EEC_T and is the major energy component in RCC work, contributing about 48-57% to its embodied energy (EEC_3). Thus, bricks and steel alone have an average share of about 60% in the EEC_T.

Table 1A: Embodied Energy Values (EEV) of materials used in Sample

S. No.	Building Material	Size (Dim. in cm)	Unit	EEV (MJ/Unit)
1.	Traditional brick	22.9x11.4x7.6	nos	4.50[1]
2.	Cement	-	kg	4.20[2]
3.	Coarse/fine sand	-	cum	0.00[3]
4.	Stone (coarse) aggregate	-	cum	538.00[4]

Table 1B: Sample Derivations of Embodied Energy Rates (EER)

Item Code No.*	Description of Item of Work	Materials	Unit	Quantity	Energy Value (MJ/ Unit)	Energy Value (MJ)	EER (MJ/ Unit)
1.22.	Mortar Work Cement mortar 1:6 (1 cement: 6 coarse sand) (Details for 1 cum)#	Cement Fine sand	kg cum	250.00 1.07	4.20[2] 0.00[3]	1050.00 0.00	**1050.00[5] MJ/cum**
2.2.15.	Masonry Work 1st class brick work in foundations & plinth in cement mortar 1:6 (1 cement : 6 coarse sand) (Details for 1 cum)	1st class bricks Cement mortar 1:6	nos cum	494 0.25	4.50[1] 1050.00[5]	2223.00 262.50	**2485.50 MJ/cum**
3.18.	Concrete Work Providing & laying cement concrete 1:2:4 (1 cement: 2 coarse sand : 4 graded stone agg. 20 mm nom. size) – foundation and plinth (Details for 1cum)	Cement Coarse sand Stone agg. (10 mm) Stone agg. (20mm nom.size)	kg cum cum cum	320.00 0.445 0.22 0.89	4.2 0.00 572.00 572.00	1344.00 0.00 125.84 383.24	**1853.08 MJ/cum**

** As listed in Chani, P.S., Ph.D. Thesis, 'Schedule of Energy Rates'; # Obtained from the 'Analysis of Rates', CPWD Publication, GoI.*

Table 2: Sample Sheet Showing Application of EER to Estimate EEC_T for Project No. 1 (Floor Area = 23.6 sqm)

S. No.	Item of work	Unit	Quantity	EER in MJ/ Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement : course sand)	cum	7.05	2422.50	17078.63	2.2.11
2	1st class brick work in superstructure above plinth in cement mortar 1:6 (1 cement : course sand)	cum	16.07	2422.50	38929.58	2.2.11+2.2.17
	EEC for Masonry work (EEC_1)				**56008.20**	
	FINISHING					
10	12 mm plastering with cement mortar1: 6 (1 cement 6 : fine sand)	sqm	151.54	11.49	1741.19	6.1.9
11	20mm plastering in steps with cement mortar 1 : 3 (1 cement : 3 fine sand), finished with a floating coat of neat cement	sqm	2.37	53.26	126.23	6.1.26
12	white washing 3 coats- inside	sqm	93.47	1.69	157.96	6.3.1
13	colour washing (2 coats) over one coat of white washing - outside	sqm	77.09	1.69	130.28	6.3.3
	EEC for Finishing work (EEC_5)				**2155.67**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**89176.79**	

