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Resilient urban economies.

Cities as drivers of growth and recovery

bmTPC

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"

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From the Desk of Executive Director

The rapid urbanization & meeting the aspirations of the people migrating towards cities poses unprecedented challenges to these urban agglomerates which are unable to cope with the sudden upsurge resulting into disruptions time & again. Whether it is extreme weather events such as high outdoor temperatures, excessive rains, urban flooding, thunderstorms, earthquakes or manmade hazards such as fire, traffic congestion, industrial pollution, poor indoor air quality, chemical explosions etc., the cities are found to be wanting. Therefore, a robust system is needed which prepares the city to be resilient against such extreme events. This year's theme of World Habitat Day ***"Resilient urban economies. Cities as drivers of growth and recovery"*** gels well with the looming threats cities are facing on account of climate change, global rise in temperatures, GHG emissions, diminishing water bodies & natural resources & so on.

This fast-paced urbanization has opened doors for thriving economy and India has initiated several urban renewal schemes to make its cities livable and resilient. The kind of scales India is dealing with are unheard and unprecedented. More than 30 million houses in urban and rural areas are being constructed for poorest of the poor, 100 smart cities being developed, 95 million toilets built across India, 40 km per day is the target achieved for construction of national highways, more than 2322 parks adding 4512 acres of green spaces, 692 storm water drainage projects have been completed covering around 500 cities with population over 100,000. The healthy governance has led India to be one of the largest and fastest growing economies in the world with US $3 trillion GDP. The country is witnessing massive public investment, robust private consumption, and structural reforms leading to rapid growth of more than 7% despite of covid disruptions. Further, India is poised to become $5 trillion economy by 2025-26 & aspiring to become a $26 trillion economy by 2047. Our cities, which will contribute over 80% to GDP by 2050, are slowly transforming to be Receptive, Innovative and Productive to foster sustainable growth and ensure better quality of living.

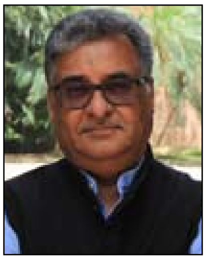
BMTPC since its establishment has been successfully propagating use of sustainable materials & building technologies which are resource-efficient, climate-responsive & disaster-resilient. The GHTC-India conducted by MoHUA, Govt. of India in 2019 to choose & shortlist proven construction systems from the Globe & adapt them suiting to our geo-climatic conditions through ongoing Light House Projects has been a torchbearer for the construction sector as it has triggered technology transition & now more & more building & infrastructure is built with these industrialized building systems leading to resilient & sustainable habitat.

I am indeed privileged to publish this special E-newsletter **'निर्माण सारिका'** of BMTPC dedicated to this year's theme of World Habitat Day. The newsletter is amalgamation of papers & articles related with the theme and of other contributions dealing with innovative materials, planning & policies. For me, it is personal milestone, as I am writing the message for this special newsletter for the 16th time since 2008 as Executive Director of the council. The help and support of Shri Sharad Gupta & Shri Dalip Kumar of BMTPC and the contributors for bringing out this publication is gratefully acknowledged.

Let us develop ***Lifestyle for Environment & be Pro Planet People.***

(Dr. Shailesh Kr. Agrawal)

Catalyzing Urban Climate Action for a Resilient Future



Sanjay Seth [1]   *Rhea Srivastava* [2]

The world is currently experiencing a fast-paced global transformation. With the United Nations estimating 75% of the world's population to live in cities by year 2050, cities have emerged as the epicentres of economic growth, innovation and the drive for sustainable development.

However, despite being crucial players on the global stage, cities are not immune to the significant challenges of our interconnected world encounters. The escalating risks of climate change impacts, environmental degradation and the emergence of unprecedented threats, such as the COVID-19 pandemic, have highlighted the susceptibility of urban centres to various shocks and crises. In the past months, Indian cities witnessed the severe realities of likely climate disasters as the region endured the devastating consequences of record-breaking rainfall, flooding and heatwaves. Furthermore, with over 70 percent of greenhouse gas emissions and 75 percent of global primary energy consumption originating in urban areas, cities hold significant sway over the course of climate change.

Countries like India must strategise and respond appropriately to confront these critical issues, with cities playing a leading role in formulating effective approaches to urgent global challenges. India's G20 presidency has taken commendable steps to empower cities and elevate their role in addressing global development agendas. The G20 - New Delhi Leaders' Declaration' represents a significant milestone, as it promotes a transformative agenda, highlighting the growing recognition of global urban challenges and advocating for measures to mitigate the impact of natural disasters on cities of the future. The 'Declaration' firmly underscores the imperative of fostering inclusive, resilient and sustainable cities, encompassing aspects such as mobilizing finances, advocating for innovative urban planning approaches, implementing climate-resilient infrastructure and strengthening the capacities of urban administrators to bolster their institutional capabilities.

