Special Issue

निर्माण सारिका

A Newsletter of BMTPC

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October 4, 2021
World Habitat Day
Accelerating urban action for a carbon-free world

World Habitat Day

4th October, 2021

Accelerating Urban Action for a Carbon-Free World

निर्माण सामग्री एवं प्रौद्योगिकी संवर्द्धन परिषद्
आवासन और शहरी कार्य मंत्रालय, भारत सरकार
BUILDING MATERIALS & TECHNOLOGY PROMOTION COUNCIL
Ministry of Housing & Urban Affairs, Government of India

"Creating Enabling Environment for Affordable Housing for All"

CONTENTS

From the Desk of Executive Director

I vividly remember the last year when I was writing my message for this special E-newsletter "निर्माण सारिका", world was grappling with Covid-19 pandemic and today, things have improved despite of onset of second/third wave across the world as there have been massive vaccination drive taken by all the countries together. Globally, as on 27 September 2021, there have been 231 million confirmed cases of COVID-19, including 4.7 million deaths. A total of 5.925 billion vaccine doses have been administered world over. The resilience shown by the world communities towards confronting this pandemic have been exemplary and similar action is needed towards climate change and this year's theme of World Habitat Day *"Accelerating Urban Action for a Carbon-Free World"* is soft reminder for the communities to adopt sustainable, green, carbon-free strategies in all the walks of lives including services, manufacturing, construction etc. World is being encountered with extreme weather events, global warming, rise in sea levels as our cities are still not equipped for sustainable zero-carbon growth whether it is urban transport, building & infrastructure or energy & waste management. It is time to initiate long term actionable plans for Carbon-free world by the national, regional & local governments including organizations, communities, academic institutions, the private sector and all relevant stakeholders around the globe.

India is committed to reduce its green house gas emissions & ensure sustainable inclusive growth. Govt. of India is driving transition from linear to circular economy & all the urban renewal schemes in India e.g. Housing for All, Swath Bharat Mission, Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Smart Cities Mission, Urban Transport do incorporate green & clean practices leading to carbon-neutral development. A few recent initiatives such as *Vocal for Local*, *AtamNirbhar Bharat* (Self-reliant India) are also in line with accelerating urban action towards greener & cleaner world.

BMTPC being promotion Council, in the area of building materials & construction technologies, has been working hand in hand with Ministry of Housing & Urban Affairs (MoHUA), Govt. of India to promote innovative construction systems, materials & processes which are resource efficient, climate responsive, eco-friendly & disaster resilient. The *Light House Projects (LHPs)* being constructed at six places in six different States with six different innovative housing technologies (shortlisted through Global Housing Technology Challenge-India) are being projected as pilots to transit from traditional construction practices to cutting-edge state-of-the-art sustainable practices. This transition will help India not only to build faster but also bring energy-efficiency, waste minimization, less GHG emissions & affordability. MoHUA has also launched an enrolment drive where any individual can register as Technograhi and visit the LHP project sites, learn, adapt & replicate these practices in future construction. Technograhis will act as catalysts to transform the urban landscape to new Urban India.

It is my proud privilege to publish BMTPC's special E-newsletter comprising of papers, articles on this year theme of *"Accelerating Urban Action for a Carbon-Free World"*. It is being published since BMTPC was founded in 1990 without a skip. The help and support of Shri Dalip Kumar and Shri Alok Bhatnagar of BMTPC and the contributors for bringing out this publication is gratefully acknowledged.

Try to make our planet a better place before it is too late

(Dr. Shailesh Kr. Agrawal)

ANTÓNIO GUTERRES
Secretary - General
UNITED NATIONS

Message

On this World Habitat Day, cities and towns across the globe are facing – and fighting – the dual crises of COVID-19 and climate change. Home to 4.5 billion people today, they are projected to grow by almost 50 per cent by 2050.

By mid-century, over 1.6 billion urban residents may have to survive through average summertime highs of 35 degrees Celsius.

This year's theme – 'Accelerating Urban Action for a Carbon-Free World' – highlights how cities and towns are at the core of climate action to keep the 1.5 degrees goal within reach.

Three-quarters of the infrastructure that will exist in 2050 has yet to be built. Economic recovery plans offer a generational opportunity to put climate action, renewable energy, and sustainable development at the heart of cities' strategies and policies.

City leadership in using green materials and constructing energy-efficient, resilient buildings powered by renewable energy is essential to achieve net-zero emissions by 2050. The benefits are enormous: less pollution and climate risk, more jobs, and better health and well-being.

As populations grow in emerging economies, demand for transport, which accounts for nearly 20 per cent of global carbon emissions, is multiplying. Cities are working to ensure that this demand is met by zero-emission vehicles and public transit. We need a global moratorium on internal combustion engines by 2040 at the latest to underpin these efforts.

On World Habitat Day, let us work together to harness the transformative potential of sustainable urban action for the benefit of our planet and all people.

António Guterres

KEY MESSAGES

October 4, 2021 | Yaoundé, Cameroon

World Habitat Day

Accelerating urban action for a carbon-free world

World Habitat Day theme on mitigation – Accelerating urban action for a carbon-free world

- The fight against climate change will be won or lost in cities and towns. The future of the planet depends on the actions of our urban residents. The concentration of economic growth and population in cities makes them key contributors to climate change.
- Cities account for more than 50 per cent of the global population, two-thirds of global energy consumption and more than 70 per cent of annual global carbon emissions.
- We must cut global emissions by 45 per cent by 2030 compared with 2010 levels reaching net zero around 2050 to limit the global temperature rise to 1.5 C above pre-industrial temperatures. Most severe climate impacts are expected when global temperatures rise above this.
- Ambitious net-zero climate action must leave no one and no place behind, taking a holistic approach to action that reduces emissions.
- This is a critical moment to plan, build, manage and power cities differently. Every country, city, financial institution and company should adopt plans for transitioning to net-zero emissions by 2050. Low- and zero-carbon ambitions provide domestic economic opportunities, increase the resilience of the energy grid, and trade and export competitiveness.
- Most of the carbon emissions in cities come from buildings. Towns and cities need to build energy-efficient infrastructure and housing designed for local conditions, At the same time existing buildings must be retrofitted by implementing measures or technologies to make them more efficient such as improved insulation or ventilation so they use far less energy.
- The energy used to operate buildings – including heating, lighting and air conditioning accounts for 28 per cent of all carbon emissions. Countries need to generate clean, resource-efficient energy and move away from fossil fuels. Since 2009, the cost of renewable electricity has dropped both for solar and wind power and will keep going down. Energy consumption and related costs now and in the future will be reduced and health-related benefits, for example by reducing air pollution, will secure a more sustainable future.
- The move from polluting to renewable energy must be a just transition, involving local governments, unions and the private sector to support affected communities and generate green jobs.

UN HABITAT
FOR A BETTER URBAN FUTURE

IMPLEMENTING THE NEW URBAN AGENDA

- Much of the infrastructure that will exist in 2050 has yet to be built. Building materials and construction sector account for 11 per cent of annual carbon dioxide emissions. Using materials that do not produce carbon dioxide while being extracted or manufactured will slash emissions.

- Transport via road, rail, air and water generates approximately a fifth of carbon dioxide emissions – the majority coming from road transport including car trips within cities. There is an urgent need for a focus on safe, accessible, affordable and low-carbon public transport as well as integrated models including facilities for walking and cycling. Planning compact cities with good transit infrastructure is key to reducing greenhouse gas emissions.

- Stepping up climate action for an inclusive green recovery from COVID-19 to support the transition to resource-efficient economies will slow climate change. Integrated, connected and greener cities driven by renewable energy will ensure the health of urban communities as well as the planet.

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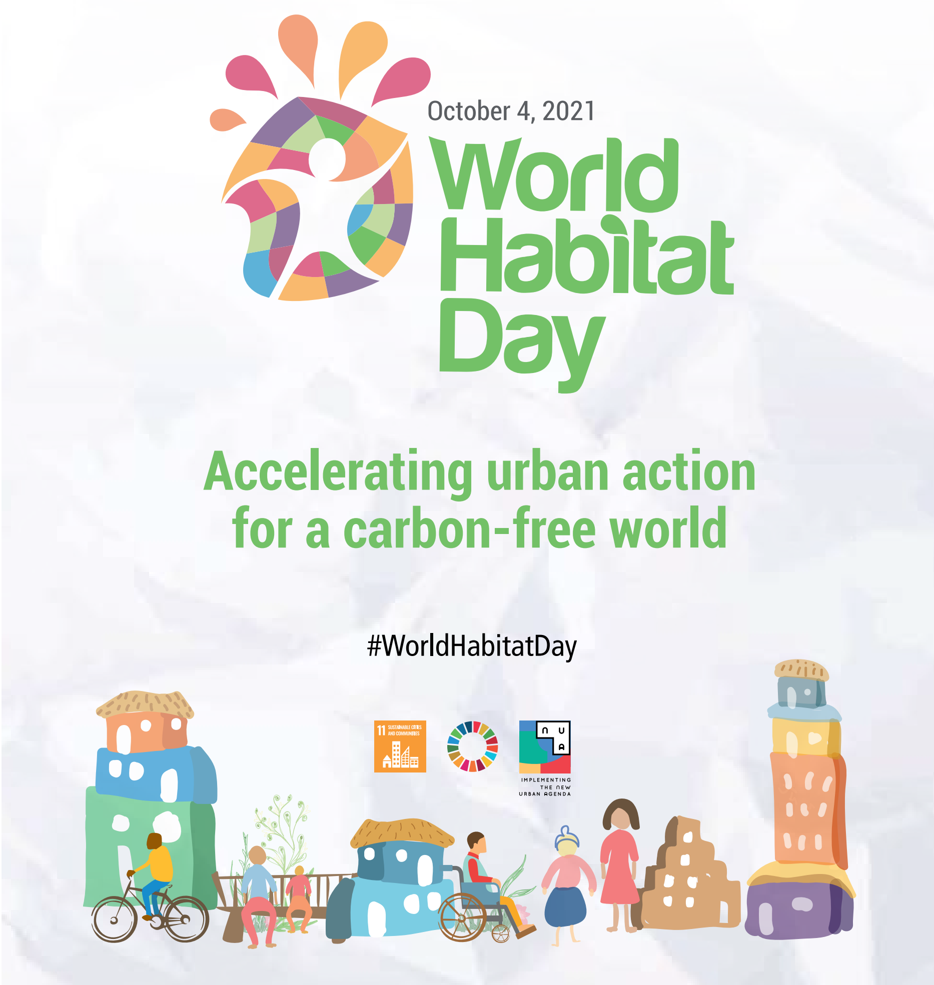
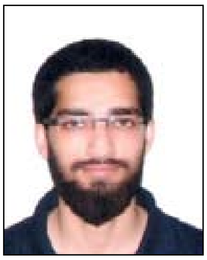
Urban OCTOBER



Accelerating adoption of thermally comfortable homes


S Vikash Ranjan[1] *Abdullah Nisar Siddiqui*[2] *Divya Bansal Talwar*[3]

Rapid urbanization is creating an unprecedented demand for the construction of buildings. Today, India is at a unique crossroads where **two-thirds of the commercial and residential structures that will exist in 2030, are yet to be built**. A lot of this demand lies in the affordable housing segment, which has taken a major leap in India after the launch of the Pradhan Mantri Awas Yojana (PMAY) in 2015. Affordable housing essentially means bringing low-cost housing in the market with purchase prices that are within reach for the various income segments in society, primarily focusing on Economically Weaker Sections (EWS) & Low Income Groups (LIG). As an outcome of PMAY-U, 11.3 million houses are being constructed within the Mission period. The houses built under the Mission will last at least 50-60 years and thus have a potential to impact resource usage during their life span. A major energy saving potential lies in reducing the energy demand in the housing stock being built today.

The mission needs to go beyond fulfilling the basic need of shelter and ensure an improved living environment for a better quality of life. Occupant comfort is the prime goal and thermal comfort is a major contributor in this regard. With climate change and rising temperatures on one hand and the rising aspirational demands on the other, more and more households will move towards air-conditioning in the coming years. The massive housing stock generated today is bound to put a lot of pressure on the energy demand in the future. Projections show that **electricity consumption in residential buildings alone is expected to increase seven-fold during the period 2012-2032**[1]. It is critical to anticipate these needs and to integrate thermal comfort in affordable housing today to ensure that it remains sustainable and affordable for its occupants in the future. The government's mission to provide housing for all has to go hand in hand with the commitment towards Sustainable Development Goals and the commitments towards climate change mitigation (COP21). This calls for keeping a check on the Embodied energy as well as the Operational energy without compromising on comfort.

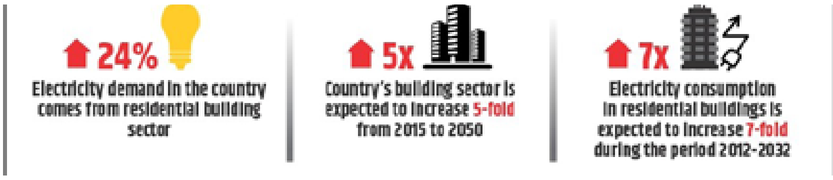


Figure 1 Energy demand from the building sector

To meet its climate targets The Ministry of Environment, Forest and Climate change (MoEF&CC) launched the India Cooling Action Plan (ICAP) in 2019. The plan provides a 20 year perspective with a target to reduce cooling demand across sectors by 20%-25% and reduce cooling energy requirements by 25%-40% by 2037-38[2]. The plan goes beyond energy efficient technologies and looks to manage cooling demands through design, passive strategies and adopting

1 *Guidelines for multistory residential buildings (https://beeindia.gov.in/sites/default/files/Design%20Guideline_Book_0.pdf)*

2 India Cooling Action Plan (http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf)

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Figure 2 Sustainable Development Goals and Nationally Determined Contributions

Figure 3 Environmental & Behavioral parameters impacting thermal comfort

the adaptive thermal comfort standards. This is a major move in steering away from rigid temperature set points and towards ranges of thermal comfort based on climate and context. National Building Code defines Thermal comfort as that condition of thermal environment under which a person can maintain a body heat balance at normal body temperature and without perceptible sweating. The perception of thermal comfort depends on a number of environmental and behavioral parameters.

Achieving thermal comfort in Affordable housing

The refrigerant based HVAC systems are not the only solution to achieve thermal comfort. The adaptive comfort model puts forward separate temperature ranges of comfort for non-air-conditioned, mixed mode and air-conditioned buildings. This sets realistic comfort standards which can be achieved through energy efficient design, passive strategies and mixed mode cooling. A combination of these strategies can bring down the hours of discomfort within a home which can then be tackled with mixed mode strategies like evaporative cooling thereby reducing/ eliminating the need for refrigerant based air-conditioning. The study conducted by Environmental Design Solutions (EDS)[3] shows that the percentage share of embodied energy to operational energy for air conditioned affordable housing shifts to 68% as compared to 40% for non-Air-conditioned housing for a life span of 20 years.

3 (http://cdn.cseindia.org/userfiles/tanmay-climate-responsive-affordable-housing-cse-mar2016.pdf)

Principles of energy efficiency:

Compactness of building plan: The principle is to reduce the wall surface area to minimum for a given floor area. This reduces the area exposed to heat gain or loss to the environment. Thus buildings with simple rectangular configurations and shared walls perform better.

Window to wall ratio & ventilation: The openings in the building envelope are more prone to heat gains/ losses than wall masonry therefore the window sizes should be optimised to reduce glazing without compromising daylight and ventilation.

Insulation: Large exposed surfaces such as end walls and roofs contribute to heat gains inside the units and insulation at these locations is effective in reducing discomfort hours substancially, specially in worst affected units such at top floor units or end units in a residential block.

Shading: Direct sunshine and indirect sky radiation entering a room through a glazed window is the largest contributor to discomfort during warm and hot seasons. Appropriate shading elements designed as per orientation and location of the opening can cut down solar gains in a cost effective manner.

Figure 4 Compactness depends on the geometry of the building. In this figure the surface to volume ratio increases from A to C

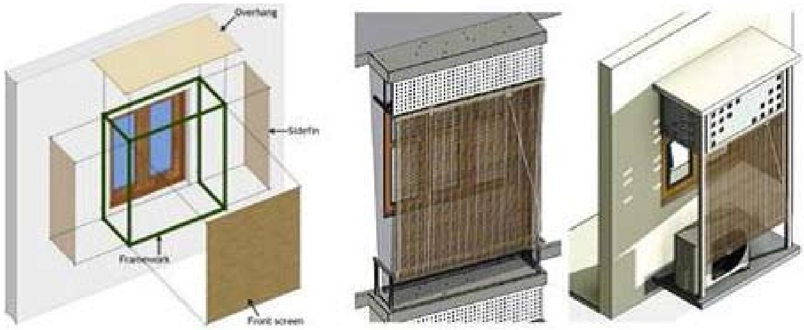

Figure 5 Protection of openings through shading

Figure 6 Replicable Design Handbook & Tool available at www.econiwas.com

In order to achieve thermal comfort in Affordable housing it is imperative to break the myth that providing thermal comfort comes at an increased cost. Good passive design measures like the right envelop design, optimizing opening location and sizes for ventilation make an enormous contribution in improving the thermal performance of a building before we even consider expensive products like double glazed windows or insulation. Programs to educate, incentivize and empower the investor market, the service providers, be it the government sector or the private developers, and the end users can help in this domain.

The selection of materials also plays an important role in defining the carbon footprint of the buildings. The construction materials not only contribute to the embodied energy but also impact thermal comfort and need for air-conditioning. This in turn adds to the operational energy demand and costs. A mandate to achieve set standards of thermal comfort in affordable housing can bring about a change in the selection criteria for building materials. Thermal performance needs to become a key indicator for material selection for mass affordable housing projects.

Catalogue of Replicable designs for Energy Efficient Residential Buildings

Architectural design services that are available for the majority of mass housing construction are yet to develop the knowledge and skills to integrate energy efficiency and thermal comfort into the design. The Catalogue of replicable designs for energy efficient residential buildings is launched by Bureau of Energy Efficiency (BEE) in order to fast-track the adoption of energy efficient, thermally comfortable residential buildings for a wide user-base. This catalogue is a ready to use directory of thermally comfortable, energy efficient house designs. It offers a range of residential layouts addressing single family plotted development as well as multi-family apartments. The house designs developed in this catalogue carefully correlate various unit sizes and typologies that can be adopted in different climatic zones. The unit sizes range from 40sqm to 250 sqm in a combination of low-rise, mid-rise and high-rise buildings.

The catalogue has 2 design sets:

Set 1 : Designed for Hot-dry, Warm-humid, Composite and Temperate climatic zones. The primary strategy is to reduce solar heat gain and to optimize ventilation, thereby, removing internal heat.

Set 2: Set of plans designed for the Cold Climate. Here the strategy focuses on capturing solar heat gains and restricting heat loss.

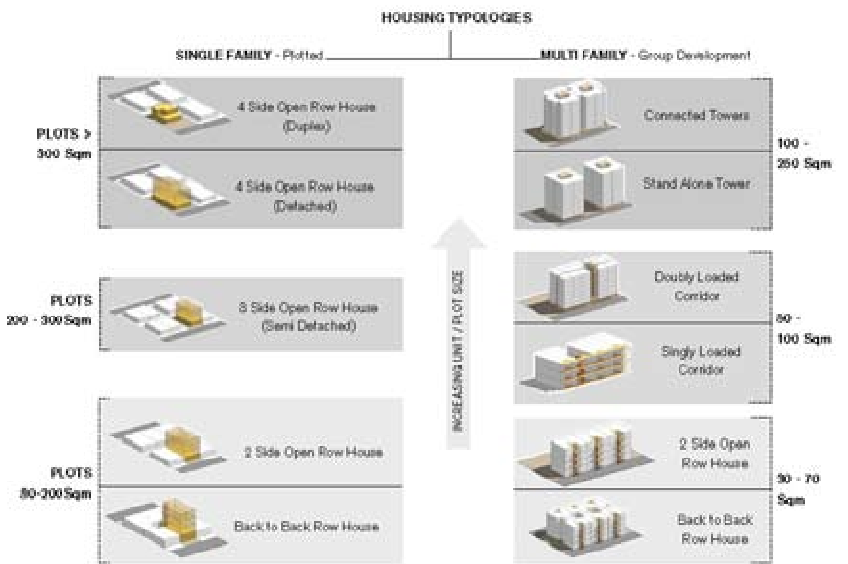

Figure 7 The catalogue caters to a range of housing typologies and dwelling unit sizes

This handbook explains the principles of energy efficient design in simple terms and demonstrates their application through the replicable designs. A defining feature of these dwelling unit designs is that it is in the planning and configuration of the building that the greatest energy efficiency gains are affected thereby incurring no additional cost.