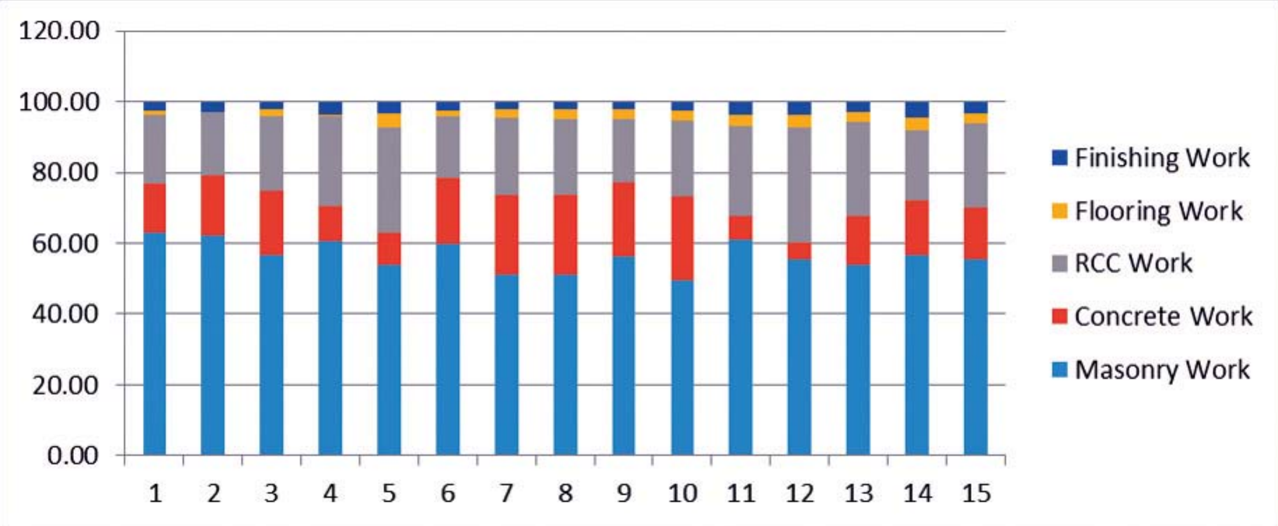

Figure 2: Ratios of EEC values of different materials across 15 case studies

Advantages

This methodology allows Industry people to quickly access the embodied energy of building without separate calculation of materials. The advantage of this method is in its ability to use the same quantity measuring technique followed in cost estimation and tendering process. This method of estimation is always backed with a database of Schedule of Energy Rates.

References:

1. The energy required to quarry, manufacture and transport the material to the distribution outlet
2. Reddy, B.V.V., Embodied Energy in Buildings, Dept. of Civil Engg. Bangalore
3. T. Ibn-Mohammed, R. Greenough, S. Taylor, L. Ozawa-Meida and A. Acquaye; Operational vs. embodied emissions in buildings—A review of current trends; Energy and Buildings; Elsevier; UK; 2013
4. Sahu,S., Kaushik, S.K. and Chani, P.S., Energy Cost Relationship for Housing Projects in India, Intl. Seminar on Civil Engg. Practices in the Twenty First Century, Roorkee, India, 1996

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Demonstration Housing Project by BMTPC : Status

The work for construction of 32 demonstration houses (G+3) at Bhubaneswer, Odhisha using EPS Panel System has reached upto plinth level. The work for construction of 36 houses in G+2 using stay-in-place formwork system have been awarded and work is likely to start very shortly in Biharshariff, Bihar. After Planning and designing of construction of 32 demonstration housing (G+3) project at Building Centre, Gachibowli, Hyderabad, Telangana using various emerging technologies, tenders have been invited. Planning & designing for construction of 40 demonstration housing projects at District Kanchipuram, Tamil Nadu and Lucknow, Uttar Pradesh is in progress.

Housing with Honeycomb

*Radhika Gupta**

The Need of The Hour

A demographic trend suggests that India is on the verge of large scale urbanisation over the next few decades. With more than one crore population getting added annually to urban areas, India's urban population is expected to reach about 81 crore by 2050.

Housing, a basic need for humans, plays an important role in accommodating high urban growth in India. However, several structural issues such as high gestation period of housing projects, limited and expensive capital, spiralling land and construction cost, high fees and taxes, unfavourable development norms and low affordability by Economically Weaker Section (EWS) and Lower Income Group (LIG) households are bottlenecks restricting desired growth in housing supply in India with respect to housing demand.

On one hand, builders and facility providers are facing challenges in installation and fabrication with materials that are not only time consuming and labour intensive but may also sometimes fail to suit the specific geographical conditions. Consider emergency shelters for medical camps or refuge purposes, or hygienic public convenience facilities in rural and sub-urban areas, or sustainable communities to house the mass. Each of these situations calls for analysis of the culture, geography and efficient use of resources (people, land, electricity, water, etc.).

On the other hand, there are users and inhabitants – people - that urgently need shelter that promise minimal recurring costs but provide a decent standard of living. High urbanization rate, coupled with high rate of migration from rural areas is stressing the limited urban infrastructure.