The pursuit of a low-carbon future, a topic of paramount importance discussed in all G20 deliberations, necessitates a fundamental transformation in how local governments approach urban planning, governance, management and financing. Measuring their progress in addressing climate change and identifying areas for improvement become critical steps in this pivotal transition.

Measuring Progress for Visible Impact:

Cities must be aware of their current position with respect to existing policies, measures put in place to reduce greenhouse gas emissions and enhance resilience and the availability of climate data.

This data-driven approach serves as the foundation for setting ambitious targets, tracking progress and making informed policies and decisions. By developing credible frameworks with clear evaluation criteria, cities can establish a common language,

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benchmark their performance against peers, identify strengths and weaknesses in development policies and foster transparency and accountability. This facilitates evidence-based decision-making processes, empowering urban administrators to make impactful changes for a sustainable and resilient future.

Moreover, measuring climate progress can also help cities make more informed budgeting decisions and garnering financial support from external funders. Private financiers prioritize the bankability of projects and require accurate direction for effective investment. Access to standardized, up-to-date climate information, including budgetary allocations, benefits both city officials and private investors. This also acts as a stepping stone in bridging the bankability gap and mobilizing financial resources to support cities' sustainable endeavours.

Many Indian cities, such as Mumbai and Ahmedabad are taking the lead in combating climate change by creating their own climate action plans. These plans go beyond greenhouse gas inventories and include identifying climate vulnerable areas, proposing effective implementation measures and outlining the required financial resources. Additionally, the Climate Smart Cities Assessment Framework (CSCAF) by the Government of India serves as a credible and valuable guide, helping cities diagnose climate action gaps and collate data for a comprehensive understanding of progress and improvement areas. Other innovative tools like the cost-benefit analysis tool for smart surfaces, developed by the Smart Surfaces Coalition (SSC) and The Energy and Resources Institute (TERI) can also be shared among city governments to combat extreme summer heat and facilitate better urban planning. Apart from that, it is also important to maximize synergies between such frameworks in order to harness them in a holistic manner.

However, to translate and implement the learnings from such frameworks, two other key elements come into play: institutional capacity and political will. Efforts to enhance capacity should take a bottom-up approach, focusing on improving the competencies at the institutional, organizational and individual levels necessary to effectively carry out the roles and responsibilities within each designation, function and department. It is essential for urban administrators to possess the requisite skills for tasks like data collection, strategic planning, investment evaluation and administrative coordination. The G20 - New Delhi Leaders' Declaration also acknowledges this and references the G20/ADB Framework on Capacity Building of Urban Administration, designed to assist local governments in evaluating and strengthening their institutional capacity to ensure efficient public service delivery.

Another common challenge that municipalities often face is the compartmentalization of climate change expertise within specific departments, which results in silos and hinders comprehensive, cross-cutting interventions. To overcome this, strong emphasis must be placed on ensuring accountability in administration. Furthermore, limited jurisdiction of city governments, coupled with a preference for other development concerns, such as access to basic infrastructure, can pose additional obstacles. Striking a balance between these priorities and integrating climate action into overall development planning are crucial for a sustainable future.

As we endeavour to translate the outcomes of prominent global forums, like the G20, COP and World Urban Forum (WUF) into tangible actions, the importance of forging the right partnerships and collaborations cannot be overstated. In this pivotal 'decade of action', encouraging more ambitious cooperation between national governments, cities, citizens and other stakeholders is the linchpin to guide us towards a future that is both sustainable and resilient in the face of a changing climate.

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Photo Source: World Wide Web

Resilient Urban Economies: Cities as Catalysts for Growth and Recovery

*Hitesh Vaidya**

The 21st century is the 'Urban Century' unequivocally, witnessing an unprecedented influx of people into urban centres. According to the United Nations, it's estimated that by 2050, nearly 68% of the world's population will reside in urban areas, a significant rise from the current 55%. Urbanisation is becoming a defining characteristic of our modern world. As rural populations migrate to cities, urban spaces are central to global economic development. In this paradigm, cities emerge as hubs of innovation, culture and crucial drivers of economic growth and recovery. The resilience of urban economies is pivotal in shaping the prosperity and sustainability of nations and the world at large. The surge in urbanisation isn't merely a product of population growth; it also reflects the allure of urban areas, offering superior economic prospects, upgraded infrastructure, and an enhanced quality of life.