These design options are available as an online tool offering a complete set of working drawings, cost details along with energy performance parameters in an easy to comprehend format. The users can compare across various templates and make informed choices by reviewing the energy and thermal performance of each design through its key performance indicators such as Building envelope performance (RETV), Ventilation Potential, Daylight Availability, Comfort Hours with natural Ventilation and Energy Performance Index. The techno-commercial feasibility is also assessed through Payback duration, Life Cycle Cost (LCC), Energy savings etc.

Replicable Designs tool

The online Replicable Designs tool offers Energy performance of every design layout, assessed for different orientations, Storey and locations in the building block and additional measures such as shading and insulation recommended to achieve thermal comfort in the worst affected cases. With each design there is a step by step improvement recommendation in terms of materials, insulation, shading and other modifications to achieve various levels of energy performance. The tool further offers all working files, 3D model and simulation files for each design template as a downloadable set for modification and customization by individual users, design professional, builders and other stakeholders.

The passive measures to achieve thermal comfort work with design, orientation, ventilation, insulation etc and can be incorporated only in the design and construction stages. Missing this chance today will lead to an energy guzzling housing stock in the future. Therefore there is a need to fast-track the adoption of environmentally conscious design. The way forward is to focus on resilience to meet the needs of the present with solutions that are sustainable. A lot of work, research and programs are being carried out in this domain but the implementation gap is a large one to fill. Therefore, it is important to create awareness among the end users to help them understand the long term benefits such as cost saving in operational energy, thereby creating demand by pitching it as an aspirational value. All the data, knowledge & research is still limited within a close circle of professionals in the field and

Figure 8 Layout options in various typologies for different climate zones

it needs to be brought out to the common man who is the end user that will benefit.

Many Organizations like IIFL, BMTPC, BEE and many others have started creating knowledge banks and workshops towards achieving this goal. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) is implementing the Indo-German Energy Programme (IGEN) on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) and the Government of India. The aim of this programme is to foster sustainability in built environment in order to use sustainable materials for Thermal comfort and in turn improve the environment and climate conditions. This programme has supported Government of India in the development of Catalogue of replicable designs for energy efficient residential buildings. IGEN's new programme, Climate Smart Buildings (CSB), with Ministry of Housing and Urban Affairs (MoHUA) proposes to extend technical assistance and cooperation for main-streaming thermal comfort in Affordable Housing.

Replicable Design options for Thermally Comfortable Affordable Housing

The next phase of this project is focused on replicable design templates specifically targeting affordable housing that is yet to be constructed and encourage compliance with the best practices. This will provide a platform with a database on sustainable building design in a user-friendly format. The idea is to ensure that a wide range of users understand the strategies and are able to adopt these energy efficiency measures into the design to go beyond the existing standards. For home-owners and small developers who do not have the capacity or expertise to assess their designs with simulation software these replicable designs offer ready to use and tested solution sets to construct thermally comfortable homes. While many codes, standards and policies are in place and many more are underway to address energy efficiency and thermal comfort in buildings, this project is able to translate the objectives of these policies into simple designs that can be adopted across various platforms and stakeholders, thus bridging the gap between policy and implementation.

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India's cities will continue to expand, but could we do that without emitting carbon?


Sumedha Malaviya[1] *Kunal Shankar*[1]

What is common between Mumbai, Berlin, Austin, Cape Town and Rio de Janerio? These are member of the ***Cities Race to Zero***. Race to Zero is a global campaign run by the COP 26 presidency and High-Level Climate Champions recognized by the United Nations Framework Convention on Climate Change (UNFCCC). The Race to Zero campaign was launched at the World Environment Day in 2020 to build momentum around international climate action by cities, regions, countries, businesses, investors and other organizations committed to achieving net-zero emissions by 2050. Net-zero means reaching a point where cities absorb all the carbon they emit.

Photo Source: https://www.unpri.org/pri-blog/race-to-zero-global-campaign-to-achieve-net-zero-emissions-launched/5933.article

Cities are at the centre of action needed for a decarbonized future

Various studies indicate that cities consume 60-80% of energy production globally and account for 70% of Carbondioxide (CO_2) emissions. A review of greenhouse gas (GHG) inventories of 167 cities globally found that just 25 cities were responsible for 52% of all urban emissions. There are debates and complications associated with attributing emissions from energy consumption and production within or outside city boundaries. But to simplify the identification of opportunities - CO_2 emissions from cities can be broadly categorized as those from consumption of energy in five sectors – buildings, transport, provision of municipal services, construction of infrastructure (like roads, drains, and flyovers) and the use of products and services by people living in the city. In buildings the sector, both embodied carbon (from the production of materials) and operational carbon (produced from use of energy to run or operate equipment inside buildings or fuel used in transport or for delivering municipal services) are important in the Indian context since our cities are still growing. The floor area of residential buildings alone is expected to grow from 15.3 million square metres in 2017-18 to 21.9 million m2 by 2027-28.

The buildings sector was said to be responsible for 32% of global final energy use and 19% of energy-related to GHGs in 2010. In India, buildings consume 33% of electricity. In cities, measures to mitigate

1 World Resources Institute, India's Energy Program.
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emissions from the buildings sector can yield significant benefits like improved productivity, better air quality, reduction in urban heat islands and strengthening resilience to climate impacts. Global calls for action on Zero Carbon Buildings have grown stronger- with commitments being signed by multiple cities and countries to decarbonize all new buildings by 2030 and all buildings by 2050; and this includes targets for both embodied and operational carbon reductions.

And yet, buildings sector actions in Indian cities are too few and not enough. In the 2021assessment of 126 smart cities on the Ministry of Housing and Urban Affairs' Climate Smart cities assessment framework, only one city scored five stars (the highest) for their performance on criteria on the thematic area- ''green buildings and energy''. The indicators evaluate the implementation of actions to promote energy efficiency and clean energy in buildings.

Historically, the government has set urban planning and construction standards, providing the market pull for innovations by the private sector and influencing supply chains. As the largest developer of public assets and procurer of materials and services, government bodies, can transform markets to promote low carbon buildings.

It is also important to recognize that governments own many public buildings, including the secretariat, court buildings, town halls, schools and colleges, employee residences, police stations, district offices, taluk offices, etc. In cities, municipal bodies also maintain and operate an extensive portfolio of public buildings. Here are three focus areas for cities to demonstrate leadership in accelerating the transition to zero carbon buildings (ZCB):

Energy performance and renewable energy generation requirements for public buildings:

India's progressive building energy codes system includes both enablers of a ZCB- energy efficiency and renewable energy (RE) integration in buildings. The Energy Conservation Building Codes (ECBC) for commercial and residential buildings (EcoNiwas Samhita or ENS) describes energy performance standards and requirements for on-site RE generation from solar PV. Additional capacity-building resources developed by the Bureau of Energy Efficiency (BEE) and its partners seek to facilitate implementation by local agencies. E.g., the launch of ENS part 2 in 2021 included a building materials directory and a guidebook on design templates for incorporating ENS provisions in new residential constructions. Similarly, to streamline enforcement and compliance with ECBC, checklists, templates and online tools are available. Municipal bodies can mandate the incorporation of ECBC and ENS design principles, performance requirements and RE generation in their plans for new public buildings and housing. These codes have been around for more than a decade. There is no reason why every new office or hospital being constructed by an Urban Local Body (ULB) should not comply with the ECBC. To build internal capacity (or of their contractors) in constructing code-compliant buildings, ULBs can reach out to their respective State Designated Agencies (SDAs) to organize training programs and workshops. ULBs' leadership in transforming their building stock will create a ripple effect in local markets- encouraging manufacturers and retailers to provide materials needed for code-compliant buildings. Mandatory on-site RE generation requirements for public buildings will indicate the government's commitment to decarbonizing municipal building stock.

Reforming public procurement practices:

Changing public procurement practices are some of the most transformative mechanisms to influence supply chains towards low carbon constructions. There are ongoing efforts to introduce changes in the government's e-marketplace (GeM) – the Indian government's online procurement platform. For instance, in June this year, the platform added a category called Green Room Air Conditioners to encourage the procurement of environment-friendly and energy-efficient ACs for government buildings. GeM is accessible to state and central government agencies and ULBs to procure green alternatives to appliances and equipment. Additionally, ULBs can work with state governments to price low embodied carbon materials competitively in the schedule of rates (SoRs) to enhance their accessibility and share in procurements. The SOR is a comprehensive document used to execute electrical, mechanical, and civil works by the Central Public Works Department and several public sector undertakings. Given the volume of procurement, small steps like these can increase the availability and affordability of energy-efficient and low carbon materials. These SOR changes must happen parallelly with revisions to procurement rules and guidelines. Given the complexity of procurement rules, state governments would need to support ULBs by easing paperwork, issuing department-wide memos, notifications, and government orders.

Introducing embodied carbon and circularity considerations:

Given the size of Indian cities and their growth prospects, cities can get a head start on introducing embodied carbon and circular economy principles in local planning. In the buildings sector, a circular economy would imply minimizing use of materials for construction through better design, promoting material waste reuse, recycling and recovery especially during construction and demolition of older structures. Several cities have already developed or are developing master plans. Since such plans usually determine the fate of built environments in cities for future generations, we could avoid the concentration of resource inefficiencies and high emissions zoning by embedding circular economy principles in the planning process.

Urban planning must set standards for carbon intensity and resource efficiency on layouts or planned townships. E.g., formulating rules on sourcing and procurement of local construction materials; regulations that fix a range for building height/density to limit carbon intensity. Some cities are doing more and specifying a percentage of recycled materials or components that can be disassembled, reused and recycled. For example, Austin, Texas, passed an ordinance fixing the maximum amount of waste that can be disposed of per square foot and a minimum of 50% waste diversion from landfills. To address embodied carbon, organizations like BMPTC can play an important role by helping ULBs understand and implement low carbon impact construction processes and technologies. BMPTC's guidebook on utilization of recycled C&D waste needs to be disseminated widely and its adoption initiated by cities.

By implementing these three recommendations, Indian cities could achieve a significant reduction in their energy use while also demonstrating leadership in accelerating the transition to zero carbon buildings.

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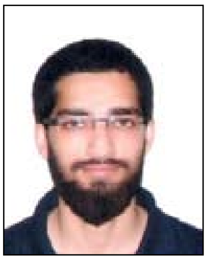
Source: https://urbanoctober.unhabitat.org/whd

Smart Home Automation Technologies to enhance Energy Efficiency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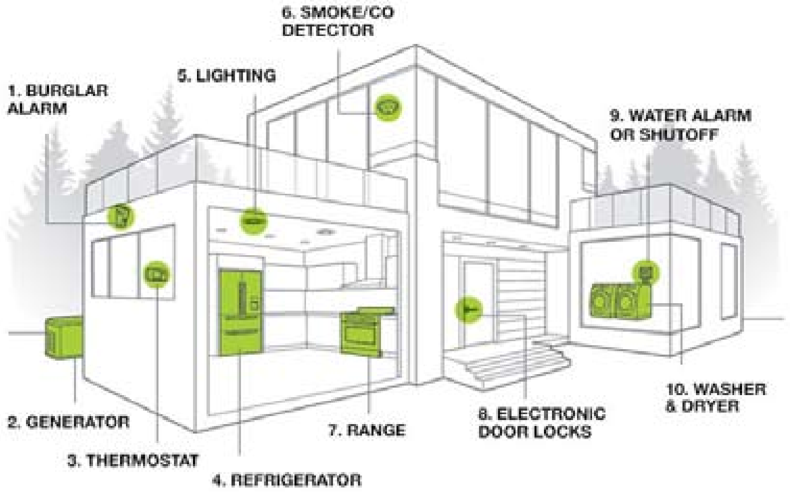
With recent technological advancements in the world, the concept of smart home automation has seen quite a surge in its market. The technology that brought a revolution in the field of automation is the Internet of Things (IoT). [1] A Smart Home also referred to as an automated home, intelligent home consists of numerous technologies which are embedded in a single frame. A home furnished with all the common devices but with the feature to interact with each other as well as with humans is a Smart Home.



Source: homeautomation.jpg (598×418) (seabreezeelectric.com)

Figure 1: Smart Home Integration

It uses internet-connected devices to enable remote monitoring and control of appliances and systems, such as lighting and heating. In the residential sector, energy consumption includes all energy consumed by households, excluding transport uses. This requires electricity for heating, refrigeration, lighting, water heating and consumer goods. Residential sector accounts for over 25% of India's electrical consumption which is primarily used for lighting, heating and cooling[2].

Between 2000 and 2013, electricity demand in the buildings sector increased at a rate of 8 % per annum. The Smart-Cities government's mission to develop smart cities/ homes has given rise to the concept of home automation systems in India.

Growing technology/ IoT adoption in every area of daily life, aspirations for improved living conditions, and growing disposable income reinforce the home automation sector, which looks very promising. Global analysis indicates that, with the help of progressive legal, regulatory and policy structures in the electricity sector, the idea of smart homes provides a significant opportunity to minimize energy consumption in the building sector, save on energy costs and eliminate excessive capital expenditure to enhance electricity production, transmission and distribution efficiency. In India, the concept of smart homes is in developing phase which offers huge potential of achieving energy efficiency

1 Vyas, Chinmaya & Patil, Shashikant. (2016). Smart Home Analysis in India:An IOT Perspective. International Journal of Computer Applications. 144. 29-33. 10.5120/ijca2016910384.

2 Bureau of Energy Efficiency, Ministry of Power, Govt. of India. (2019). "Unlocking National Energy Efficiency Potential – UNNATEE, Strategy plan towards developing an energy efficient nation (2017-2031)".

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in residential sector. Therefore, improving energy efficiency, dynamic optimization of energy consumption, and integration with the overall smartness of the electrical distribution network becomes the need of the hour.

"WORKING OF A SMART HOME"

There is a simple approach for the functioning of a Smart Home. Firstly, the system is set up where all the devices used in the home are provided with sensors to sense the internal and external environment, home occupancy, etc. These devices include electricity and energy meter - controls and monitors units consumed on a daily basis and calculates the energy consumed, energy consuming appliances like lighting, HVAC system, refrigerator, electric vehicle, washing machine, television, water heaters etc., components of house that have bearing of energy consumption such as curtains, windows, doors, thermostats etc., user interface devices like smart phones and monitors, information devices like AV (audio visual) systems, Chatbots etc., home security system and other devices like home and health management systems. All the connected devices mentioned above have the ability to sense the physical conditions, understand user's commands, have capability to act on the data sensed, user instructions and store the data regarding event, incidents/preference and use analytics to understand information from gathered data.

Different data is collected by these devices depending on the desirability of the user and these data are sent to the main node (central controller/hub). Hub stores all the data coming from different nodes and sends the data to the server through internet where the data is stored and processed. When the processed data is analysed if the actual value is beyond the required value, the data is again sent to the primary node and if the data is correct and within the required value then it is monitored if there exists any issue which could be alerted via SMS, alarm, etc. The flowchart is given in figure 2.

With the smart home concept, energy consumption parameters are to be taken into consideration. Energy efficiency can be achieved by various strategies like preventing idle running of energy consuming system, optimization of adjustable building envelope elements and operating parameters to minimize energy demand and synchronize with the user's preferences, shifting the operation of non-essential energy consuming systems to off peak time, making use of renewable energy generation source, storing the surplus renewable energy to offset peak demand etc[3].

Smart Home should be incorporated with low power and low-cost computing devices for its efficient utilization which can produce low energy making or homes smart and energy efficient. This leads to many technologies[4] that can contribute our homes to be intelligent

3 H. Singh, V. Pallagani, V. Khandelwal, and U. Venkanna, "Iot based smart home automation system using sensor node," in 2018 4th International Conference on Recent Advances in Information Technology (RAIT), pp. 1–5, IEEE, 2018.

4 R. J. Robles and T.-h. Kim, "Context aware systems, methods and trends in smart home technology," in International Conference on Security-Enriched Urban Computing and Smart Grid, pp. 149–158, Springer, 2010

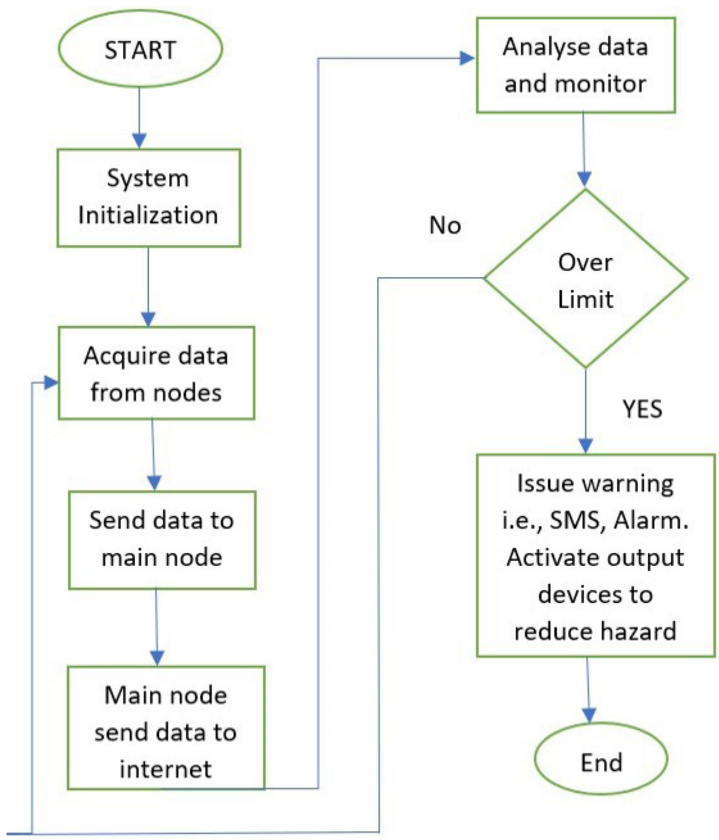

Figure 2: Working flowchart of Smart Home

enough. Some technologies are: Internet of Things as a technology (IoT), Machine Learning (ML), Artificial Intelligence (AI), Z wave, ZigBee Technology, Cloud Computing, Edge Computing etc. User interface for Smart Home can be of three kinds 1) App/dashboard based, 2) Voice based, 3) Gesture based.

The smart home market in India is influenced by factors such as a significant increase in the IoT market, cost-reduction measures made possible by home automation systems, manufacturers expanding their product portfolios and increasing the importance of remote home monitoring. In addition to safety and security concerns factors such as increased disposable income, smartphone penetration, availability of affordable Internet access, and increased knowledge of smart systems have also boosted adoption, driving the growth of the Indian home automation industry. According to the report of the Ministry of Communication, the demand for smart homes in India is estimated at US $355.4 million in 2016 and projected to rise at 43.75 % (CAGR) from 2016 to 2020. The present global market size for smart homes is estimated at US $1 billion[5].

Under "Indo-German Energy Programme" (IGEN) – Energy Efficiency Residential Buildings (EERB) - a study has been conducted on baseline assessment of smart home automation technologies market and technology mapping in India by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in collaboration with Bureau of Energy Efficiency (BEE), and Deloitte Touche Tohmatsu India LLP. Surveys have been conducted to understand the consumer needs, preference, awareness and barriers regarding smart home technology and policies. The respondents of the survey included consumers from 13 cities of age group 30-60 years. The respondents are households of 1 BHK to 4 BHK and individual bungalow with annual income from less than 10 lakhs to above 50 lakhs. During the survey, the consumers are requested to indicate their preference from options 1 to 9 about the products which are currently in use or planning to buy in the coming five years.

36% of the respondents preferred security and access as their first preference and smart lighting as second preference with 36%. Smart AV system is considered as third preference with 55% of survey responses. During the course of survey responses have been collected to identify the key drivers for adoption of smart home appliances. It is observed that 91% of respondent opted for convenience and life style, followed by 82% for interior enhancement. It is also observed that energy savings wasn't the primary concern as only 45% of the respondents opted smart home appliances for saving energy at home.

Also, the consumer responses demonstrated that the major barriers for smart home automation technologies are data security and cyber risk (67%), cost of technology resources (53%). Some of the other factors which affect are the complexity of installation and lack of clarity of energy savings. The following figure indicates the percentage of these barriers as per the survey responses.

On the basis of surveys and interviews with manufacturers and service providers, it was learned that the building codes and the green rating system, i.e. In the current scenario, ECO Niwas Samhita (ECBC for residential sector) has little to no impact on demand on smart home products. Approximately 55% of respondents indicated that there is no impact of the policies mentioned on the demand for their products and services. In this context, 36 % of respondents do not have an opinion, and about 9% of respondents agree that this policy has an impact on the demand for their products and services.