The Revolutionary Innovation – HonCorZ

In 2012, Anjani Technoplast Ltd. developed the manufacturing of plastic honeycomb panels (branded "HonCorZ") (Fig.1). HonCorZ honeycomb panels are made of food-grade polypropylene that offers benefits such as chemical inertness and strong strength to weight ratio.

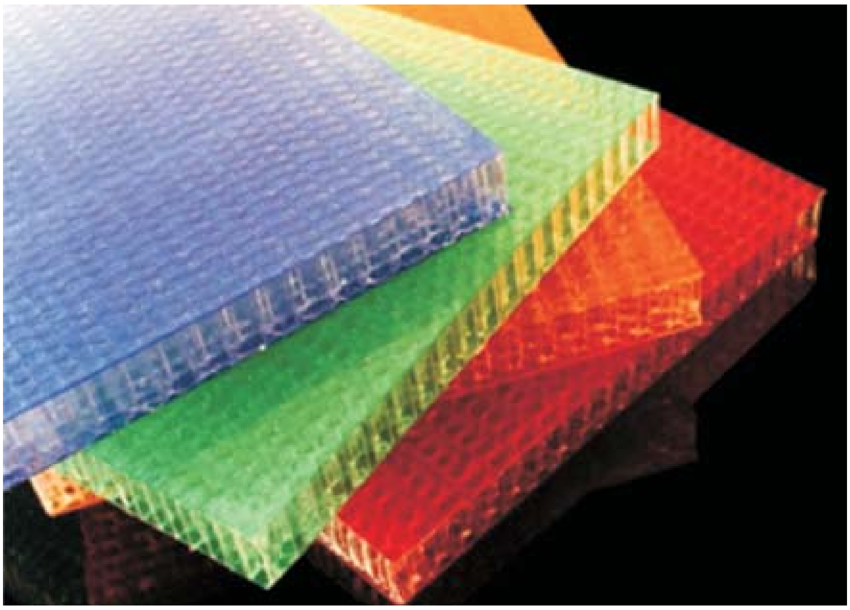

Fig. 1 – Anjani's HonCorZ – Plastic Honeycomb Panels in various thicknesses & colours

* Anjani Technoplast Ltd., Greater Noida, E-mail: info@anjani.com

Fig. 2 – Examples of different finishes with HonCorZ – Honeycomb Panels

The hexagons of honeycomb provide the strength whereas plastic makes it lightweight. Honeycomb panels have been used for some time in aircraft and are rapidly gaining favour in truck bodies as well as a sandwich panel for door fillers and furniture.

The first market opportunities for plastic honeycomb, on an industrial as well as commercial basis, began with the requirement of a lightweight structural material of high strength. In 2014 Anjani entered the market with an exponentially growing range of applications for planned urbanization such as affordable homes, cabins, toilets, bathrooms, mass community complex.

When income is limited, people cannot fathom what a home looks like. Anjani has taken the initiative to put the honeycomb technology in use for the ambitious 'housing for all' campaign. Anjani's honeycomb can be used to take care of any shelter need, temporary as well as permanent, be it a porta-cabin, refuge structure or even a housing community to accommodate large masses. Subsequently, Anjani's 'Mera Ghar', a housing structure that is affordable and built-to-last, can align itself with different program incentives that require facilities such as solar panel installation, bio-digester waste management, etc. Why institutions such as DUSIB and DUAC have already procured Anjani's modular pre-fabricated building applications is that they are termite proof, moisture proof and eco-friendly, suitable for any extreme weather conditions that any Indian region might face. In addition, minimal utility and repair tariff ensure economic benefits to tenants.

HonCorZ panels are manufactured as load bearing walls, floors and roofs. Any finish can be applied on the honeycomb core – marble, aluminium checkerboard, vinyl, steel, pain, PP fabric sheet or only fleece (see Fig. 2). The finishes can be suited according to the local demands or regional specificities.

Mass Housing Made Convenient

The beauty (and convenience) of this modular structure is that, unlike bricks or other conventional material, it offers quick installation and ensures faster provision of houses to the masses. With just four standard panels, each of 8 feet by 4 feet, one can erect a toilet or a cabin within 24 hours with only basic tools and a levelled ground at disposal. Not only are the honeycomb panels easy to fabricate, but they are easy to transport in vehicles. Without any effort, one can pick a panel, load it on to the truck in a pile that allows space efficiency, unload them on construction site or store them without worrying about any damage due to water or bacteria.