The resilience of an urban economy hinges on its capacity to adapt, recover, and grow in the face of challenges and shocks. These challenges include economic downturns, natural disasters, public health crises, and technological disruptions. Resilient urban economies can withstand such shocks, absorb their impact, and swiftly return to normalcy. Cities are not mere geographic locations; they are engines of economic growth. Infrastructure is rightly acknowledged as a 'crucial enabler of growth' for elevating India's competitiveness and achieving the target of a $5 trillion economy by 2025.

Cities will be at the core of driving these ambitious targets. However, there's an urgent need to reimagine the urban infrastructure space and devise strategic solutions for the sector's planning, delivery, management, and financing. These solutions should be adaptable and scalable to diverse urban contexts. The availability of adequate, equitable, technologically advanced, high-quality, and sustainable urban infrastructure will be critical for powering such growth. Simultaneously, cities must be empowered with the capacity for planning, execution, and management of such infrastructure to attract talent, investments, and businesses, fostering a dynamic environment for innovation and productivity. Building resilient urban economies requires a strategic approach encompassing a range of essential elements. The "7R" framework highlights these critical aspects:

1. Reimagine Cities as the Trilogy of Economic, Inclusive, and Sustainable Growth:

Cities are the nexus where economic dynamism, inclusive progress, and sustainable development converge, forming a powerful trilogy that propels nations forward. They offer expansive market and trade prospects and provide a platform to harmonise sustainable development goals, ensuring no one is left behind. They serve as hubs for domestic and international trade, attracting businesses seeking access to a large and diverse customer base. The concentration of consumers in urban areas fosters market expansion, facilitating the growth of businesses and the overall economy. The proximity of businesses and industries in urban areas creates

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agglomeration effects, increasing productivity and efficiency. Businesses benefit from shared resources, specialised labour markets, knowledge spillovers, and a competitive environment. This dynamic amplifies economic growth within the city and its surrounding regions. A harmonious balance between these facets is crucial for shaping a future where urban centres are economically thriving, socially inclusive, and environmentally sustainable. As cities evolve, embracing this trilogy becomes imperative for a prosperous and equitable global society.

2. Rethink for Integrated and Strategic Planning:

Urbanization has given rise to novel urban configurations, including city regions, conurbations, and more. In pursuing resilient economies, it becomes imperative to acknowledge these evolving growth patterns and embrace multi-jurisdictional approaches to urban planning. This recognition is particularly critical due to the regional-level demand for shared infrastructures, encompassing vital elements like airports, landfill sites, water supply systems, and regional transit networks. Understanding the intricate interplay between infrastructure and services and their far-reaching economic impacts is equally indispensable. Effective planning necessitates formulating strategies to cultivate a skilled workforce proficient in installation and maintenance services, especially for emerging technologies that contribute to delivering comprehensive end-to-end services to citizens. A holistic planning framework goes beyond conventional approaches, emphasising a harmonious balance among multiple objectives. These include catering to the long-term requirements of a burgeoning population, ensuring seamless alignment with other sectors, and intricately interweaving infrastructural considerations with spatial development strategies. In essence, this holistic perspective on integrated and strategic urban planning is the cornerstone of building resilient and thriving urban economies that can adapt, grow, and prosper in the face of ever-changing challenges and opportunities.

3. Robust Infrastructure as a Foundation:

Robust infrastructure is the foundation of a resilient urban economy. Efficient transportation systems, modern communication networks, reliable energy sources, and advanced healthcare facilities are all critical components. Well-planned infrastructure enhances connectivity, reduces logistical bottlenecks, and attracts businesses, investors, and skilled talent. Urban economies must embrace sustainable practices to ensure long-term viability. Sustainable development encompasses environmental, social, and economic dimensions. This includes investing in renewable energy, efficient transportation, waste management, and creating green spaces. Sustainable urban planning ensures that cities thrive without depleting resources, preserving the environment for future generations.

4. Resilience as an essential element for a Diverse Economy:

Resilience in the context of an economy refers to its ability to withstand and recover from various shocks and stresses, including economic downturns, natural disasters, technological shifts, or global crises like the one witnessed during the COVID-19 pandemic. Embracing diversity in economic activities and sectors is fundamental to building resilience within an economy. It promotes stability, innovation, and inclusivity, ensuring communities can weather challenges and thrive in adversity. Balancing economic, social, and environmental aspects is more achievable in a diverse economy. A resilient and diverse economy positively impacts the overall well-being of the community. It supports social services, infrastructure development, education, and healthcare through tax revenues generated from multiple sectors. This, in turn, leads to a higher quality of life for residents. Cities boasting a variety of industries and sectors are better positioned to weather economic downturns. Industries such as finance, technology, healthcare, tourism, and education flourish in cities, employing millions. Job creation is fundamental to economic growth, enhancing individual and household incomes and stimulating consumer spending and investment. If one sector faces a decline, other sectors can compensate, reducing the overall impact on the local economy. For instance, a city with a mix of manufacturing, technology, healthcare, and tourism is less susceptible to the adverse effects of a downturn in a single industry.