Based on the data on average expenditure on smart home au-

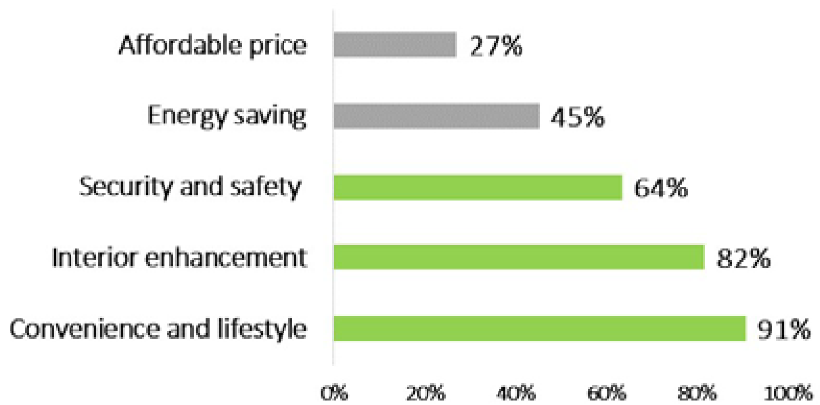

Figure 3: Key Drivers for adoption

5 Technical report on Smart Homes (March, 2017) by Telecommunication Engineering Centre, Ministry of communication, GoI

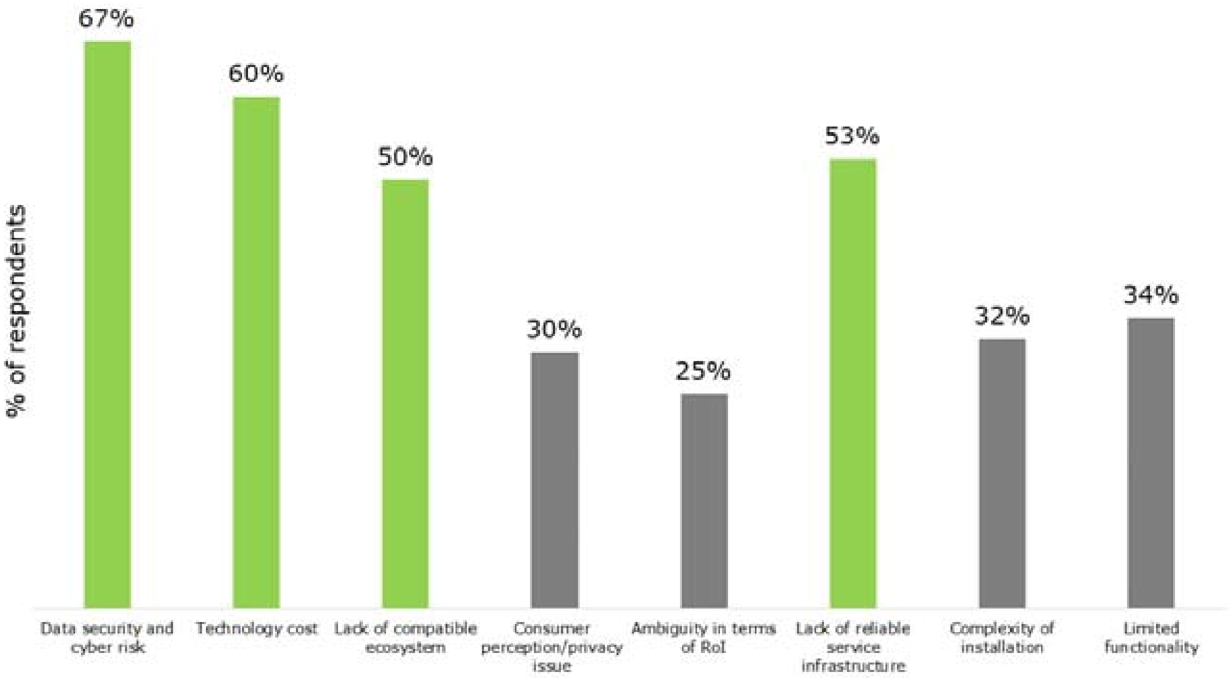

Figure 4: Major barriers for Smart Home Automation

tomation products and services collected during the consumer survey, the penetration of smart home automation products is estimated to be 0.07% in 2016 and is expected to increase to 0.20% by the end of 2020. With business-as-usual scenario, the penetration is expected to reach about 2.8% by the end of 2030.Some of the key policy required to disrupt Indian smart home market, identified based on the discussion with industry leaders and subject matter experts, includes: 1) Policy for data safety and cyber security to protect consumer privacy and to mitigate risk of data theft. 2) Policy to standardize products for seamless integration of products of different make 3) Policy to promote use of smart home in new and existing homes by voluntary or mandatory compliance. Indian market may follow the trends similar to other developed nations, where the smart home market is expected to grow by ten folds due to implementation of some of the above-mentioned policies[6]. Considering this factor and reduction in cost of technology with economies of scale, Indian smart home market size is expected to grow to about US $62.8 billion by the end of 2030 (with regular policy interventions by concerned departments) and the penetration level (with reference to total number of households in 2030) is exacted to reach 28%.Inclusion of smart home policies in the country and creating awareness about the different existing technologies and policies would foster the growth of smart home market. In India, therefore, the promotion of smart homes should be encouraged to make it digitalised, safe and efficient.

GIZ on behalf of The Federal Ministry of Economic Cooperation and Development (BMZ), Germany, and Ministry of Housing and Urban Affairs (MoHUA), India under the Indo-German Technical Cooperation, agreed to jointly promote the "Indo-German Energy Programme" (IGEN) with the aim to foster sustainability in built environment. IGEN's programme, Climate Smart Buildings (CSB) proposes to extend technical assistance and cooperation to improve thermal comfort conditions in the affordable housing sector, and implementation of Global Housing Technology Challenge-India (GHTC-India).

The CSB programme is aligned with the commitments made by the Indian Government to meet its objectives submitted under NDC. Under this programme, GIZ is exploring opportunities to include smart home applications in affordable housing sector to make houses energy efficient and thermally comfortable.

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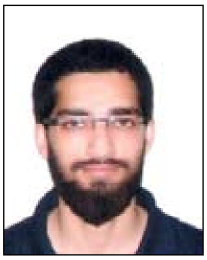
6 International Energy Agency (IEA)-4E.MARCH 2018 - INTELLIGENT EFFICIENCY - A CASE STUDY OF BARRIERS & SOLUTIONS - SMART HOMES. https://cda.iea-4e.org/publications-library

Enhancing Thermal Comfort in buildings through Innovative Construction Technologies and Materials


S Vikash Ranjan[1] Abdullah Nisar Siddiqui[2] Anurag Verma[3]

Buildings are and continue to be responsible for consuming a major portion of energy that is produced in the world. According to the latest estimates from the UN environment[1], the energy consumption by buildings and constructions in 2019 globally stood at 35 per cent (with 38 per cent associated CO_2 emissions), accounting for the largest share of final energy use. Lowering of energy and emissions intensity of this sector and implementing focused strategies on materials to reduce life-cycle carbon emissions is recognized to be the most cost-effective way of combating climate change.

Nearly 95 percent of the housing shortage in India is in the lower income categories. PMAY-U (Pradhan Mantri Awas Yojna-Urban), government of India's flagship program for affordable housing for all in the urban and rural areas, is set to address the deficit by adding 11.3 million new housing. As these houses will be operational for at-least 50-60 years, this will not only have a bearing on the energy demand from the residential sector but also require huge quantities of building materials, putting tremendous pressure on our natural reserves.

The problem is twofold – the increase in residential floor space would lead to a 5 fold increase in electricity demand by 2032[2], as a significant percentage of Indian households will be living in thermally uncomfortable dwelling[3], therefore relying on mechanical means of cooling. Additionally, it will also put a burden on its already dwindling natural resources needed for construction. The current policies are focusing largely on the speed, ease, and cost of construction in utilizing new construction technologies and materials. This is a tremendous opportunity to mainstream energy efficiency and environmental sustainability in these housing projects, particularly in the affordable housing sector to provide thermally comfortable housing through passive means.

Construction materials used in Indian housing have mostly been dominated by conventional materials like solid burnt clay bricks. From villages to cities, clay bricks are easily available and provide a sturdy and cheap building material for all income groups in India. However, the environmental costs associated with this material is high. From the initial stages of procurement of soil (which is mostly the most fertile topsoil), to the energy intensive process of baking in brick kilns to higher energy costs during building operations.

Building envelope made from conventional materials (such as clay bricks) are responsible for extensive heat gains and losses in a building due to poor insulating properties (U-value) of the material which is unable to provide indoor temperatures within acceptable thermal comfort levels. These material choices end up having a large implication on the consumer's choice for opting for mechanical cooling, increasing operational energy, which in turn affects the long term affordability of the occupants.

However, over the years there has been an increase in the availability of alternate building materials and technologies and several private players have entered the market. Many states are already utilizing alternate building techniques like monolithic concrete construction system and pre-cast

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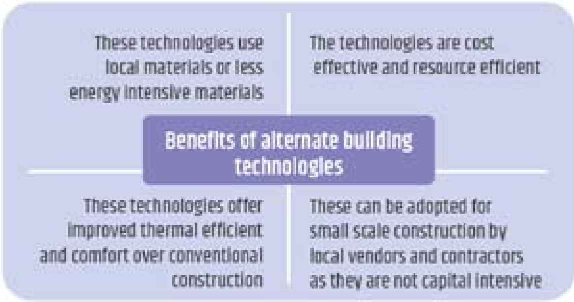

concrete. But these choices have predominantly been motivated due to their speed and ease of construction and do not consider energy efficiency, thermal comfort, and environmental sustainability as a guiding criterion.

Several new age building materials and walling assemblies are now available which provide better insulation (lower U-values) and can help in maintaining acceptable thermal comfort levels throughout the year besides performing well on other criteria such as strength, resistance to fire, water resistance, stability, etc. The Building Materials and Technology Promotion Council (BMTPC) has recognized some of these walling assemblies and technologies which have demonstrated acceptable structural and functional performance. These materials and technologies are currently being utilized in various Light house Projects (LHP) and Demonstrations Housing Projects (DHP) being executed in different states of India, to showcase their performance and demonstrate innovative construction methodologies.

A scoping study[4] conducted in a pilot affordable housing project in Telangana established that replacement with several of these new age materials and walling assemblies in a high-rise apartment building led to acceptable RETV values (acceptable heat gains) as prescribed by the building energy code for residential buildings (ECBC-R or Eco-Niwas Samhita 2018), as opposed to the base case scenario (made from fly ash concrete blocks) which had higher heat gains. Building materials such as AAC blocks and stay in place formwork systems utilizing EPS (Expanded Polystyrene insulation) based insulation lowered the heat gains to acceptable limits due to their superior insulating properties and led to higher number of thermally comfortable hours annually. This makes a case for the importance of proper selection of walling materials and the need for building performance studies in the early stages of the project.

Material selection for affordable and sustainable housing is not just limited to energy efficiency and thermal comfort. Their impact is multifaceted and affects embodied energies and associated environmental impact due to extraction, production and transportation. Therefore, these considerations along with their reusability and recyclability must also become deciding factors for evaluating the performance of building materials and new technologies, on the principles of circular economy. Currently, Construction and De-

molition (C&D) waste management rules 2016 mandates utilization of recycled C&D waste in public projects, however the assessment of such products in terms of energy efficiency and thermal comfort is still in a nascent stage.

The policy mandate as prescribed by ECBC-R makes it clear that achieving energy efficiency is an interplay between material choices and building design and both must be carefully analyzed and evaluated to achieve the desired goal. Policy mandate to design for energy efficiency are now available in the form of ECBC-R and NBC (National Building Code), 2016. Since most affordable housing projects are naturally ventilated or mixed mode, developing specific thermal comfort standards for affordable housing projects for different climatic zones of India can initiate adoption of native materials and tailored passive design strategies for construction in each climatic zone.

India is aggressively building affordable housing and promoting new materials and technologies. Therefore, it is imperative to evaluate them on multifaceted criteria of energy efficiency, thermal comfort, and resource efficiency and to make sure right materials and designs that are responsive to native climate are used. New materials such as AAC blocks and fly ash bricks have become increasingly popular for construction in India and are made from byproducts of other industries besides having potential for recyclability.

India currently has in place energy conservation building codes for both commercial and residential buildings which are addressing efficient building constructions by bringing down the cooling requirements of buildings through both passive and active means. Affordable housing projects that are to be build will not only be required to be sustainable, but also must provide thermal comfort through passive means, which may otherwise affect the affordability of the occupants in the long term due to high electricity costs for cooling and heating. Therefore, the transition in the affordable housing sector to provide thermal comfort and energy efficiency require a road map in the form of Thermal Comfort action plan which will be a guideline for policy makers and implementers such as Ministry of Housing and Urban Affairs (MoHUA), BMTPC, State Agencies, Central Public Works Department (CPWD) & State PWDs, State Urban Development Ministries, and ULBs etc. The development of the Thermal Comfort action plan for affordable housing must put to use a multifaceted approach, aiming at significantly reducing the discomfort hours compared to typical design conditions and recommend strategies that integrates technologies (low cost, rapid construction, local raw materials based), sustainability, embodied energy, and advance building materials relevant for affordable housing.

Currently, the Adaptive Thermal Comfort model in National Buildings Code 2016 provides thermal comfort ranges for naturally ventilated buildings, air-conditioned buildings and mixed-mode buildings. Requirements for passive construction and material specifications suitable for the Indian contexts for enhancing the thermal comfort level in affordable housing for different climatic zones of India can be supplemented by creating a Thermal Comfort standard. Many international standards on thermal comfort like ASHRAE 55, ISO 07730, CEN EN 16798 etc. can be used to build upon and inform the development of the standard. The proposed outcome of the standard must be directly linked to the thermal comfort level and corresponding improvement in thermal comfort level and be complimentary to other national standards like NBC 2016, Eco Niwas Samhita, ISHRAE IEQ, Model building bye law 2016 etc. The new standard should be able to fill in the gap in contrast to the existing standards, codes under

implementation under the Indian scenario as compared with standards and codes available around the world.

Feedback from the relevant stakeholders and the challenges faced by states in implementing affordable housing will identify critical issues and gaps in adapting the standard for affordable housing in five climatic zones, especially the issues related to building materials (viz. building envelope), natural ventilation and mixed mode ventilation. The standard thus will provide quantifiable thermal comfort performance for various passive and active strategies based on the existing literature, gap analysis, and typology studies and modelling studies with the feedback from the relevant stakeholders incorporated.

The thermal comfort action plan and standard for affordable housing will provide the necessary environment to transform the current construction practices and help in mainstreaming of alternate materials and technologies that perform well in terms of thermal comfort, energy efficiency and environmental sustainability. These innovative materials, along with building designs, can form the backbone for coming up with ready to use passive and active design construction measures and guidelines which will facilitate in the implementation of the standard and help in achieving goals as envisaged in the Thermal comfort Action Plan for affordable housing. These guidelines therefore will become a one stop shop for primary users like developers, builders, building contractors who will be able to utilize this knowledge on ground.

GIZ on behalf of The Federal Ministry of Economic Cooperation and Development (BMZ), Germany, and in cooperation with the Ministry of Housing and Urban Affairs (MoHUA), Government of India aims to foster sustainability in built environment in order to use sustainable materials for Thermal comfort and in turn improve the environment and climate conditions. Currently, it is providing technical assistance in developing thermal comfort action plan for climate resilience building for mass scale application in selected states for Affordable Housing and the implementation of the Global Housing Technology Challenge India (GHTC-India).

Endnotes:

1 Global alliance for buildings and construction. 2020. Global Status Report for Buildings and Construction. Available at https://globalabc.org/sites/default/files/inline-files/2020%20Buildings%20GSR_FULL%20REPORT.pdf (accessed on 23/09/2021)

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4 Centre for Science and Environment, New Delhi. 2020. Optimizing the third skin. Available at https://www.cseindia.org/optimizing-the-third-skin-10150 (Accessed on 23/09/21)

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Ministry of Housing and Urban Affairs

Government of India

प्रधान मंत्री आवास योजना–शहरी Pradhan Mantri Awas Yojana-Urban

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e-Course on Vulnerability Atlas of India

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The e-course on Vulnerability Atlas of India has been launched by Shri Hardeep S Puri, Hon'ble Minister of State (I/C) for Housing and Urban Affairs, Government of India on August 29, 2019. The e-Course is being offered jointly by the School of Planning & Architecture, New Delhi and Building Materials & Technology Promotion Council (BMTPC), New Delhi.

It is a basic e-learning course that offers awareness and understanding about natural hazards, helps identify regions with high vulnerability with respect to various hazards (earthquakes, cyclones, landslides, floods, etc.) and specifies district-wise level of damage risks to the existing housing stock.

The e-course will be a tool for effective & efficient disaster mitigation & management in the field of Architecture, Civil Engineering, Urban & Regional Planning, Housing & Infrastructure Planning, Construction Engineering & Management and Building & Materials Research.

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Course Contents

Module 1: Concept of Vulnerability Atlas of India

Module 2: Earthquake Hazard and Vulnerability to Housing

Module 3: Wind / Cyclone Hazard and Vulnerability to Housing

Module 4: Flood Hazard and Vulnerability to Housing

Module 5: Landslides, Thunderstorm and Tsunami Hazards

Module 6: Housing Vulnerability Risk Table

Module 7: Using Vulnerability Atlas of India

Building Materials & Technology Promotion Council
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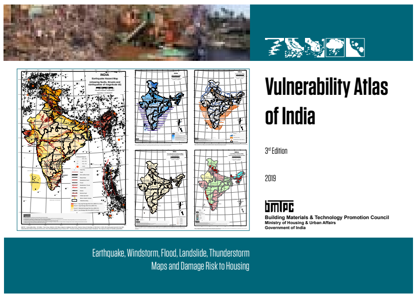
Webinar on Vulnerability Atlas of India and Disaster Resistant Design & Construction Practices



To build capacities in the area of disaster mitigation and management, BMTPC has been imparting training to professionals and creating mass awareness amongst various stakeholders. BMTPC has brought out the third edition of the Vulnerability Atlas of India (VAI) which includes hazard maps of earthquakes, wind/cyclones, floods, landslides, thunderstorms and vulnerability risk tables based on available latest data. The VAI is a step towards disaster preparedness and create disaster resilient society

The digital version of Third Edition of Vulnerability Atlas of India was released by Hon'ble Prime Minister of India during CTI 2019 – Global Housing Technology Challenge – India (GHTC-India) on 2nd March, 2019 organised by Ministry of Housing & Urban Affairs and has been made available at websites of Ministry of Housing & Urban Affairs, GHTC-India and BMTPC (https://vai.bmtpc.org) for wider access by one & all.

Taking the agenda of Building Disaster Resilient India and to educate masses, BMTPC is organizing webinars on Vulnerability Atlas of India and Disaster Resistant Design & Construction Practices on regular basis. In this series, a Webinar on Vulnerability Atlas of India was organized on 20th September, 2021 from 1730 hrs. onwards through video conferencing.

Design Efficiency of Indian Affordable Houses for Built up Area, Embodied Energy & Construction Cost

Bansal Deepak[1]

Abstract:

LCE of Indian affordable housing is dependent on its embodied energy, as energy required for its construction, transportation, demolition & recycling is less and its requirements for operational energy may be met through renewable sources. Embodied energy is dependent on quantity of construction materials used in construction. Usage of construction materials are dependent on built up area. But usable area is carpet areas, not built up areas. There is huge variation between carpet areas and built up areas of buildings, due to its architectural designs. To understand this and to choose efficient designs of affordable housing in India, more than 30 housing designs are analysed and it is found that ratio of built up area-carpet area varies from 1.30 to 1.62, which results in large variation in consumption of construction materials, thus in embodied energy (4-6.5 GJ/m^2) & construction cost (INR 13,425-20,138/m^2) on carpet areas basis. Lower embodied energy & construction cost is generally associated with lower ratio. Hence sustainability of affordable housing heavily depends on its architectural design.