To ensure that 'Mera Ghar', 'Sahaj Toilet' and 'CabinZ' prioritizes the long-term needs of low-income renters and disadvantaged communities, Anjani's efforts gave special

Fig. 3 - Sahaj Toilet installed for Delhi Urban Art Commission (DUAC) in Shahadra, New Delhi

Interiors of 'Mera Ghar' – bedroom, living room & toilet; structure and furniture made with HonCorZ – Honeycomb Panels

attention to matters of providing economic benefits to low-income inhabitants. 'Mera Ghar' addresses the needs of disadvantaged communities by integrating energy efficiency into the modular building structure, assessing the eligibility of energy storage and its role in preserving and enhancing benefits for this market, and developing a structure to ensure that the projects are financially feasible and can be supported by the affordable housing property owners.

Recent Projects With HonCorZ

Now let us take a journey which starts in the present and ends with visions of the future. With the approval of BMTPC, procurement by multiple state authorities and installations for private corporations such as Sharda University among others, Honeycomb has found its way into the head and heart of major housing and facility providers. Where DUAC, NBCC and DUSIB have procured the Sahaj Toilet and Bathroom (sanitary solutions) (see fig. 3), others have found value in using the pre-fabricated modular porta-cabins. 'Mera Ghar' installed at the Hindustan Prefab Limited (HPL), New Delhi stands as testament of durability and strength.

With the HonCorZ applications for planned urbanization, Anjani has developed solutions to shift the attention from simply building houses to a holistic system for housing development with material of the future while placing convenience for the people at the forefront.

We invite you to experience how the combination of plastics and honeycomb is not only capable of making a difference, but also solve the challenges that the industry is facing. For further details or to understand how we can customize the solution to your specific needs, please write to us at info@anjani.com or visit our website www.anjani.com or call us on +91 99109 98000.

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Housing for Aspirant Future India

*Dr. Mahua Mukherjee**

Housing is mixing pot for socio-economic and environmental wellbeing of people. Dwelling units in a housing are of prime importance to residents as life evolves centering these units. Housing, historically, enabled families and individuals to expand capability of good life. If 70 - 80 % of the India of 2030 is yet to be built (The 2010 McKinsey Report) and more than 50% population below the age of 25 (Basu, 2007), then housing will be the center stage activity for future India.

To be at the centre, Housing shall take the role comparable with the mother for a family. It shall enrich quality of living for the residents and their neighbours through recognizing opportunities, drawing robust designs and realizing the same on ground with appropriate material and technology management. Now the pertinent question is what robust design is? How shall we construct to meet our need and not our demand? What shall be our next-gen housing solutions? Again image of better living is changing with the young aspirant India.

A good housing invariably provide shelter to the physical needs of its users and nurture their socio-economical aspirations for inter-generational changing context. We continuously learn from approaches and initiatives of past about good housing which is safe, functional and inspirational. Indian housings are under-prepared to address the human comfort, safety, environmental concerns ranging from waste to energy and productivity. Environmental, technological or social functioning of housing in India has enormous opportunity to improve to address varied local climate and geo-spatial characteristics, by using locally sourced resources or suitable emerging technology for speedier construction.

Context has changed dramatically in urban India. Next-gen housing has three basic premises of site, building and infrastructure to deal with unlike previous decades. These are now intertwined with more complex delivery process; computational and information technology, simulated scenario generation, evolved and matured building bye-laws, emerging materials and construction technology, continuously evolving components for infrastructure systems, changing life patterns and aspirations of families influencing housing process immensely. Expectation from housings are spiraling as discussed below:

(a) Site level: Every upcoming housing project exerts on surrounding natural environment and local residents. They result in reducing green cover and water resource, interrupting access to daylight and airflow, releasing fumes, generating solid waste and waste water. Timely consideration of ground realities during design and construction phase may control these losses and help in achieving climate-responsive, disaster resilient and sustainable built environment.

At site level, interrelation between blocks will depend much on siting them thoughtfully. In hilly areas choices among terrace, stepped and deck types depend on contour, drainage, slope gradient and orientation of the hill section.