Key Words: Buildings, Architecture & Structural design; Indian affordable housing; Carpet area; Built up area; Embodied energy; Construction Cost;

1.0 Introduction:

Annual contribution of buildings in emission of Green Houses Gases (GHGs) is about 40%. Buildings have two major phases of primary energy consumption & GHGs emission, known as construction phase and operational phase. Housing is a major stakeholder in building sector. Generally, energy in demolition and recycling of housing is very less. Energy in transportation of construction materials & construction equipment is also negligible. Energy in construction is estimated to be insignificant in housing due to predominance of manual labour in India. Hence in Indian housing, only embodied and operational energy contributes predominantly towards its LCE. In conventional buildings, operational energy is more important and in sustainable buildings, embodied energy is more important. Low rise and high rise buildings have different pattern of energy consumption. In Indian affordable houses, embodied energy is more important as its operational energy requirement is low due to poor affordability of the users. Use of high cost & high energy, construction materials and fancy sanitary, electrical fixtures & fittings are minimal in Indian affordable housing.

Many designers have analysed, energy in construction of different type of buildings and suggested some values of LCE, embodied energy and operational energy, in different countries in different time per sqm (m^2) of floor area of buildings. However, neither design efficiency of the buildings was discussed nor buildings components/specifications. Calculation of floor areas (carpet, plinth/built up) is also not explained. Although carpet area is usable area, construction materials are dependent on plinth/built up areas, as construction materials are also required in external walls, circulation spaces, common spaces, staircases, lifts and external building works. Since there is a huge variation in ratio of built up areas and carpet areas, depending upon efficiency of architectural designs, embodied energy & construction cost of buildings

1 Joint General Manager with Housing and Urban Development Corporation Limited (HUDCO), New Delhi 110003, India.

with same carpet areas, in different architectural designs, may vary to a large extent. The best design would be a design with minimal variation between carpet areas & built up areas, less construction cost, embodied & operating energy and more life span of the buildings with same or better functional utility & indoor comfort condition.

In this study 30 designs of Indian affordable housing from the field are selected and analysed for its design efficiency in terms of carpet areas & built up areas. Embodied energy & construction cost are calculated per m^2 of built up & carpet areas, to choose optimum architectural design with least embodied energy & construction cost.

2.0 Case Study:

In the current study, 30 architectural designs of Indian affordable housing have been selected from the Ministry of Housing & Urban Affairs, Government of India's social housing programme, PMAY, and its detailed bill of quantities have been calculated along with its carpet areas & built up areas. Service life of buildings in India is about 50 years. These 30 houses are load bearing G+2 (ground, first and second) storeyed high with carpet areas varying from 20.02 - 29.99 m^2 & built up areas varying from 28.47 - 42.06 m^2 respectively. These designs have been planned in a cluster of houses, varying from 2 housing units at a floor to 12 units at a floor. A typical studied architectural design is presented in Figure 1.

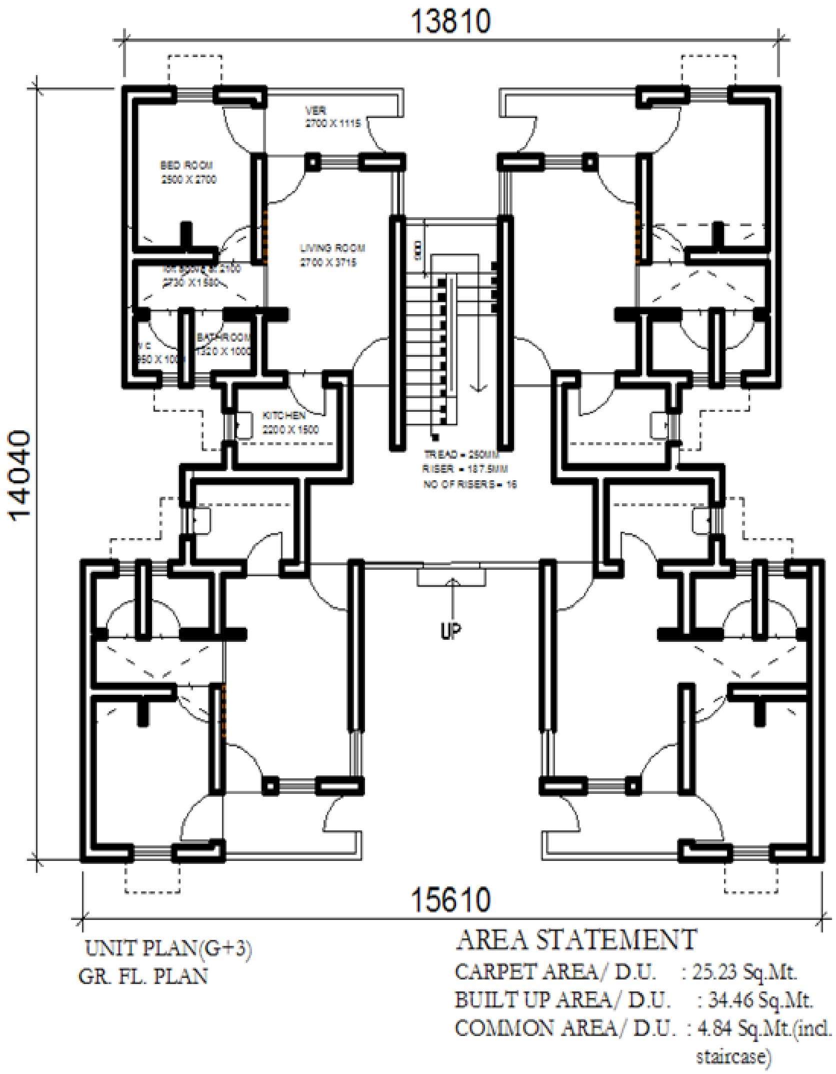


Figure 1. Typical architectural design of an Indian affordable housing (G+2).

Assumptions of designing of these housing are:

SBC (Safe bearing capacity of soil) 11 T/m^2 at 1.0 metre depth from NGL (Natural Ground Level). Size of Foundation 750*750 mm up to two storied and 900*900 mm for 3 storied. Seismic Zone III and Basic Wind speed 47m/s as per National Building Code 2016. Live loads and dead loads are also taken National building Code, 2016.

These designs have been given names as A1-A12, B1-B4, C1-C11 and D1-D3, just to identify them without any meaning to their name, as analysis has been done in different tranches (A, B, C & D). The embodied energy of few common construction materials are taken from Indian references like, BMTPC (Building Materials Technology Promotion Council) & Development Alternatives (DA), and international sources like ICE (Inventory of carbon and Energy), UK . There is huge variation in embodied energy values of Indian and European (ICE) construction materials that may be due to different local conditions, specifications, service life, technological, time zone and system boundaries. The LCE analysis done based on different values of embodied energy of construction materials (Indian & ICE) will give a very different LCE result, even in the same type of house, hence LCE must be carefully compared for input values, typology of buildings, area statements and system boundaries.

Table 1. Cost of few common construction materials as per CPWD DSR 2016

Items	Cement	Steel	Bricks	Sand	Coarse aggregates
Unit	Bags of 50 kg	Kg	No's	Cum (m^3)	Cum (m^3)
Cost in INR	285/	37.30/	5.20	1200/	1300/

Cost of few most common construction materials are taken from publications of Indian public agency, Central Public Works Department, (CPWD), Delhi scheduled of Rates (DSR) 2016 and presented in Table 1.

3.0 Result:

All 30 architectural designs have been analysed for built up areas-carpet areas ratio, construction cost and results are presented in Table 2. Cost of basic construction materials & cost based on construction materials as per bill of quantities of different designs have been calculated and presented in Table 3. Embodied energy of construction materials and buildings have been calculated and presented in Table 4. Results show that there is direct relationship between embodied energy, construction cost & built-up/carpet area ratio with few exceptions. Built up area- carpet area ratio varies 1.30 - 1.62 in these 30 designs. Cost of construction varies between INR 13,425-20,138/m^2 and cost of prominent construction materials varies from INR 4,697-7,433 /m^2 on carpet area basis. Embodied energy varies from 4.0- 6.5 GJ/m^2 on carpet areas basis. Minimum cost & embodied energy is corresponding to 1.31 ratio (design A5) and maximum with 1.51 ratio (design A12). These ratios are not minimum (1.30) or maximum (1.62), but are very close to them. This shows that there is direct relationship between cost, embodied energy and built up- carpet area ratios with few exceptions.

It is seen from Table 2, that the built up areas varies from 1.30 to 1.62 of carpet areas, due to different architectural designs with same specifications and same functional requirements. This result in variation in cost from INR 13,425/m^2 to INR 20,138/m^2 of carpet area and INR 17,552/ to INR 30,504/ per sqm of plinth area, without any value addition in different architectural designs. Variation in quantities of basic construction materials results in variation in cost & embodied energy (Table 3 & 4). These results are plotted at Figure 2 (Built up area/ carpet area is plotted on distorted scale to make it visible).

Figure 2, makes it clear that design A5 (with built up area /carpet area ratio of 1.31) is the most efficient with cost of construction materials as INR 4,697/m^2, cost of construction INR 13,426/m^2 & embodied energy of 4.0 GJ/m^2 and design A12 (with built up area / carpet area ratio 1.51) is the most inefficient design with cost of construction materials as 7,433/m^2, construction cost as INR 20,138/ m^2 & embodied energy as 6.5 GJ/ m^2on carpet area basis. Figure 2 shows that all these parameters are dependent on built up-carpet area ratio.

4.0 Discussions:

This study shows that there is a relationship between construction costs, cost of construction materials, embodied energy and built up area -carpet area ratio with some exceptions. More this ratio, more inefficient design would be. Cost of construction materials varies from INR 4,697 to 7,433/m^2 of carpet

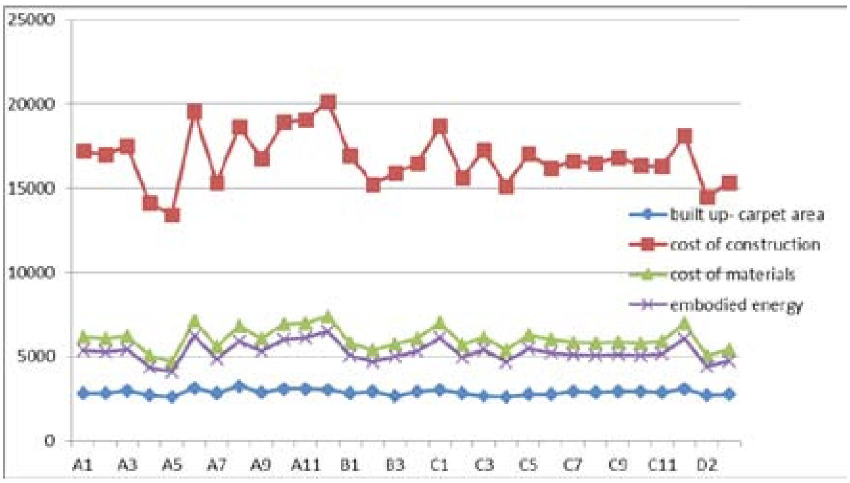


Figure 2: Relationship between built up area-carpet area, cost of construction (INR/ m^2), cost of construction materials (INR/m^2), and Embodied energy (MJ/m^2) on carpet areas. (Built up area- carpet area ratio is multiplied by 2000 for better visibility in this scale)

Table 2: 30 Building Design and its Carpet areas, Built-up area, Built up- Carpet area ratio and construction cost/m² of carpet area & built up area.

S/ N	Drawing No	Carpet Area (m²)	Built-up area (m²)	Built-up / Carpet area	Construction Cost INR/m² of Carpet area	Construction Cost INR/m² of Built area
1	A1	22.54	31.63	1.40	17222.26	24167.70
2	A2	22.49	31.64	1.41	17012.15	23933.49
3	A3	22.46	33.71	1.50	17537.10	26321.27
4	A4	29.99	40.52	1.35	14110.41	19064.82
5	A5	28.34	37.05	1.31	13425.83	17552.11
6	A6	22.39	34.98	1.56	19558.89	30559.67
7	A7	28.93	40.76	1.41	15329.75	21598.36
8	A8	21.54	34.94	1.62	18666.13	30278.30
9	A9	25.46	36.34	1.43	16784.81	23957.58
10	A10	22.43	34.68	1.55	18918.65	29250.95
11	A11	21.94	33.77	1.54	19096.25	29392.91
12	A12	22.38	33.9	1.51	20138.31	30504.41
13	B1	20.02	28.47	1.42	16958.97	24113.59
14	B2	25.29	37.31	1.48	15248.91	22496.51
15	B3	26.48	35.32	1.33	15910.67	21222.24
16	B4	28.4	41.58	1.46	16458.23	24096.25
17	C1	25.90	39.2	1.51	18685.40	28270.77
18	C2	28.78	40.82	1.42	15634.69	22175.40
19	C3	23.03	30.81	1.34	17260.68	23091.69
20	C4	26.32	34.139	1.30	15155.91	19658.34
21	C5	25.83	35.7	1.38	17044.65	23557.65
22	C6	29.43	40.8	1.39	16209.59	22472.01
23	C7	22.48	32.84	1.46	16611.51	24267.00
24	C8	22.67	32.56	1.44	16485.14	23676.94
25	C9	20.79	30.5	1.47	16852.84	24723.98
26	C10	23.39	34.11	1.46	16362.00	23860.97
27	C11	25.61	36.97	1.44	16293.65	23521.14
28	D1	27.33	42.06	1.54	18099.73	27854.91
29	D2	25.26	34.25	1.36	14491.13	19648.50
30	D3	24.06	33.27	1.38	15361.28	21241.48
	SUM	741.97	1064.63		502925.52	726530.92
	AVERAGE	24.73	35.49	1.43	16764.18	24217.69

Table 3: Cost of major construction materials as per CPWD DSR 2016 in INR/m^2 of carpet area.

S/N	Drawing No	Cement (INR 570/Q)	Steel (INR 37.3/Kg)	Bricks (INR 5.2/ No's)	Sand (INR 1200/m^3 or INR 80/Q	Aggregates INR 1300/ m^3 or INR 74.20/Q)	Material based Cost INR/m^2 of carpet area	Material Cost as % of Carpet area rates
1	A1	1556.1	1180.91	2202.72	716.8	501.45	6158.00	36%
2	A2	1539.0	1176.81	2146.19	704.8	500.71	6067.53	36%
3	A3	1601.7	1217.84	2147.34	727.2	530.43	6224.52	35%
4	A4	1328.1	980.61	1683.81	595.2	454.65	5042.38	36%
5	A5	1254	969.42	1481.01	548.8	443.51	4696.75	35%
6	A6	1761.3	1396.51	2624.80	818.4	560.88	7161.91	37%
7	A7	1413.6	1083.93	1964.09	646.4	475.45	5583.49	36%
8	A8	1641.6	1253.65	2584.45	780.8	535.63	6796.14	36%
9	A9	1527.6	1146.97	2215.09	709.6	494.77	6094.04	36%
10	A10	1664.4	1253.65	2682.26	796	526.71	6923.03	37%
11	A11	1670.1	1228.28	2776.02	808.8	523.74	7006.95	37%
12	A12	1812.6	1424.11	2785.84	846.4	563.86	7432.82	37%
13	B1	1499.1	1140.26	1980.83	681.6	494.77	5796.57	34%
14	B2	1419.3	1062.67	1753.38	632	493.28	5360.65	35%
15	B3	1459.2	1053.35	2077.08	675.2	473.22	5738.07	36%
16	B4	1533.3	1170.10	2187.06	704	506.65	6101.13	37%
17	C1	1704.3	1164.87	2800.51	824.8	523.74	7018.24	38%
18	C2	1447.8	1021.64	2092.01	674.4	473.97	5709.83	37%
19	C3	1556.1	1163.01	2272.60	725.6	486.59	6203.92	36%
20	C4	1402.2	1055.96	1847.92	632.8	458.36	5397.26	36%
21	C5	1556.1	1134.66	2374.84	732.8	487.34	6285.75	37%
22	C6	1527.6	1049.24	2245.82	713.6	484.37	6020.65	37%
23	C7	1487.7	1117.88	2094.09	684.8	499.97	5884.44	35%
24	C8	1487.7	1113.77	2030.28	680.8	499.22	5811.79	35%
25	C9	1499.1	1147.72	2021.96	682.4	507.40	5858.59	35%
26	C10	1476.3	1099.60	2067.20	679.2	496.25	5818.57	36%
27	C11	1493.4	1076.47	2160.49	693.6	491.05	5915.03	36%
28	D1	1767	1211.50	2637.28	805.6	557.91	6979.31	39%
29	D2	1316.7	1042.53	1684.02	589.6	456.88	5089.74	35%
30	D3	1390.8	1086.92	1856.29	628	470.25	5432.27	35%
	Sum	45793.8	34224.98	65477.41	21140	14973.14	181609.35	36%
	AVERAGE	1526.46	1140.83	2182.58	704.67	499.10	6053.64	36%

Table 4: Embodied energy of 30 houses per m² of carpet area.

S/ N	Drawing No	Cement	Steel	Bricks	Sand	Aggregates	Construction Material based embodied energy/m² of carpet area
	Basic Embodied Energy	685 MJ/Q	35.1MJ/Kg	4.7 MJ/ Nos	15 MJ/Q	40 MJ/Q	MJ/m²
1	A1	1870.05	1111.27	1990.92	134.40	270.00	5376.64
2	A2	1849.50	1107.41	1939.83	132.15	269.60	5298.49
3	A3	1924.85	1146.02	1940.87	136.35	285.60	5433.68
4	A4	1596.05	922.78	1521.91	111.60	244.80	4397.14
5	A5	1507.00	912.25	1338.61	102.90	238.80	4099.56
6	A6	2116.65	1314.14	2372.42	153.45	302.00	6258.66
7	A7	1698.80	1020.01	1775.24	121.20	256.00	4871.24
8	A8	1972.80	1179.71	2335.95	146.40	288.40	5923.26
9	A9	1835.80	1079.33	2002.11	133.05	266.40	5316.68
10	A10	2000.20	1179.71	2424.35	149.25	283.60	6037.12
11	A11	2007.05	1155.84	2509.10	151.65	282.00	6105.64
12	A12	2178.30	1340.12	2517.98	158.70	303.60	6498.70
13	B1	1801.55	1073.01	1790.37	127.80	266.40	5059.13
14	B2	1705.65	1000.00	1584.79	118.50	265.60	4674.54
15	B3	1753.60	991.22	1877.37	126.60	254.80	5003.59
16	B4	1842.65	1101.09	1976.77	132.00	272.80	5325.31
17	C1	2048.15	1096.17	2531.23	154.65	282.00	6112.21
18	C2	1739.90	961.39	1890.86	126.45	255.20	4973.80
19	C3	1870.05	1094.42	2054.09	136.05	262.00	5416.61
20	C4	1685.10	993.68	1670.24	118.65	246.80	4714.47
21	C5	1870.05	1067.74	2146.49	137.40	262.40	5484.08
22	C6	1835.80	987.36	2029.88	133.80	260.80	5247.65
23	C7	1787.85	1051.95	1892.74	128.40	269.20	5130.13
24	C8	1787.85	1048.09	1835.07	127.65	268.80	5067.45
25	C9	1801.55	1080.03	1827.55	127.95	273.20	5110.28
26	C10	1774.15	1034.75	1868.44	127.35	267.20	5071.89
27	C11	1794.70	1012.99	1952.76	130.05	264.40	5154.89
28	D1	2123.50	1140.05	2383.70	151.05	300.40	6098.70
29	D2	1582.35	981.05	1522.10	110.55	246.00	4442.04
30	D3	1671.40	1022.81	1677.81	117.75	253.20	4742.97
	SUM	55032.90	32206.36	59181.51	3963.75	8062.00	158446.51
	AVERAGE	1834.43	1073.55	1972.72	132.13	268.73	5281.55

area, which is about 35-37% of construction cost per sqm of carpet area. As per CPWD 2016, construction cost is arrived at by adding cost of construction materials, which is about 36% in this case, cost of labour, which is generally 30% in India, PHE/Electrical works, which is about 7% , hire charges of tool & plants, consumables and miscellaneous at @12% and contractors profit @15%, making a total of 100%. Hence in overall cost, construction materials represents 36% of cost out of 43% cost of materials, which is 83% of total cost of construction materials.

It is seen from this study that architectural designs have an important bearing on construction cost & embodied energy of affordable housing, as in an architectural designs, spaces are arranged in a particular way, which results in different arrangements of walls and circulation areas. This results in different built up areas for the same carpet areas. Since construction materials are dependent on built up areas, cost of construction and embodied energy are also dependent on it. The ratio of built up area and carpet area is an indicator of design efficiency in terms of construction cost and embodied energy, hence architectural designs must be chosen very carefully.

5.0 Acknowledgement:

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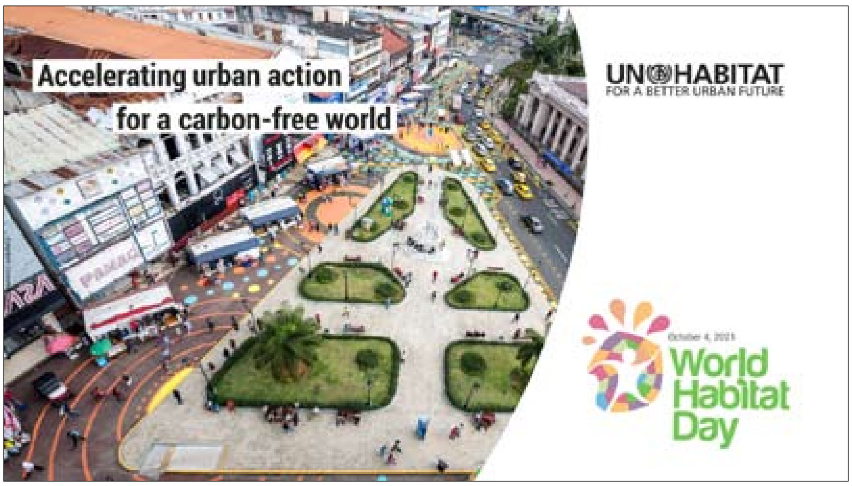


नवरीतिः NAVARITIH – Certificate Course on Innovative Construction Technologies

It is of paramount importance that building professionals learn about the new and emerging building materials and technologies for housing and building construction. The Ministry of Housing & Urban Affairs in collaboration with SPA, New Delhi and BMTPC, has started NAVARITIH : Certificate Course on Innovative Construction Technologies to train engineers and architects including students.

The objectives of the Certificate Course are to (a) Familiarize the professionals with the latest materials and technologies being used worldwide for housing, (b) Provide an awareness of the state of art of materials and technologies in terms of properties, specifications, performance, design and construction methodologies so that professionals can successfully employ these in their day to day practice and (c) Provide exposure to executed projects where such materials and technologies have been implemented.

The NAVARITIH Course was launched by Hon'ble Prime Minister through video conferencing on January 1, 2021 during the foundation stone laying ceremony of six Light House Projects (LHPs) being constructed under Global Housing Technology Challenge - India – Pradhan Mantri Awas Yojana (Urban). Subsequently, first batch of NAVARITIH was inaugurated by Secretary (HUA) on 11.02.2021.

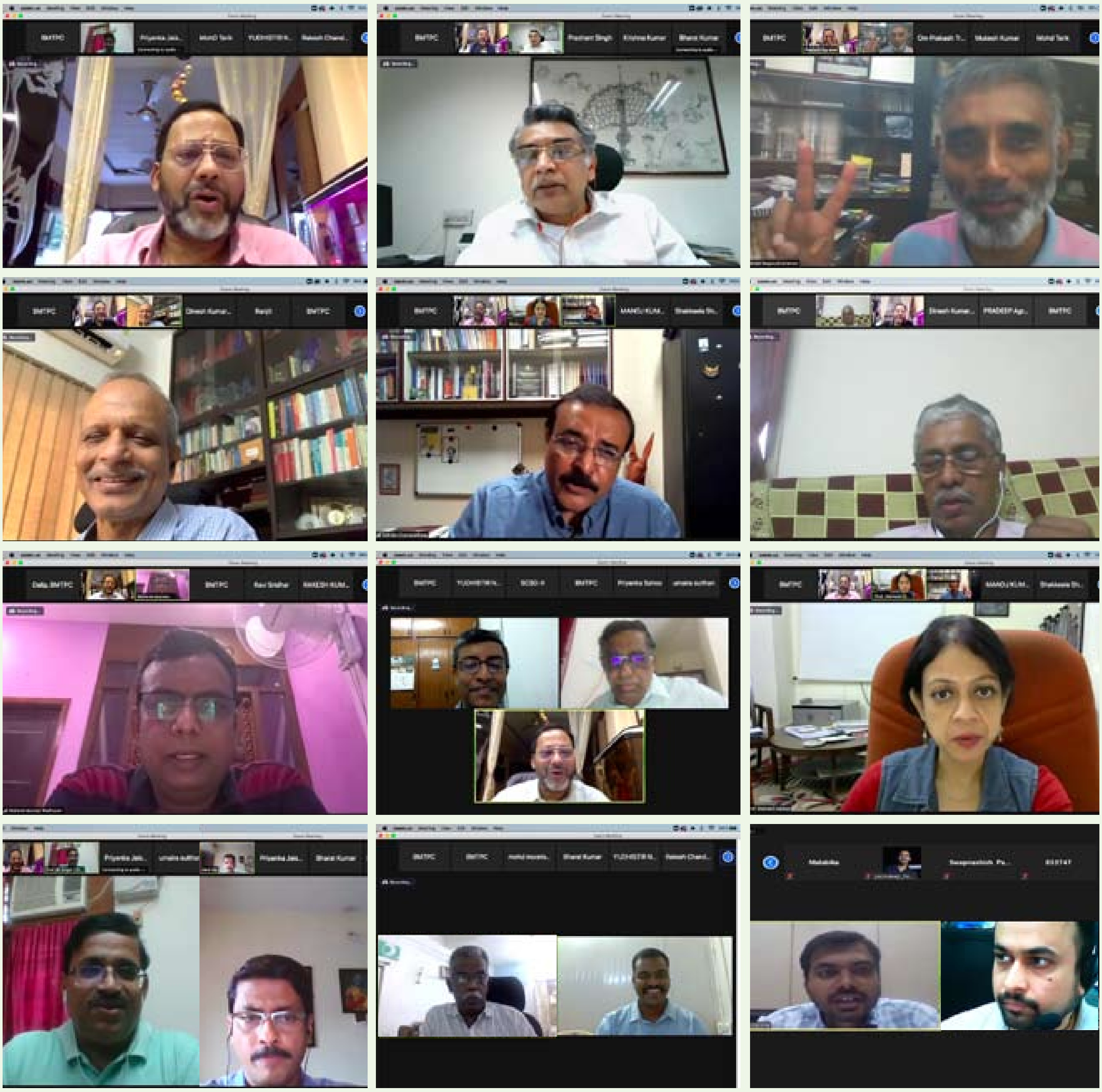
Hon'ble Prime Minister of India launched NAVARITIH during Foundation Stone Laying ceremony of six Light House Projects (LHPs) on 1.1.2021

Secretary, HUA inaugurating First Batch of NAVARITIH on 11.02.2021

The Course has received very good response so far and six batches have been conducted till now. Out of total 744 participants, who have attended the Course so far in six batches, 435 have already completed the Course and awarded certificates. The participants were mainly civil engineers and architects from CPWD, NBCC and faculty & students from various engineering and architectural colleges.

Batch No.	Organising Dates	No. of Participants
First Batch	February 12 to 18, 2021	125
Second Batch	March 19 to 26, 2021	116
Third Batch	April 30 to May 7, 2021	134
Fourth Batch	June 4 to 11, 2021	162
Fifth Batch	July 16 to 23, 2021	152
Sixth Batch	August 27 to September 3, 2021	55
Seventh Batch	November 12, 2021 onwards	-

Glipmses of NAVARITIH Batches



Ministry of Housing and Urban Affairs
Government of India

प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

School of Planning and Architecture, New Delhi

Building Materials & Technology Promotion Council, New Delhi

नवरीतिः (NAVARITIH)

Certificate Course on Innovative Construction Technologies

NAVARITIH : New, Affordable, Validated, Research Innovation Technologies for Indian Housing

An initiative of Ministry of Housing & Urban Affairs, Govt. of India in collaboration with SPA, New Delhi & BMTPC

The objectives of the Course are to (1) **Familiarise** the professionals with the latest materials and technologies being used worldwide for housing, (2) **Provide an awareness** of the state of art of materials and technologies in terms of properties, specifications, performance, design and construction methodologies so that professionals can successfully employ these in their day to day practice, and (3) **Provide exposure** to executed projects where such materials and technologies have been implemented.

LAUNCHED BY

Hon'ble Prime Minister during laying of Foundation Stones of Light House Projects at six locations on January 1, 2021

COURSE FEE

Rs.2,500 per person
(One-time, Non-refundable)

REGISTRATION

Registrations open at
www.spa.ac.in and https://ict.bmtpc.org

Interested applicants may also write to drpsnrao@hotmail.com / ghtc-mhua@gov.in / ska@bmtpc.org for applying to Course.

Target Group

Any person who has successfully completed and in possession of a minimum qualification of B.E. / B.Tech (Civil) or B.Arch. (or equivalent) or Diploma in Civil with 5 years' experience shall be eligible to take up the Course. Self-Attested photocopy of Degree/ Diploma certificate (or equivalent) to be submitted with application.

Classes & Venue

The duration of the Course will be 8 days.

Classes will be held in the evening from 5.30 pm to 8.30 pm on weekdays and on Saturday and Sunday from 2.00 pm to 5.00 pm.

In view of prevailing global pandemic scenario, the Course will be conducted on virtual platform through online classes.

On successful completion of the course, a Certificate will be awarded to the participant.

The Course on Innovative Construction Technologies has been launched as one of the activities under "Construction Technology Year (2019-20)" which was announced by the Hon'ble Prime Minister during Construction Technology India 2019: Expo-cum-Conference under Global Housing Technology Challenge – India on 2nd March, 2019 at New Delhi.

It is being offered jointly by the School of Planning & Architecture, New Delhi and Building Materials & Technology Promotion Council (BMTPC), Ministry of Housing & Urban Affairs.

Demonstration Housing Projects
– propagation of sustainable emerging construction systems under PMAY (U)

BMTPC has been propagating use of new / alternate building materials & technologies in housing through identification, evaluation, standardization, certification, capacity building, training and field level application by demonstration construction. Under Technology Sub-Mission of PMAY(U), MoHUA has taken an initiative to construct Demonstration Housing Project (DHP) through BMTPC. The construction of Demonstration Housing Projects in different parts of the country aims to facilitate wide spread dissemination and adoption of new / alternate and sustainable building materials and technologies in preference to the conventional technologies. It further helps build confidence and create enabling environment for the large scale adoption of such materials & technologies suiting to different geo-climatic regions of the country, thus making housing more affordable and accessible. Earlier, BMTPC has completed DHPs at Nellore, Andhra Pradesh; Bhubaneswar, Odisha; Lucknow, Uttar Pradesh; Biharshariff, Bihar; Hyderabad, Telangana; and Panchkula, Haryana using emerging technologies. The Demonstration Housing Project at Panchkula, Haryana was inaugurated by Secretary, Ministry of Housing & Urban Affairs on 8th June

Shri Durga Shanker Mishra, Secretary, Ministry of Housing & Urban Affairs inaugurating the DHP at Panchkula, Haryana on 8th June 2021 through video conferencing.

Completed Demonstration Housing Project at Panchkula, Haryana

Use of Structural Stay-in-Place Steel Formwork (Coffor) System at Agartala, Tripura

2021 through video conferencing. The status of ongoing DHPs are as follows:

Demonstration Housing Project at Agartala, Tripura

Technology: Structural Stay In Place Steel Formwork (Coffor)

The Social welfare & Education Department has provided the land measuring 2360 sqmts (approx.) for construction of Demonstration housing projects to be used for social purpose. The proposed building would be used as hostel / home for destitute women.

Salient Features of the Project

- Plot Area for DHP : 2360 Sq.mts.
- Total Covered Area : 1833.74 Sq.mts.
- No. of Units/Rooms: 40 (G+1)
- Carpet Area of a unit : 21.86 Sq.mts.
- Each unit consist of room with attached toilet and Pantry
- Other provisions includes Guest Room Medical Room, Care Taker Room, , Common Dining Room with Kitchen and Activity Room

Technology being used:

Foundation

- Isolated RCC column footing with Plinth beam

Walling

- Structural Stay in Place Steel Formwork (Coffor)
- Floor Slabs/Roofing Cast in situ RCC Slab

Joinery & Finishing

Door frame/shutters:

- Pressed steel door frame with flush shutter
- PVC door frame with PVC Shutters in toilets

Window Fame/ Shutter:

- uPVC frame with glazed panel and wire mesh shutters

Flooring:

- Vitrified tile flooring in Rooms & Kitchen
- Anti-skid ceramic tiles in bath & WC
- Kota Stone Flooring in Common area and Staircase

Finishing:

- Weather Proof Acrylic Emulsion paint on external walls
- Oil Bound distemper over POP on internal walls

Infrastructure Components

- CC Roads & Paver tiles in pavements,
- Provision for Rain water Harvesting,
- Solar Street Lights,
- Landscaped Court

Demonstration Housing Project at Ahmedabad, Gujarat

Technology: Integrated Hybrid Solution-One (IHS-ONE)

The Gujarat Housing Board has provided the land measuring 2400 sq.mts for construction DHP consists 40 DUs.The main feature of the project are:

Salient Features of the Project

- Plot Area for DHP : 3400 Sqm
- Total Covered Area : 2179 Sqm
- No. of Units/Rooms : 40 (G+2)
- Carpet Area of a unit : 35.78 Sqm
- Each unit consist of a living room, bed room, lobby kitchen, bath, WC, verandah and separate wash area.

Technology being Used

Foundation

- Strip-step footing with plinth bend for earthquake resistant structure

Walling

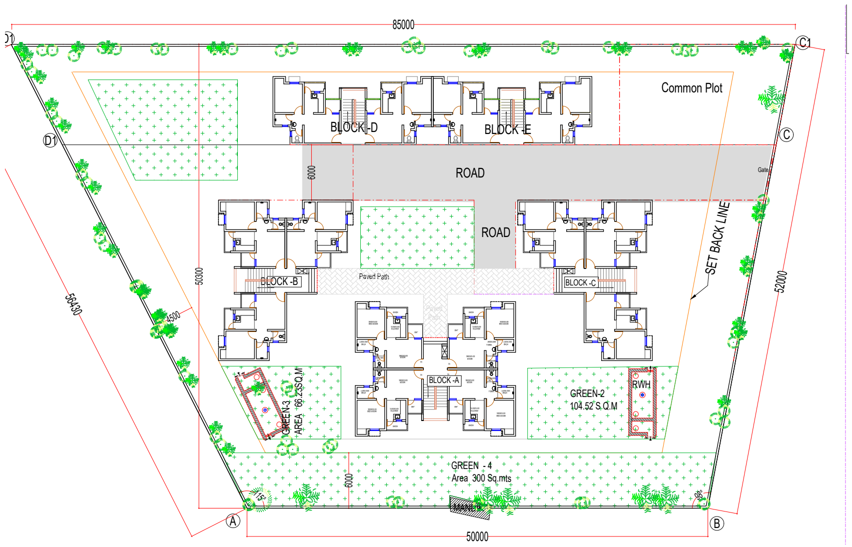
- Load bearing interlocking blocks (Hydra Form Blocks)

Floor Slabs/Roofing

- Precast RC Planks and Joists System with screeding.

Joinery & Finishing

Door frame/shutters



Layout Plan of Demonstration Housing Project at Ahmedabad, Gujarat

- Pressed steel door frame with flush shutter.
- PVC door frame with PVC Shutters in toilets.

Window Fame/ Shutter:

- uPVC frame with glazed panel and wire mesh shutters

Flooring

- Vitrified tile flooring in Rooms & Kitchen
- Anti-skid ceramic in bath & WC
- Kota Stone Flooring in Common area and Staircase

Finishing

- Weather Proof Acrylic Emulsion paint on external walls
- Oil Bound distemper over POP on internal walls

Infrastructure Components

- CC Roads & Paver tiles in pavements,
- Boundary wall with gate
- Under water tank
- Rain water Harvesting,
- Solar Street Lights,
- Landscaped Court
- Firefighting work

Demonstration Housing Project at Goa

Technology: Light Gauge Steel Framed Structure With Precast Concrete Panels On Both Side Of Wall And Light Weight Concrete As Infill

Goa State Urban Development Agency, Goa has proposed to use the DHP for social welfare cause (Old Age Home) and Institute of Public Assistance (Provedoria) provided the land within its own premises at Chimbel, Goa measuring 2000 sq.mts for DHP. The main feature of the project are:

Salient Features of the Project

- Plot Area for DHP: 2000 Sq.mts.
- Total Covered Area: 1954.2 Sq. mts.
- DHP is double storied building consists of five single rooms, two double rooms, one 3-sharing, four 4-sharing, one 7-sharing and one 10-sharing rooms
- The other provisions includes Activity room, prayer room, dining hall with kitchen reading room doctors room, Physio therapy room, emergency care room, nurses room, caretaker room guest room, office, convenience room, and separate toilets for ladies & gents, ramp & Lift Room

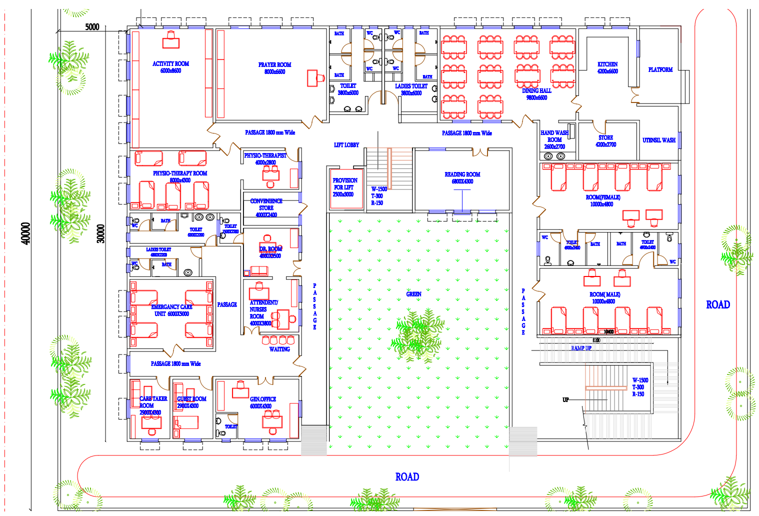
Technology being Used

- Foundation: Isolated RCC column footing with Plinth beam
- Walling: Light Gauge Steel Framework System (LGSFS) with Precast concerte panel on both side of walls and light weight concrete as infill.
- Floor/Roofing Slabs: Light Gauge Steel roof truss with MS deck sheeting resting on web joist & screed concrete with false ceiling of gypsum board.

Joinery & Finishing

Door frame/shutters

- Pressed steel door frame with flush shutter
- PVC door frame with PVC Shut-



Layout Plan of Demonstration Housing Project at Chimbel, Goa ters

Window Fame/ Shutter:

- uPVC frame with glazed panel and wire mesh shutters

Flooring

- Vitrified tile flooring in Rooms & Kitchen
- Anti-skid ceramic in bath & WC
- Kota Stone Flooring in Common area and Staircase

Finishing

- Weather Proof Acrylic Emulsion paint on external walls
- Oil Bound distemper over POP on internal walls

Infrastructure Components

- CC Roads & Paver tiles in pavements,
- Boundary wall with gate
- Under water tank
- Rain water Harvesting,
- Solar Street Lights,
- Landscaped Court
- Firefighting work
- Barrier Free Building.

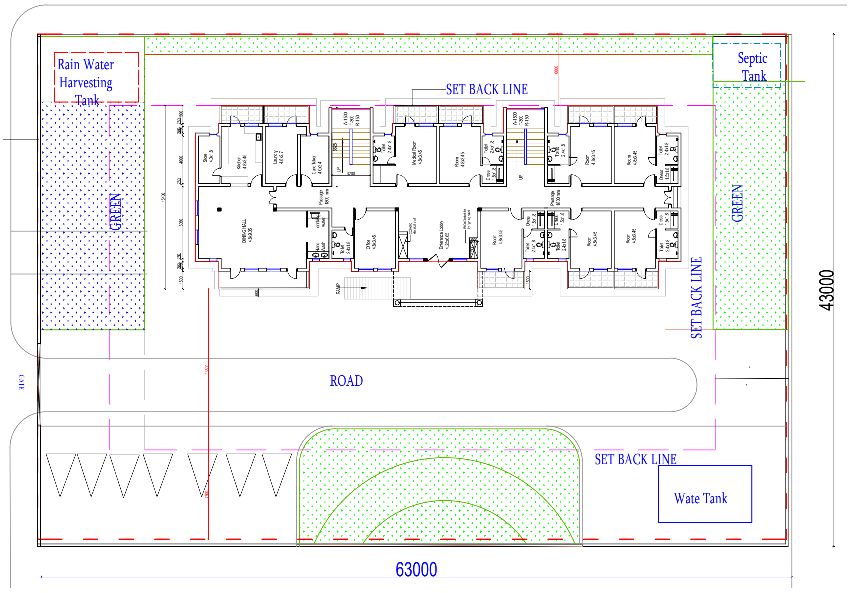
Demonstration Housing Project at Bhopal, MP

Technology: Insulated Concrete Forms (ICF)

Directorate of Urban Administration and Development, MP has allotted in the premises of NIGUM campus at Bhouri Distt. Bhopal for DHP. The proposed DHP consists of 40 units in G+3 configuration.