* Associate Professor, Department of Architecture and Planning, Indian Institute of Technology Roorkee, Roorkee

(b) Building Level: Housing has inherent issues with loss of identity; the added problem to that is dwindling social interaction, disconnect with nature and affordability. Interaction of individual unit with its immediate spaces and other units outlines quality living and needs careful consideration. Social interaction, sharing moments without pervading privacy shall be facilitated through design of access and units. Greening the corridors, getting ample daylight and natural ventilation shall be a requisite. Selection of materials and techniques help achieving economy – both immediate and long term (maintenance). So privacy, daylighting, ventilation, thermal comfort, maximum use of indoor spaces through circulation optimization, wet-space clustering, storage and openings, structural safety of units etc. shall get due attention.

Barrier free environment shall be integrated through design and detailing. Adherence to building bye-laws will provide the much-needed safety guard from any abrupt failure of function or structure. If prefabrication is the choice for construction, integration of this decision is a necessity from the design stage so that seamless solution can be arrived at.

(c) Infrastructure (Physical, Social and Soft): Infrastructure singularly is responsible to bring community quality living in any housing. Advanced/ innovative system integration and resource optimization during installation and operation and maintenance stages are critical for any infrastructure. Physical infrastructure for circulation, water and waste management, electricity etc., and social infrastructure like primary health and education centre, cretche for children of working parents, interaction places, open ground for physical activities and recreation, senior people-specific spaces/ facilities, livelihood-opportunity based commercial activity, banking etc. makes housing functional across time, space and inter-generation. Qualitative and quantitative presence of soft infrastructure like continued adult literacy (financial, digital, computer etc.), library, meditation and prayer, museum, cultural centre, ease of access from housing complex to various amenities are some pertinent factors which need to attended in integrated fashion.

Site level infrastructure system management starts with sustainable fresh and waste water, and solid waste; service level benchmarks and target for net-zero towards water, waste and electricity are getting wider application. Healthy residents are always an asset to any such housing. So, jogging track, playfield, gymnasium for workout etc. shall be integral part of design. Senior people-centric design of open space facility will support different sets of activity among the senior residents and will keep them interactive, socially responsive and healthy. Social safety for children, women and aged people and physical safety of building occupants against fire, heat and water stress and earthquake improves resiliency. Combining senior people and children activities, Limited use of impervious materials, use of solar panels for electricity generation as well as for shading devices are few useful performance-oriented innovative initiatives.

Ecology-based economy can be intricately weaved with the housing programme, be it urban agriculture, pisciculture or other livelihood options. Community spaces can act doubly as source for revenue without compromising residents' privacy, safety and security. It is essential to link income generation (jobs, productivity) to housing policies for ensuring long-term employment creation, and this is especially important in the context of developing countries like India which has large growing population base. Even the ownership of dwellings can be utilized for appropriate loan for economic activities through mortgage or other banking systems like micro-finance. Today's concept of smart city is revolving around economic opportunity generation (MoUD, 2014) in addition to basic standard of living. Jobs can be created in the sectors of new construction or retrofitting, maintenance, production of energy efficient or recycled materials, renewable energy systems, solid-waste and water treatment related technologies etc.

Housing for All by 2022 (PMAY-MoHUPA, 2015) is an opportunity to bring large section of urban poor out of poverty and house them into improved living quality. The mission can be managed as skill development, showcase for best practices and capability expansion mission involving people who are in dire need to come out of vulnerable environment. It is important to link housing process to create local employments. Workshops and training sessions during the planning and implementation of housing construction projects can instill capacity of local communities as well as other stakeholders including professionals to support long-term socio-economic sustainability of Urban India. Meeting the aspiration of urban population is responsibility some of these missions can shoulder.

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Performance Appraisal Certification Scheme (PACS)

The various activities under Performance Appraisal Certification Scheme (PACS) being implemented by BMTPC are highlighted below:

I. Approval of PACs

Technical Assessment Committee (TAC) in its meeting held on March 10, 2016 has approved issue of Performance Appraisal Certificates (PACs) for the following new products/systems:

i) Sismo Building Technology manufactured by M/s M K S Infosolutions Pvt. Ltd., Manesar

ii) Rapid Panels manufactured by M/s Worldhaus Construction Pvt. Ltd., Bangalore

iii) Precast Large Concrete Panel System manufactured by M/s Larsen & Toubro, Bangalore

iv) Light Gauge Steel Framed Structure with Infill Concrete Panels manufactured by M/s Society for Development of Composites, Bangalore