Salient Features of the Project

- Plot Area for DHP: 2709.0 Sq.mts.
- Total Covered Area: 2180.0 Sq.mts.
- No. of Units/Rooms: 40 (G+3)
- Carpet Area of a unit: 29.05 sqmts
- Each unit consist of a room with attached toilet , dress and a balcony.



Layout Plan of Demonstration Housing Project at Bhopal, MP

- Other provisions includes Dining Hall with Kitchen and store, Common Room with toilet, General office, Medical Room with toilet ,Care Taker Room, Activity Rooms and Laundry

Technology being used:

Foundation

- Isolated RCC column/strip footing with Plinth beam

Walling

- The Insulating Concrete Forms (ICF) Concrete filled Expandable Polystyrene (EPS) blocks.

Floor Slabs/Roofing

- RCC slab/Roof as per specifications

Joinery & Finishing

Door frame/shutters:

- Pressed steel door frame with flush shutters
- PVC door frame with PVC Shutters in toilets

Window Fame/ Shutter:

- 3-track uPVC frame with glazed panel and wire mesh shutters.

Flooring:

- Vitrified tile flooring in Rooms & Kitchen
- Anti-skid ceramic tiles in bath & WC
- Kota Stone Flooring in Common area and Staircase

Finishing:

- Weather Proof Acrylic Emulsion paint on external walls
- Oil Bound distemper over POP on internal walls

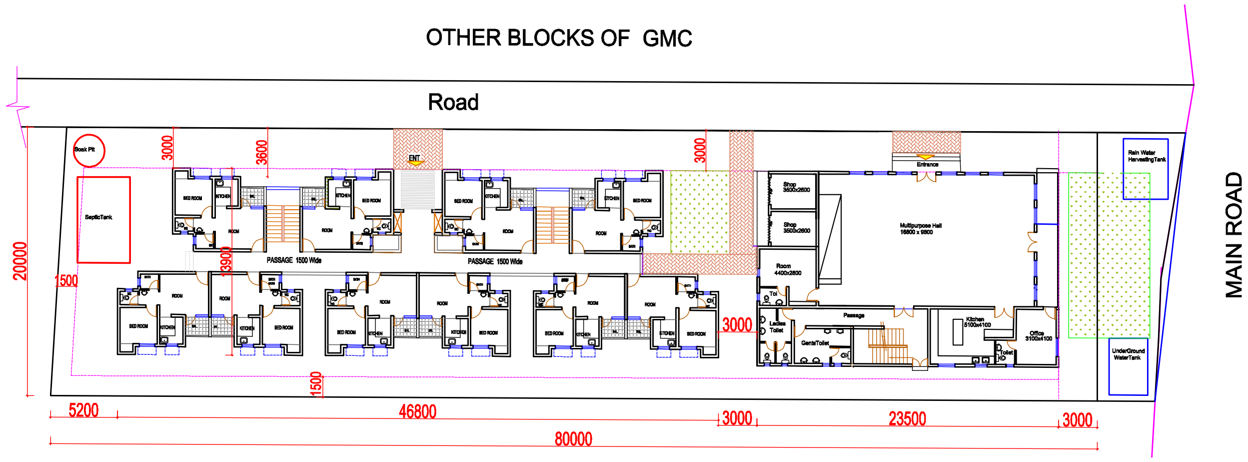
Infrastructure Components

- CC Roads & Paver tiles in pavements,
- Boundary Wall with gate,
- External water supply & Underground water tank,
- Sewerage,&Septic Tank,
- Drainage, &Rain water Harvesting Tank,
- External Electrification,
- Solar street lights, Transformer
- Fire-fighting provisions
- Landscaped Court.Barrier
- Free Building

Demonstration Housing Project at Guwahati , Assam

Technology: Light Gauge Steel Frame Structure with V-infill concrete wall

Guwahati Municipal Corporation, Guwahati, Assam has allotted 1600 sqmts of land for development of DHP. The proposed DHP



Layout Plan of Demonstration Housing Project at Guwahati, Assam

consists of 40 units in G+3 configuration and a community center.

Salient Features of the Project

- Plot Area for DHP:1600 Sq.mts
- Total Covered Area: 2215.9 Sq.mts
- No. of Units/Rooms: 40 (G+3)
- Carpet Area of a unit: 31.03 Sq.mts
- Each unit consist of a living room, a bed room, a kitchen, a bath room, a W.C., a lobby and a balcony.
- Community Centre consist of Single storey Multipurpose Hall with Kitchen, office, green room, shops and toilet.

Technology being used:

Foundation

- Isolated RCC column footing with Plinth beam

Walling

- Light Gauge Steel Framework System (LGSFS) with V-infill walls of 8/10mm fibre cement boards (V board) on either side of GI studs and filled with light weight concrete.

Floor Slabs/Roofing

- Light Gauge Steel roof truss with MS deck sheeting resting on web joist with false ceiling of gypsum board.

Joinery & Finishing

Door frame/shutters:

- Pressed steel door frame with flush shutters
- PVC door frame with PVC Shutters in toilets

Window Fame/ Shutter:

- 33-track uPVC frame with glazed panel and wire mesh shutters.

Flooring:

- Vitrified tile flooring in Rooms & Kitchen
- Anti-skid ceramic tiles in bath & WC
- Kota Stone Flooring in Common area and Staircase

Finishing:

- Weather Proof Acrylic Emulsion paint on external walls
- Oil Bound distemper over POP on internal walls

Infrastructure Components

- CC Roads & Paver tiles in pavements,
- Boundary Wall with gate,
- Borewell, External water supply & Underground water tank,
- Sewerage,&Septic Tank,
- Drainage, &Rain water Harvesting Tank,
- External Electrification,
- Solar street lights,
- Fire-fighting provisions
- Landscaped Court
- Barrier Free Building

Demonstration Housing Project at Tiruppur, Tamil Nadu

Technology: Precast Construction System

Tamil Nadu Slum Clearance Board has identified a land measuring 1113 sqmts at Tiruppur, Distt. Tiruppur Tamil Nadu to construct DHP to be used as Working Women Hostel & Widow Home (Rental Basis).

Salient Features of the Project

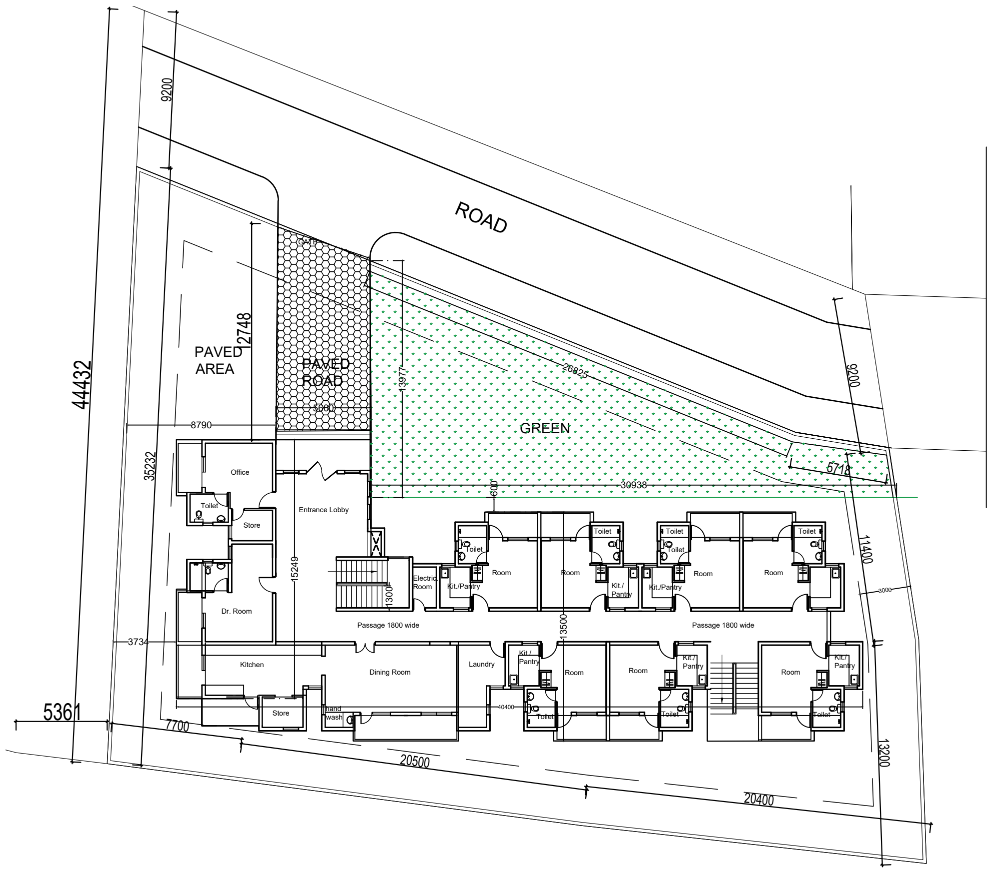
- Plot Area for DHP: 1113.0 Sq mt.
- Total Covered Area: 2044.0 Sq mts.
- No. of Units/Rooms: 40 (G+3)
- Carpet Area of a unit: 26.66 sq mts
- Each unit consist of a room with attached toilet and kitchen
- Other provisions includes a Dining Hall with Kitchen and store, Common Room with toilet, General office, Medical Room with toilet ,Care Taker Room Activity Rooms and Laundry

Technology being used:

Foundation

- Strip footing/Isolated Footing for shear walls and columns respectively

Walling



Layout Plan of Demonstration Housing Project at Tiruppur, Tamil Nadu

- Precast Construction System using Precast beams and columns and precast wall panels of M40 grade of concrete casted at plant and assembled at site

Floor Slabs/Roofing

- Precast Solid Slabs of 100 mm thickness of M40 grade with 60 mm thickness M40 grade structural topping

Joinery & Finishing

Door frame/shutters:

- Pressed steel door frame with flush shutters
- PVC door frame with PVC Shutters in toilets

Window Fame/ Shutter:

- 3-track uPVC frame with glazed panel and wire mesh shutters

Flooring:

- Vitrified tile flooring in Rooms & Kitchen
- Anti-skid ceramic tiles in bath & WC
- Kota Stone Flooring in Common area and Staircase

Finishing:

- Weather Proof Acrylic Emulsion paint on external walls
- Oil Bound distemper over POP on internal walls

Infrastructure Components

- CC Roads & Paver tiles in pavements,
- Boundary Wall with gate,
- External water supply & Underground water tank,
- Sewerage &Septic Tank,
- Drainage & Rain water Harvesting Tank,
- External Electrification,
- Solar street lights,
- Fire-fighting provisions
- Landscaped Court
- Barrier Free Building

Demonstration Housing Project at Ayodhya, Uttar Pradesh

Technology: Light Gauge Steel Frame structure with cement fiber board and mineral wool as in-fill

The Mission Director, Housing for All/SLNA-SUDA (UP) associated with Mahila Kalyan Vibhag/Siksha Vibhag, Ayodhya for construction of DHP and identified land at, Malikpur, Pargana Avadh,Tehsil Sadar, Janpad Ayodhya, Uttar Pradesh to construct DHP to be used as home for Destitute Widows and orphans.

Salient Features of the Project

- Plot Area for DHP: 3600 sq.mts out of 5 acre
- Total Covered Area: 2690 Sq mts
- No. of Units/Rooms: 40 (G+2)
- Carpet Area of a unit: 29.34

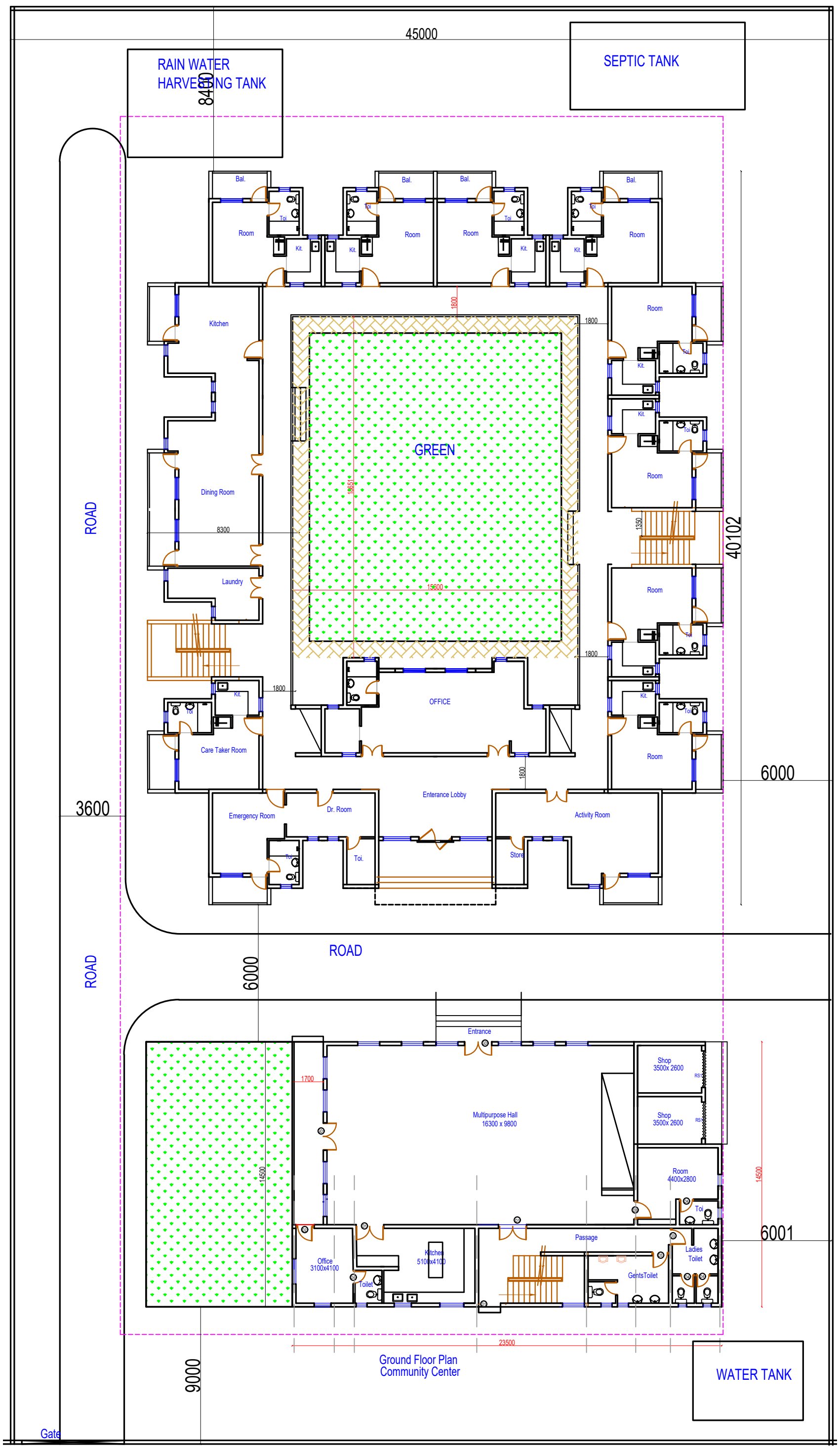
sqmts

- Each unit consist of a room with attached toilet and kitchen
- Other provisions includes Dining Hall with Kitchen and store, Common Room with toilet, General office ,Medical Room with toilet ,Care Taker Room, Activity Rooms and Laundry
- Community Centre consist of Single storey Multipurpose Hall with Kitchen, office, green room, shops and toilet.

Technology being used:

Foundation

- Isolated RCC column footing with Plinth beam



Layout Plan of Demonstration Housing Project at Ayodhya, Uttar Pradesh

Walling

- Light Gauge Steel Framework System (LGSFS) with Cement Fiber board on both side of walls and mineral wool as infill.

Floor Slabs/Roofing

- Light Gauge Steel roof truss with MS deck sheeting resting on web joist with false ceiling of gypsum board

Joinery & Finishing

Door frame/shutters:

- Pressed steel door frame with flush shutters
- PVC door frame with PVC Shutters in toilets

Window Fame/ Shutter:

- 3-track uPVC frame with glazed panel and wire mesh shutters

Flooring:

- Vitrified tile flooring in Rooms & Kitchen
- Anti-skid ceramic tiles in bath & WC
- Kota Stone Flooring in Common area and Staircase

Finishing:

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Infrastructure Components

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- External Electrification,
- Solar street lights,
- Fire-fighting provisions
- Landscaped Court
- Barrier Free Building

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Head Bars for Improved Performance of RC Beam-Column Joint



Ajay Chourasia[1] *Shubham Singha*[2] *Jalaj Parashar*[3]

Abstract

In reinforced concrete (RC) frames, conventional anchorage system of development length, standard 90º or 180º bend hooked bar anchor terminating at the joint, protruding into the face of the column have many drawbacks such as reinforcement congestion, improper concreting and compaction, honey-combing etc. which consequently results in joint strength deterioration and joint damage during the earthquakes. Moreover, development length requires high amount of steel, which leads to depletion of natural resources; along with increased cost. This evolved need for development of alternate anchorage systems such as headed bars, which have the potential to eliminate the shortcomings of conventional anchorage without any compromise on economy. Headed bar is formed by attaching a steel anchor at the end of beam reinforcement bar through welding or threading. This paper presents the application of headed bars as mechanical anchorage system in RC beam-column joints, which bestows a cost-effective and construction efficient alternative to conventional anchorage system of development length. Geometrical recommendations for headed bars are made for their application in RC beam-column joints, through pull-out tests. The paper further demonstrates cost-effectiveness of headed bars through rigorous cost analysis and comparison with costing of conventional anchorage system of development length for different rebar diameters.

Keywords: Headed bars, RC beam-column joint, development length, mechanical anchorage, pull-out tests.

1. Introduction

The reinforced concrete (RC) beam-column joint is a critical region in RC frame structures, which experience stresses during the seismic loading. The peak stresses so developed beyond the critical section at the either end of the member requires a minimum embedment length of reinforcement to develop its yield stress. This minimum embedment length of reinforcement is achieved by providing development length, which is extension of beam longitudinal rebars into the column and usually bent at 90º. Current trend of architectural design in structures which constraints the dimension of member hinders the proper provision of this development length. Longitudinal flexural reinforcing bar protruding into the column owing to inadequate space for development length reinforcing bar causes steel congestion problem, which leads to improper concreting and difficulty in compaction, consequently resulting in honey combing and inadequate structural performance of joint. Further to this, high amount of steel reinforcement in construction leads to cost over-run and depletion of natural resources. The potential solution could be headed bars, which are formed by attaching a steel anchor at the end of beam reinforcement bar through welding or threading. Headed bars are highly advocated by the researchers due to their cost-effectiveness, easy installation, time saving fabrication, minimization of steel congestion in RC beam-column joints and construction efficiency, without affecting the structural performance. Fig. 1

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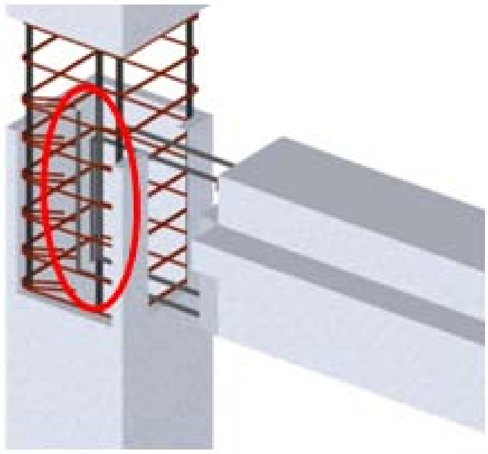
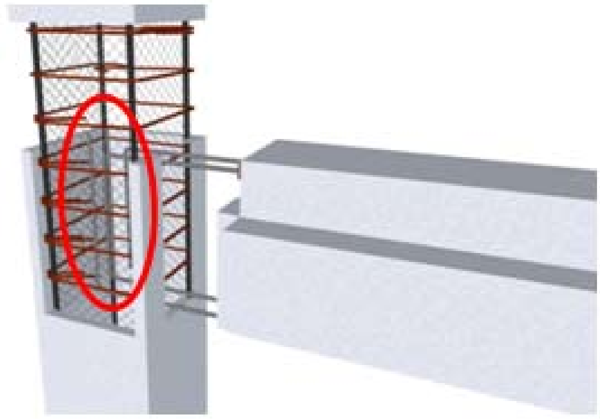


(a) Development Length



(b) Headed Bars

Fig. 1. Beam-column Joints with (a) Development Length; and (b) Headed Bars

shows the conventional anchorage of development length and headed bars in RC beam-column joints.

The headed bar was first introduced in ACI 318-08, using limited test data with strict strength and design data (ACI Committee 318, 2008). The performance of headed bars in pull-out test depends on various variables like loading types, embedment depths, edge distances, plate types, single or multiple number of bars, distances between bars, reinforcement strengths, concrete strengths and existing reinforcement. Investigations have been performed to evaluate the effectiveness of headed bars with regards to rebar diameter, head diameter, head shape, head attaching technique and embedment depth of headed bars into the concrete, location of headed bars, clear spacing and clear cover of headed bars and its comparisons to standard hooked bars (development length). Significant research on bond behaviour of headed bars have been carried out by Berner and Hoff (1994), Choi (2006), DeVries (1997), Hong and Park (2012), Kang et al. (2010), Kang and Mitra (2012), Lee and Yu (2009), Park et al. (2003), Thompson et al. (2005), Wallace et al. (1998), Chun et al. (2017). However, limited research has been performed on length of head and its influence on the anchorage capacity. Some ACI codes are incorporated with the guidelines for provision of headed bar with certain restrictions on various parameters such as embedment depth, grade of concrete, grade of steel, clear spacing etc. However, there still lies ambiguity while deciding on embedment depth and head geometry. This paper provides geometrical recommendations for headed bars for their application in RC beam-column joints, through pull-out tests. The paper further demonstrates cost-effectiveness of headed bars through rigorous cost analysis and comparison with costing of conventional anchorage system of development length for different rebar diameters.

2. Pull-out Tests

To draw geometrical recommendations for headed bars, pull-out tests were performed on headed bars embedded into concrete. The concrete and reinforcement steel of 20 MPa and Fe 415 grade have been used in the study. A total of 45 different types of specimens with three different profile heads (plain, groove and ribbed) and five different lengths of head (11, 19, 27, 35 and 43 mm) were used in the study. Fig. 2 demonstrates different types of headed bars used. The headed bars were embedded into the concrete cube of 300 mm

(a) (b) (c)

Fig. 2. Types of Headed Bars: (a) Plain Headed Bars; (b) Grooved Headed Bars; and (c) Ribbed Headed Bars

at varying embedment depths of 6.25d_b, 8.33d_b and 10.42d_b (d_b is bar diameter). A total of 145 cuboids (45 x 3) specimens were casted for the pull-out test. The free end of headed bar protruded out over a length of 150 mm to ensure proper gripping of bar to conduct the pull out test in Universal Testing Machine (UTM) of 1000 kN capacity as shown in Fig. 3. The specimens were tested monotonically under tension load until the occurrence of failure. pull-out strength obtained from the test is referred as bond capacity or anchorage capacity of the headed bar.

2.1. Behaviour of Headed Bars

Dowel bars exhibited pull-out failure with low bond capacity, while headed bars showed slip of bar and concrete failure along with higher bond capacity. Among five different lengths of head, 27 mm head (head length = head diameter) was influential enough for bond stress resistance. All three headed bars (plain, grooved and ribbed) were found to have similar behaviour on initial stage of loading and at the ultimate loading point, the failure pattern differed for each specimen for each embedment depth. Failure pattern was almost similar for plain and grooved headed bar. Ribbed headed bar was found to give better performance in terms of bond capacity and failure pattern as compared to plain and grooved headed bars. Fig. 4 presents the bond capacity of different types of headed bars tested under pull-out loading.

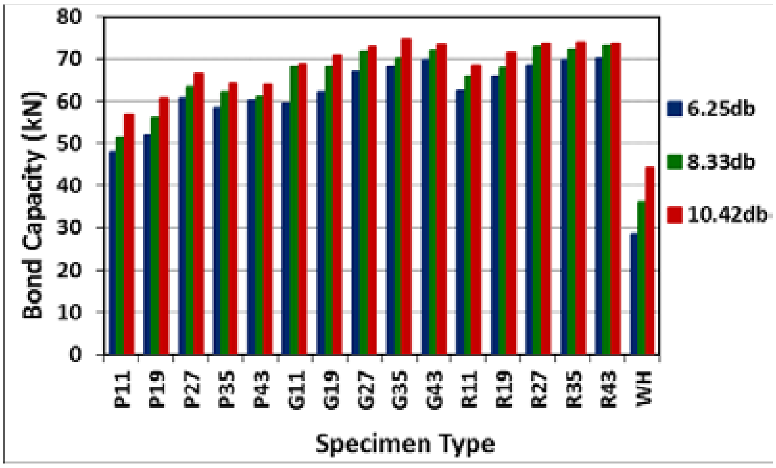


Fig. 4. Bond Capacity of Headed Bars with Varying Embedment Depth
P: Plain, G: Grooved, R: Ribbed, 11,19, 27, 35, 43: Length (mm)

Fig. 3. Experimental Set-up for Pull-out Tests

3. Geometrical Recommendations for Headed Bars in RC Beam-Column Joints

Based on pull-out tests and results obtained thereof, following recommendations are made for application of headed bars in RC beam-column joints.

Table 1. Recommended Specifications for Headed Bars

Parameter	Recommendation
Yield strength of headed bar	500 MPa
Head area	>5 x rebar dia
Bearing ratio	4
Minimum diameter of rebar	12 mm
Head diameter	≥ 2.25 x rebar dia
Ratio of head dia and length	1
Head profile	Ribbed

4. Cost Analysis

Cost of implementing headed bars in beam-column joints was estimated and compared to the cost of conventional development length for different rebar diameters. Cost of anchor is considered as per manufacturer's rate. Rate of steel work is considered as ₹60/kg, including labor charges as prevalent in construction. Rebar embedment depth into the joint is considered as 300 mm in case of headed bars, while embedment depth for development length is determined as per IS 456- 2000 and IS 13920- 2016. Table 2 illustrates the cost analysis and comparison of headed bars and development length for different rebar diameters. Cost analysis indicated that the headed bars are economic substitute to development length, with percentage saving increasing with the increasing rebar diameter (Fig. 5).

5. Conclusion

Headed bars were found to be effective enough as compared to dowel bars in terms of bond capacity and failure mode. With regards to head profile, it can be generalized that ribbed headed

Table 2. Cost Analysis of Headed Bars

Rebar Dia (mm)	Anchor Dia (mm)	Anchor Length (mm)	Anchor Cost* (₹)	Total Costing of Anchor# (₹)	Costing of Development Length% (₹)
12	24	27	20.50	36.50	38.40
16	32	36	32.50	64.36	91.02
20	40	45	53.00	104.11	177.78
25	50	56	90.50	172.91	347.22
32	64	72	174.50	315.58	728.18

**Cost as per manufacturer*
#Anchor cost + rebar cost, considering rate of ₹60/kg including labour charges. (Rebar length embedded in beam considered as 300 mm)
%Development length as per IS-13920:2016, considering rate of ₹60/kg including labour charges

bars are more effective as they experienced slip of bar without any sign of damage in concrete, while plain headed bars with lower head length and shallow embedment depth lead to concrete failure. It can conveniently be summarized that the headed bars can serve as a better substitute to prevalent dowel bars as efficient mechanical anchorage system for RC beam-column joints. Table 2 presents generalized recommendations for optimum dimensional specifications of headed bars, which shall be of significant value to the engineers and structural designers involved in construction industry.

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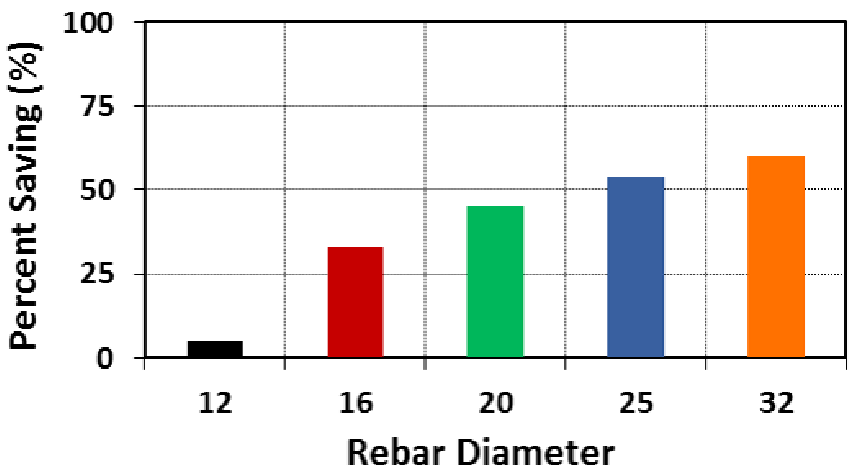

Fig. 5. Percent Saving in Headed Bars with Respect to Rebar Diameter

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Innovative Approach in Modular Housing Structural Engineering Design – Using Precast Technology

Shabbir Lokhandwala[1]

SLABS Engineering is Creative structural Engineering firm by a group of IITian's and broadly in to Structural engineering and design of Precast high rise buildings.

Project Brief: "Meriyeden: Yenepoya University Family Accomodation

SLABS designed the tallest Building in Mangalore using Precast Technology. We optimised the repeatability of elements so as to extract the best use of precast Technology.

G+8 Storied "Meriyeden" Tower is 33m Tall comprising of Shear Walls and HCS as structural framing system used to transfer gravity and lateral loads to the founding system.

Project Scale i.e. built up area is of 1 lakh sq.ft.

No Plastering required for this project as we had high quality factory finished Panels which were

Foundation comprised of laterite soil with N value less than 10. For this we have done rigorous sub soil structure integration study to eliminate pile foundation. We have used raft foundation for this project leading to enormous amount of cost saving.

Figure 1 Laterite Soil

Structural Framing

Cross Walls / Shear Walls and HCS were used as primary structural framing system for typical floors built using precast technology.

We have Transfer Girder Situation at First Floor level as open spaces for parking were required at Ground Floor Level. Construction till 1st Floor Level is cast in Situ and above floors is constructed using precast technology.

Precast Element Summary

Following is the brief of variety of Structural precast elements used in the project.

Graphic Concrete Panels are used to achieve exposed concrete aesthetics revealing architects visualizations.

Table 1: Element Summary of the Project

Element	No. of Pieces
Walls	1675
Parapet	119
Landing + Midlandings	24
Stair Flight	32
Hollow Core Slabs	1341
Bathroom Pods	208
Beams	88
Sunshade i.e. Chajja	204

Further as tabulated Light weight Bathroom PODS were one of a kind to be used in India for a project of this scale and type.

Structural Engineering Analysis

ETABS and SAFE was used to realize seismic behaviour of the Structure and its foundation. Building 3D Model were built to realize extensively tonnage, erection and for preparation of shop drawings.

Time Period of Construction

Entire Building was constructed along with substructure in a time breaking record of 5 months and handed over the clients.

All activities were carried out parallely such as installation of

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external windows, Internal Finishes, MEP etc. to reduce down the time and utilize precast technology to its optimum level.

Time Lapse Video on you tube channel of SLABS Engineering Private Limited could be found to view the construction of the "Meriyeden".

Crainage, Erection and Logistics

8Tons was the restriction to the maximum weight of the panel; which was considered in design. Accordingly Tower Crane was selected for the project. Using Single Tower Crane Entire Project was erected.

Project Site at Mangalore from the factory was about 450kms but due to road block at intermediate level of the project; distance to be travelled for transporting the panels was about 750kms. To meet this challenge few of the pallets were brought to site for casting of panels to increase Erection Speed.

MEP Integration

Electrical Conduits and Junction boxes were added in Wall Panels during Production.

Routing of Conduit in Plan was done from structural screed before pouring the concrete above the HCS.

Plumbing Grooves for Kitchen

Figure 2 Conduits congestion at DB Box Junction

Figure 3 Erection in Progress

Figure 4 Routing of Conduits in Plan within Screed

Figure 5 Typical Flat Unit : Erection In Progress

Figure 6 3D Erection View

Sink Area were provided in the Wall Panels during Production.

As Bathroom PODS were used; outlet of electrical supply and plumbing from POD were coordinated with main building surrounding wall panels to provide connectivity to the POD.

Concrete and Steel Consumption

Total Concrete along with UG Sump and Main Building; used is 5745 cu.m and Steel Consumption for the project is 478 Mt.

Project Achievements

Shortest time frame within which the entire project of 1 lakh sq.ft was completed and handed over to the client; i.e. within 5 months.

Detailed Structural Engineering design including issue of Shop Drawings of 500+ No.s within the shortest duration was achieved to support the contractor.

Use of Variety of Precast Pieces such as the following:

- Graphic Concrete Panels
- Precast Chajja / Sunshade
- Bathroom PODS
- Solid Walls
- Beams
- HCS
- Stair Flight
- Landing/Midlandings
- Solid Slabs

Soil-Structure interaction was widely used for analysis to avoid Pile foundation which led to huge savings in the project.

Innovative Connections were used to reduce cost and time required for erection of panels.

SLABS is playing pioneer role and has vision and mission to take precast technology to innovative scale and heights by its contribution in design and construction using latest technology.

SLABS is rated to be leading Precast Technology consultant in India.

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Figure 7 Meriyeden - Completed Finished Building

Energy-Efficient and Low Global-Warming-Potential Technologies for Accelerating Urban Action for a Carbon-Free India

Dr. Ashok Kumar[1] Dr. Kishor S.Kulkarnil[2]

Cities around the globe account for over 75 per cent of the world's energy consumption and are responsible for over 70 per cent of global greenhouse gas emissions. The way cities are planned, built and managed, is key to reducing carbon emissions and keeping global warming within the limits set by the 2015 Paris Agreement on Climate Change. The Paris Agreement on Climate Change sets the legally binding global aim of limiting global warming to well below 2, and preferably 1.5 degrees Celsius, compared to pre-industrial levels. These countries committed to action and strategies called Nationally Determined Contributions (NDCs). There are large occurrences due to the impacts of climate-related disasters, such as urban heat-island (UHI), floods, droughts, sea - level rise etc. If the space cooling conditioning consumes extreme energy, and continues to use high global warming potential (GWP) refrigerants, it would contribute to drive cities past the 1.5˚C warming as early as 2030 (Report of the TEA, Panel, May 2021).

As urbanization is taking place most rapidly in the less developed regions of the world like India, there is a huge opportunity to shape cities in a way that reduces overall energy consumption and greenhouse gas (GHG) emissions. Ensuring that growing cities are compact, and that expansion takes place in a planned manner to accommodate the growing number of residents helps reduce their carbon footprint. Compact cities do make the provision of basic services such as waste management, transport, energy and water and sanitation more resource-efficient and financially viable.

Therefore, planning and developing more sustainable, climate-resilient communities and cities involves addressing a range of issues like providing sustainable infrastructure including affordable and adequate housing for all and ensuring basic services, reducing urban greenhouse gas (GHG) emissions that are responsible for more than 70 percent CO_2 emissions from transport systems, buildings, energy, and by using the planet resources judiciously. UN-Habitat, therefore, promotes a strategy that combines compact city planning together with good governance and equitable provision of basic services. Avoiding urban sprawl also reduces stress on ecosystems, promoting a balanced coexistence between human settlements and nature, and contributes to the prevention of diseases such as COVID-19.

Reducing electricity consumption in building sector means lowering air pollution emissions in the power sector significantly. However, this needs to be quantified in making a significant contribution towards keeping the global temperature rise below 2˚C. Urban planning can steer urban growth towards low - carbon urban development through advancing climate-friendly urban forms (compact, mixed land-use and connected and accessible cities, low-rise high density developments) geared towards reducing vehicular trips and instead, encouraging the use of non-motorized transport such as walking and cycling.

Public and green areas play a key role as carbon sinks, in regulating temperature and reducing urban heat-island effects. Simultaneously, measures can be taken

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to improve access to basic services while reducing their carbon footprint. These could include better water demand management, waste-water treatment through nature based solutions, better municipal waste management and material recovery, uptake of micro-grids, renewable energy and net-metering, retrofitting buildings to improve their energy efficiency, promoting a transition to shared and public transport and the uptake of electric mobility.

The theme for World Habitat Day – 2021 is: ***'Accelerating urban action for a carbon-free world'*** that will explore how national, regional and local governments and organizations, communities, academic institutions, the private sector and all relevant stakeholders can work together to create sustainable, carbon-neutral, inclusive cities and towns, encourage local governments to develop actionable zero-carbon plans. The climate action, clean energy and sustainable development at the heart of cities' strategies and policies. How we design power generation, transport and buildings in cities – how we design the cities themselves - will be decisive in getting on track to achieve the Paris Agreement and the Sustainable Development Goals. We need a revolution in urban planning and in urban mobility: including better fuel efficiency; zero emission vehicles; and shifts toward walking, cycling, public transport, and shorter commutes.

Studies reported that electricity demand for space cooling in buildings in India will increase by over 700% at current levels by 2040 with additional 800 GW of power generation capacity needed just to meet space cooling needs by 2050 of which about 70% is required for residential sector only. Similarly, heating demand is likely to increase in the cold climates of J&K, Ladakh, H.P. and North- east regions. As the demand for electricity and peak electric load sharply increases in summer & winter because of the extensive use of building space conditioning systems, causing major problems in the electric power supply, alternative technologies are necessary.

Why is it possible for India to get to Carbon- Free?

The United Nations has appealed to 130 countries that have either committed themselves to carbon neutrality by 2050 or the net zero concept. Under the Paris Agreement framework, the countries with high CO_2 emission have committed themselves to a target year when they will reach net zero, meaning when they will achieve zero man – made emissions and ensure removal of such emissions to achieve neutrality. According to the International Energy Agency (IEA), refrigeration and air conditioning (RAC) causes 10% of the global CO_2 emissions. That being said, India has one of the lowest access to cooling across the world, which is reflected in its low per-capita levels of energy consumption for space cooling, at 69 kWh, as compared to the world-average of 272 kWh. India, with the third largest GHG emitters, has several plan higher ambitions, on cutting CO_2 emission. The recent one is the India's Cooling Action Plan (ICAP) and low energy / low-carbon building materials and technologies. These are briefly discussed below.

(i) Development of the India's Cooling Action Plan

The development of the India Cooling Action Plan (ICAP) provides a 20-year perspective (2017-18 to 2037-38) and recommendations, to address the cooling requirements across sectors and ways and means to provide access to sustainable cooling for all and strives to harmonize energy efficiency with the HCFC phase-out and high-GWP HFC phase-down schedules. It also re-emphasizes the principles enshrined in the Country Programme of India for phase-out of Ozone Depleting Substances (ODS), that is, to minimize economic dislocation and obsolescence cost and maximize indigenous production for combined environmental and economic gains.

The ICAP encompasses: *(a) passively-cooled building design that deploys natural and mechanical ventilation; (b) adoption of adaptive thermal comfort standards to specify pre-setting of temperatures of air conditioning equipment for commercial built spaces; (c) promoting the use of energy-efficient refrigerant based appliances as*

The R&D studies conducted and validated through full - scale test beds at CSIR-CBRI by the authors indicate that significant reduction of about 35% of the thermal and energy loads is possible by adopting passive strategies. Similarly, if we integrate daylighting with artificial lighting, a further saving of lighting loads is possible for which an Android App has been developed.

well as not-in-kind technologies; (d) policy interventions for market transformation, including public procurement of energy-efficient refrigeration and air conditioning (RAC) appliances and equipment; (e) development of energy efficient and renewable energy base cold chain for perishable foods, national skill development programme for training and certification for RAC service technicians to complement transition to energy efficient, low-GWP refrigerants, and (f) focused R&D efforts to foster an innovative ecosystem to support development and deployment of low-GWP refrigerant alternatives.

As the primary goal of ICAP is to provide sustainable cooling and thermal comfort for all while securing environmental and socio-economic benefits for the society; therefore, designers, architects and engineers etc. need to take a holistic and balanced approach by encompassing both passive and active cooling strategies as well as optimization of cooling loads using building physics known principles by are highly essential to reduce the thermal loads vis-à-vis reduction in energy requirements in buildings.

(iii) Low – energy and Low-carbon Materials and Technologies

Several low energy / low carbon building materials have been developed by researchers in Council of Scientific & Industrial Research (CSIR) institutes including CSIR-CBRI, and further research is going on to find ways to reduce GHG emissions by converting waste to value added products using agro-industrial wastes. These alternative materials, if used in buildings, will further reduce the CO_2 emissions. However, these alternatives have to be included in the state schedule of rates (SoRs) as well as CPWD - DSR, while preparing estimates from time-to-time.