II. Inspection of Works

Inspection of Works of the following new systems has been carried out with the TAC members:

i) Stay-in-Place Formwork System of M/s Coffor Construction Technology India, Vadodra

ii) Insulated Concrete Forms of M/s Reliable Insupacks Pvt. Ltd., Greater Noida

III. Surveillance Inspection of Works

Surveillance Inspection of Works of the following products/systems for renewal of the PACs has been carried out:

i) Glass fibre Reinforced Gypsum Panel manufactured by M/s RCF LTd., Mumbai

ii) Polyethylene Underground Septic Tank manufactured by M/s Sintex Industries Ltd., Kalol (Gujarat)

iii) Continuous Sandwich Panel manufactured by M/s Sintex Industries Ltd., Kalol (Gujarat)

iv) Marshal Door manufactured by M/s Sintex Industries Ltd., Kalol (Gujarat)

v) FRP Manhole manufactured by M/s Sintex Industries Ltd., Kalol (Gujarat)

vi) Bamboowood Flooring manufactured by M/s Mutha Industries Ltd., Agartala (Tripura)

vii) QuikBuild 3D Panels manufactured by M/s Beardsell Ltd., Chennai

Inspection visit to Glass fibre Reinforced Gypsum Panel manufactured by M/s RCF Ltd., Mumbai for certification under PACS

TAC Members alongwith BMTPC officials visited Stay-in-Place Formwork System of M/s Coffor Construction Technology India at Vadodra (Gujarat)

IV. Applications in the pipe line for issue of PACs

Applications received for issue of PACs are in the pipe line as per the details given below:

i) Stay- in-Place Formwork System of M/s Coffor Construction Technology India, Vadodra (Gujarat)

ii) Insulated Concrete Forms of M/s Reliable Insupacks Pvt. Ltd., Greater Noida (UP)

iii) Prefabricated Fibre Reinforced Sandwich Panels of M/s HIL Ltd., Hyderabad (AP)

iv) Easywalls Hollowcore Concrete Wall Panels of M/s Mahesh Prefab Pvt. Ltd., Gurgaon (Haryana)

v) Concrewall Panels of M/s Schnell Wire System, Italy

vi) Structurally Insulated Panels of M/s Pioneer Fabricators Pvt. Ltd., Meerut (UP)

vii) Dry Wall Insulated Panels Of M/s E-Pack Polymers Pvt. Ltd., Greater Noida (UP)

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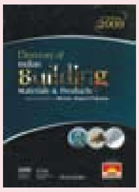

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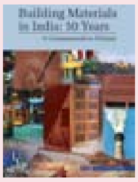

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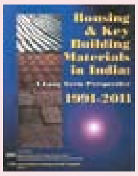

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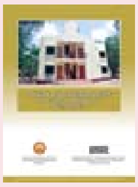

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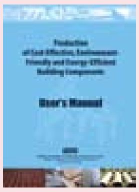

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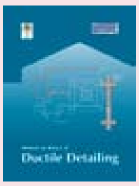

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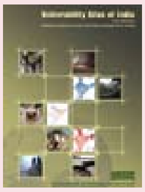

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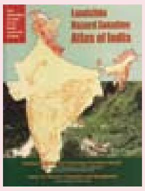

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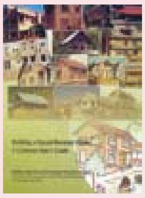

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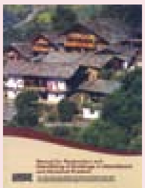

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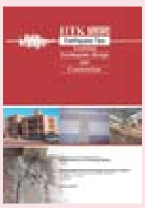

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Building Materials & Technology Promotion Council (BMTPC) under the Ministry of Housing & Urban Poverty Alleviation strives to bridge the gap between laboratory research and field level application in the area of building materials and construction technologies including disaster resistant construction practices.

Vision

"BMTPC to be world class knowledge and demonstration hub for providing solutions to all with special focus on common man in the area of sustainable building materials, appropriate construction technologies & systems including disaster resistant construction."

Mission

"To work towards a comprehensive and integrated approach for promotion and transfer of potential, cost-effective, environment-friendly, disaster resistant building materials and technologies including locally available materials from lab to land for sustainable development of housing."

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