(iii) Development of Innovative cool roof with improved thermal and energy performance

Roof tops bring a lot of heat into buildings during summer, especially when there is a high amount of solar radiation. A roof that decreases heat ingress into the buildings by reflecting and emitting the sun's heat back into the sky is said to be a cool roof. Roofs with high-reflectance (solar reflectance) coating, commonly known as cool roofs, can stay cool in the sun, thereby reducing building energy consumption. India being a country with hot tropical climate, in most of its states there exist a year - long cooling requirement, and hence, cool roof promises to be a worthy technology in decreasing the cooling energy consumption. The existing buildings are widely reported to operate inefficiently, and the optimization of buildings' performance is a key issue to reduce global energy demand. Traditionally, buildings are constructed with locally available materials like stone, wood, mud and lime.

At present, some cool roof technologies are available which specify the thermal performance based on simulation studies, however, there are less studies published that quantify their impact on improving building performance. The authors have developed innovative cool roofs that contribute to improving thermal & energy performance and thus, reduce the greenhouse emissions.

(a) Green Roofs

Green rooftops of buildings covered with grass and vegetable gardens are another solution in reducing the UHI and GHG emissions. Green roofs not only provide cooling by shading, but also by transpiration of water through the stomata. However, the evidence for green roofs providing significant air cooling remains limited. The authors have investigated the thermal behavior of an experimental room, built at CSIR-Central Building Research Institute (CBRI) campus, Roorkee, India of prefab brick panel roofing technology with green roof. The study explored the feasibility of green roof with grass carpets that require minimum irrigation, to assess the expected indoor thermal comfort improvements by doing real-time experimental studies.

The materials used in the green roof are: 200 micron HDPE sheet, flex-drain matt of 13 mm height, designed to store small quantity of water, and roots of grass can take this water through capillary action and help in the growth of vegetation, 1.2 mm thick non-woven geo-textile membrane to maintain a uniform settlement of the sub-grade, which improves strength and gives long life to the system, 100 mm thick fertile soil and grass carpets 75 mm thick. The green roof installed with grass carpets/ mats store water in their leaves, leaving them highly draught resistant. The grass carpets grow across the ground rather than upwards, offering good coverage and roof membrane protection. Therefore, they require minimum mainte-

Fig. 1 (a): Roof with vegetable gardens

Fig. 1 (b): Green Roof with grass carpets at CBRI

nance and can survive in composite type of climate in India. But in case of other climates like hot and dry regions, these grass carpets are unlikely to survive long periods without intensive irrigation.

The following steps are considered for the growth and maintenance of grass: *(a) Watering or irrigating the grass daily for about two weeks after laying the grass carpets on roof and then repeat the process in alternate days thereafter for another two weeks; (b) The grass shows the growth after about a month. Fertilizer is also used so that the grass grows uniformly; (c) For regular maintenance, irrigating the grass in alternate days during summer and spring time (about 6 months) is essential and during monsoon and winter period, minimum irrigation is required; (d) The plantation is watered daily for about two weeks after laying the grass carpets on roof and alternate days thereafter. About 100 litre of water is required per day for about a month, for a roof area of 17.0 m^2 (6 litre per m^2 of green roof) and this quantity is reduced to 4 litre thereafter; e. As the plantation also improves the microclimate around the building and reduces the cooling load, use of rotating sprinklers continuously for 1 hour (h) in the morning and one hour in the afternoon (during 1000–1600 h) per day is recommended as per the area of green roof. With this process, about 5 litre of water is required per m^2 of green roof per day.*

The studies carried out show that in warm summers, green roofs are suitable for reducing the energy demand for the space cooling, with annual reduction of the primary energy requirements between 5 - 10 %, without worsening the winter energy performance. The results show that the proposed green roof system is suitable for reducing the energy demand for space cooling during hot summer, without worsening the winter energy performance. The proposed green roofs can also be used efficiently in retrofitting existing buildings in India to improve the micro-climate on building roofs and insulation, where the additional load carrying capacity of buildings is about 100–130 kg/m^2. Therefore, the choice of green roof to improve the micro-climate of existing buildings is an acceptable strategy in line with ICAP.

(b) Cool Roofs

The use of impermeable surfaces as cool roofs material within the urban areas promote, more so the trapping of the generated heat creating Urban Heat Island (UHI) phenomenon within an ambient temperature greater than the surrounding sites, the situation demands more energy to achieve indoor human comfort. The authors have developed Innovative cool roof using earthen pots and filled with expanded lightweight concrete. The real time performance has been investigated on full scale building model, built at CSIR-Central Building Research Institute (CBRI) campus, Roorkee. The temperature difference of 10°C is observed between outer to inner surface temperature. The results show that, then building energy consumption can be reduced 22%, 33%, 44%, 49% and 34% for warm and Humid, Hot and Dry, Temperate, Cold and Composite climatic conditions of India respectively. The developed cool roofing systems offers energy efficient performance, facility protection, occupant comfort.

(c) Zero Net Energy Building (ZNEB)

Considering the multi-disciplinary aspects of NZEBs, passive strategies like daylighting, natural ventilation, thermal mass, shading integrating renewable technologies and the life cycle energy of all the systems constitutes a greater challenge. Solar air conditioning is an important use of solar energy because the supply of solar energy and the demand for cooling are greatest during the same season. Though solar energy and demand match during the seasonal variation, the daily load and generation does not match since, cooling demand tends to peak when the sun has gone down and solar electricity production diminishes. This warrants the necessity of a solar-PV energy storage system such as battery module. Also existing technology has high startup current and so requires large PV system unit to meet the startup current of Solar AC.

The R&D studies conducted and validated through full scale test beds by the authors are further taken to next Technology Readiness Level (TRL) and being demonstrated in Demo Ultra Low Energy Building that significantly reduces about 40% of the thermal loads using the correct combination between building physics and passive design principles and the balance is achieved using solar thermal system that enables generating hot water for domestic hot water use. The geothermal and solar resources to decarbonize the HVAC solution is being showcased as one of the cleanest space - conditioning system at CSIR-CBRI.

Hence, by adopting several techniques and strategies in the buildings, India can be carbon free.

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Light House Projects under GHTC-India - showcasing innovative construction technologies

Hon'ble Prime Minister's envisioned to bring technology transition in the housing sector so as to enable faster, sustainable and affordable construction and to take it forward, MoHUA organised "Global Housing Technology Challenge-India (GHTC-India)" and shortlisted basket of 54 technologies suiting different geo-climatic conditions of the country. These technologies are categorised into six broad categories and being showcased through actual ground implementation of six lighthouse projects (LHPs) located in six different States/UTs of PMAY(U) regions across the country.

An LHP means a model housing project built with alternate technology suitable to the geo-climatic and hazard conditions of the region. This will demonstrate and deliver ready to live-in houses with speed, economy and with better quality of construction in a sustainable manner.

Hon'ble Prime Minister Shri Narendra Modi laid the foundation stone of Light House Projects (LHPs) on January 1, 2021, in six cities i.e. Indore (Madhya Pradesh), Rajkot (Gujarat), Chennai (Tamil Nadu), Ranchi (Jharkhand), Agartala (Tripura) and Lucknow (Uttar Pradesh) via video conferencing. The Hon'ble Governors, Hon'ble Chief Ministers of six states along with State Ministers joined the event from the LHP sites through video conference.

Hon'ble Prime Minister during the event emphasised that these projects will be incubation centres and the technical professionals, planners, architects, engineers, students and faculty of Engineering Colleges/Technical Universities should visit the site to learn and experiment with new construction technologies and document the whole learning experience.

Accordingly, MoHUA launched an enrolment drive to register various stakeholders as Technograhis and also started e-learning module on Light House Projects. So far more than 17000 have registered and being given training on technologies being used in Light House Projects. Also, field visits to LHP sites are being organised to impart hands-on training on regular basis.

LHPs Locations, Technologies to be used and No. of houses

Location	Technology	No. of Houses
Indore	Prefabricated Sandwich Panel System	1,024
Rajkot	Monolithic Concrete Construction System	1,144
Chennai	Precast Concrete Construction System-Precast Components Assembled at Site	1,152
Ranchi	Precast Concrete Construction System-3D Pre-Cast Volumetric	1,008
Agartala	Light Gauge Steel Structural System & Pre-Engineered Steel Structural System	1,000
Lucknow	Stay in-place Formwork System	1,040


LHP at Chennai, Tamil Nadu

LHP at Chennai, Tamil Nadu

No. of Dwelling Units: 1152 Nos. (G+5)
No. of Block / Tower: 12 Blocks
Units in each Block / Tower: 96 Nos.
Technology Name: Precast Concrete Construction System-Precast Components

LHP at Indore, Madhya Pradesh

No. of Dwelling Units: 1024 Nos. (S+8)
No. of Block / Tower: 8 Blocks
Units in each Block / Tower: 128 Nos.
Technology Name: Prefabricated Sandwich Panel System with Pre-engineered Steel Structural System

LHP at Agartala, Tripura

No. of Dwelling Units: 1000 Nos. (G+6)
No. of Block / Tower : 7 Blocks
Units in each Block / Tower : A(112), B(154), C(118), D(168), E(168), F(168) & G(112)
Technology Name: Light Gauge Steel Structural System & Pre-Engineered Steel Structural System

LHP at Rajkot, Gujarat

No. of Dwelling Units: 1144 Nos. (S+13)
No. of Block / Tower: 11 Blocks
Units in each Block/ Tower: 104 Nos.
Technology Name: Monolithic Concrete Construction using Tunnel Formwork

LHP at Lucknow, Uttar Pradesh

No. of Dwelling Units: 1040 Nos. (S+13)
No. of Block/ Tower: 4 Blocks
Units in each Block/ Tower: A(494), B(130), C(208) & D(208)
Technology Name: PVC Stay in Place Formwork System with Pre-engineered Steel Structural System

LHP at Ranchi, Jharkhand

No. of Dwelling Units: 1008 Nos. (G+8)
No. of Block / Tower: 7 Blocks
Units in each Block / Tower: 144 Nos.
Technology Name: Precast Concrete Construction – 3D Volumetric Construction

Performance Appraisal Certification Scheme (PACS)

Performance Appraisal Certification Scheme (PACS), being operated by BMTPC (vide Gazette Notification No. I-16011/5/99 H-II in the Gazette of India No. 49 dated December 4, 1999), is a third party voluntary scheme for providing Performance Appraisal Certificate (PAC) to manufacturers or installers of a product which includes building materials, products, components, elements and systems etc. after due process of assessment giving independent opinion about fitness of its intended use in building construction sector.

Since the Scheme is operated for the products/systems where no relevant Indian Standards are available, it is required to first work out the desired specifications for Performance Appraisal. For the items where no Indian codes are available, international practices are also being referred. In few cases the specifications recommended by the manufacturers have to be modified based on global practices to improve the quality and performance.

Various states, their Housing Boards and other departments are also promoting and using emerging technologies and materials for construction of mass housing in their states. As such PACS has become an important tool for introduction of emerging technologies in mass housing.

PACs Approved and Issued Till Date

Within the framework of Power and Functions of Technical Assessment Committee (TAC), Applications for appraisal of new building materials and construction technologies were received by BMTPC. Performance Criteria, based on National & International practices were framed in consultation with other members.

So far 17 meetings of TAC have been held and 73 PACs have been issued till now.

The details of activities carried out recently under Performance Appraisal Certification Scheme (PACS) are highlighted below:

Approval of PACs

PAC for the following four systems/products have been approved in the TAC's 17th meeting held on 16th January, 2021.

1. KON_CRETE Reinforced Autoclaved Aerated Concrete (AAC) Panels
2. Factory assembled Insulated Sandwich Panels using Polyurethane Foam (PUF)
3. Factory Assembled Insulated Sandwich Panels using Mineral Wool
4. Dalmia Magic Premium Skim Coat

The brief about these technologies are given hereunder:

1. KON_CRETE Reinforced Autoclaved Aerated Concrete (AAC) Panels

KON_CRETE Reinforced AAC wall & floor/roof panels are innovative Autoclaved Aerated Concrete (AAC) products, having properties such as light, high thermal efficiency, acoustics performance, energy efficiency & light weight.

These are steam cured cementitious materials manufactured from a mix of flyash, cement and other additives giving the material a unique cellular lightweight internal structure. The manufacturing process involves mixing of Fly ash slurry stored in slurry tanks, the binders (lime, cement and anhydrite) stored in silos & aluminum powder which is dispersed in the water. All the components are ac-

KON_CRETE Reinforced Autoclaved Aerated Concrete (AAC) Panels curately weighed and released into the mixer in a pre-defined order. Recipe and temperature control system constantly monitors this process. The mix is then poured into the moulds & immediately after this, the reinforcement frame assembly is inserted, as per the design requirement. The product/ cake pre-cures for 2-3 hours after which it is cut by high-precision cutting machines as per required dimensions.

The reinforced AAC panels can be used for all kinds of modern-day construction with applications as external, internal, partition walls & floor / roof etc. Along with suitability for versatile needs of the building process, AAC Panels also possess advantages over conventional building materials for an array of application areas; Multistoried residential construction, Small modular residential construction, Commercial construction, Industrial warehouse,Sheds etc.

2. Factory assembled Insulated Sandwich Panels using Polyurethane Foam (PUF)

The panels are factory assembled insulated sandwich panels consisting of an insulating layer 'sandwiched' between two layers of metal sheets. These are manufactured using rigid Polyurethane Foam (PUF) bonded between pre-coated steel sheets to produce profiled finish panels. The steel sheets can either be PPGI or PPGL, with a maximum thickness of 0.8 mm. An insulation core provides insulation and sturdy bonding for better structural stability and facilitates better load bearing capacity and wider spans for panels.

Factory Assembled Insulated Sandwich Panels using PUF

These panels have high strength-weight ratio and ensure structural stability on the building envelope. The panels are used both as walling & roofing components for various applications such as residential and commercial buildings, school & training centers, steel structures, management blocks, site offices, etc. These panels come with brand names as Monowall panel, Glamet panel & Super wall panel.

Structures built using these panels can incorporate MEP (mechanical, electrical and plumbing) services along with architectural elements/features such as coving, cantilevers, mezzanine floors etc. The design and engineering of structures are done following guidelines specified in Indian Standards.

Panels are available in thickness from 30 mm to 120 mm, with standard width of 1000 mm and length as per customer requirement. The fixing mechanism of panels ensure precise interlocking, dimensional accuracy and also eliminates the risk of air gaps and thermal bridging. All joints are covered with butyl tape, sealants and flashings. It come with various facing options such as Pre-painted galvanized steel/aluminum, stainless steel and craft paper and perforated metal sheet for inner skin.

3. Factory Assembled Insulated Sandwich Panels using Mineral Wool

The panels are factory assembled insulated sandwich panels consisting of an insulating layer 'sandwiched' between two layers of metal sheets. These are manufactured using mineral wool bonded between pre-coated steel sheets to produce profiled finish panels. The steel sheets can either be PPGI or PPGL, and, with a maximum thickness of 0.8 mm. An insulation core provides insulation and sturdy bonding for better structural stability and facilitates better load bearing capacity and wider spans for panels.

The system can incorporate all types of architectural features like coving, boxes, cantilevers, projections, infill walls, mezzanine floors etc. This system can also incorporate all types of services viz. electrical, gas and plumbing etc. The design and engineering of the structures is executed by following the norms & guidelines stipulated in relevant Indian Standards.

These panels have high strength-weight ratio and ensure structural stability on the building envelope. The panels are used as both walling & roofing components for various applications such as residential and commercial buildings, school & training centers, steel structures,

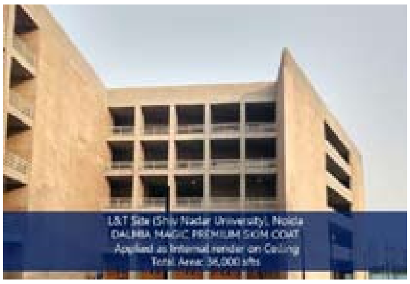
Factory Assembled Insulated Sandwich Panels using Mineral Wool management blocks & site offices, porta cabins, etc. These panels come with brand names as Hipertec Wall & Hpertec roof.

Panels are available in thickness from 50 mm to 120 mm, with standard width of 1000 mm and length as per customer requirement. The fixing mechanism of panels ensure precise interlocking, dimensional accuracy and also eliminates the risk of air gaps and thermal bridging. All joints are covered with butyl tape, sealants and flashings. It come with various facing Options such as Pre-painted galvanized steel/aluminum, stainless steel and craft paper and perforated metal sheet for inner skin.

4. Dalmia Magic Premium Skim Coat

It is a polymer optimized cementitious Skim Coat in required thickness that provides smooth leveling finish and protective coat for internal and external rendering surfaces. It provides the option of "not painting" the externally rendered surfaces, by giving a "natural tone" finish, that is aesthetically pleasing and durable.

This innovative building product with natural tone color and is made of "Active Cement Particles". The various tests conducted indicate that the product formulation is superior to common white wall putty in terms of giving more life to the paint with higher tensile adhesion & higher coverage area.



Dalmia Magic Premium Skim Coat

Features and Characteristics of the Product:

- Paint can be applied with or without primer
- Reduces use of paint on surface to about 10% & provides higher coverage
- Excellent tensile adhesion and compressive strength
- Excellent workability
- Prevents hair crack caused by material shrinkage
- Self-curing due to high water retentive property
- Enhances turnaround cycle time of finishing application
- Water resistant
- Resists growth of algae and fungus
- It satisfies best in class fire resistance category i.e Class A as per ASTM E84.
- Emulates light pink or sandstone colour
- Textured finish can be obtained by the use of texturing tools/ rollers as per the local practice

PACs for Renewal

i) PACs for the following systems/ products have been renewed;
   1. QuikBuild Panels
   2. Precast Construction Technology
   3. Bamboo wood Products
   4. Strand Wood Bamboo Floor Tiles and Wall Panels
   5. Structural Stay In Place formwork System
   6. Bamboowood Flooring & Wall Cladding

ii) Application has been received for Renewal of PACs on Stay in place PVC Wall Form system:

Receipt of Applications for PACs

Applications for the following new products/systems have been received from the manufacturers for processing further for issue of PACs:

1. Conecc Precast Compound Wall
2. uPVC Doors & Windows
3. Rapicon Walls Panel & Prefabricated Steel Structures
4. Solid Panel PVC Doors & Frames
5. Grass Floor Bamboo Flooring Tiles
6. Sandwich Panels, Prefab & PEB Structures
7. Insullite Roof Tile
8. Ferron Panel
9. VASPAR Composite Honeycomb Construction Panels
10. Moducast Precast Concrete Buildings
11. Modular Building /PEB/LGS Building
12. Light Gauge Steel Framed Structures
13. Volumetric (3D) Concrete Printing Technology (VCPT)
14. EcoPro Cement Sheets

The above applications are being processed on the basis of data furnished by the firms, information available on their web sites, inspection of manufacturing plants at site of works and testing of samples of the products/systems etc. before preparation of Performance Appraisal Certificates (PACs).

Inspection of Works

Due to COVID-19 Pandemic, the inspection of works are being conducted through video conferencing.

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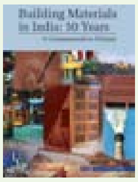
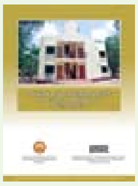
Priced Publications of BMTPC



BUILDING MATERIALS IN INDIA : 50 YEARS - 560 pages, Rs.1500 + 200 postage



MANUAL ON WATERPROOFING OF GFRG BUILDINGS
70 pages, Rs. 200 + 50 postage

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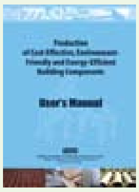

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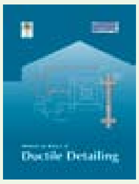

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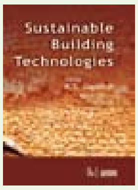

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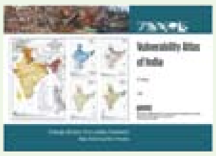

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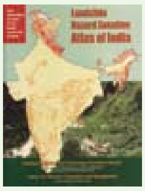

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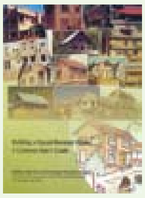

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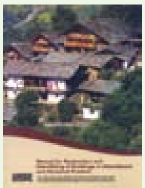

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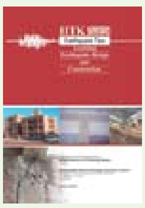

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