5. Recognize Finance as a Key Ingredient to Convert Intentions to Action:

In fostering economic growth, cities stand as the crucial engines, and at the heart of propelling these intentions into tangible actions lies the indispensable factor of finance. The imperative to finance sustainable infrastructure and environmental investments, facilitating the transition toward green economies, cannot be overstated. Cities grapple with an escalating demand for funding to underpin growth while navigating the necessity to uphold sustainability. This need for financial backing often exceeds their existing capacities, leading to a widening infrastructure gap and hampering their ability to achieve sustainable development goals. Despite being pivotal in the global pursuit of various agendas, cities find themselves mired in the struggle to meet their present operational necessities amidst mounting pressures. To forge resilient economies, it is imperative to empower cities by enhancing their revenue streams, streamlining intergovernmental transfers, and instituting conducive regulatory frameworks for borrowing—a vital facet of municipal reforms. Furthermore, enabling cities to attract private investment and bridge the infrastructure gap requires robust models, tools, frameworks, and legal foundations to borrow, establish, and sustainably manage these assets. Recognising and fortifying finance as a linchpin is pivotal, ensuring that cities can manifest their aspirations into concrete actions, fostering sustainable growth and development.

6. Reinforce Cities as Knowledge and Innovation Hubs:

Cities must nurture research, development, and the adoption of new technologies, fostering innovation. Embracing innovation can drive economic growth and provide a competitive edge on a global scale. Interactions and cross-pollination of ideas between sectors can lead to new innovations and solutions, making the overall economy more resilient and forward-thinking. Appropriate institutional frameworks will bring efficiency in planning, improving financial health, time-bound implementation and maintenance of assets, improved last-mile access and citizen-centric service delivery. Cities act as knowledge and innovation hubs, attracting skilled professionals, researchers, and entrepreneurs. The concentration of talent facilitates collaboration and the exchange of ideas, spurring innovation. Research institutions, universities, and industry clusters often coalesce in urban centres, driving advancements in various sectors and promoting economic growth.

7. Renewed focus on Skilling and Capacities to develop adaptive and agile frameworks:

Overcoming urban challenges necessitates capacity building, including staff shortages, leadership discontinuity, and skill mismatches. Incentivising reforms, ensuring last-mile access to essential services, ensuring adherence to service level benchmarks, enhancing operational efficiencies, encouraging area-based holistic planning, infusing digital technology into infrastructure and services management, improving credit rating and ease of doing business, providing various guidelines and policy frameworks to support decision making requires multidisciplinary teams at the local level. These skill sets are vital for handling diverse tasks, from contract design and management to data analytics and outcome-based planning. Implementing strategies for short-term and long-term capacity creation is essential.

As the world embraces unprecedented urbanisation, cities' role in driving economic prosperity assumes increasing importance. Cities must prioritise diversification, innovation, sustainability, and robust infrastructure to ensure resilience in the face of evolving challenges. By integrating these "7R" elements into urban development strategies, cities can cultivate resilient economies capable of withstanding challenges, promoting sustainable growth, and enhancing the overall well-being of their communities. By harnessing the potential of cities, nations can lay a solid foundation for economic growth, foster innovation, and respond effectively to crises, ensuring a brighter and more prosperous future. Resilient urban economies are not just local assets but the bedrock of global progress in the 21st century.

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Themes over the years

Year	Theme
2023	*Resilient urban economies. Cities as drivers of growth and recovery*
2022	*Mind the Gap. Leave No One and Place Behind*
2021	*Accelerating urban action for a carbon-free world*
2020	*Housing For All: A Better Urban Future*
2019	*Frontier Technologies as an Innovative Tool to Transform Waste to Wealth*
2018	*Municipal Solid Waste Management*
2017	*Housing Policies: Affordable Housing*
2016	*Housing at the Centre*
2015	*Public Spaces for All*
2014	*Voices from Slums*
2013	*Urban Mobility*
2012	*Changing Cities, Building Opportunities*
2011	*Cities and Climate Change*
2010	*Better City, Better Life*
2009	*Planning our urban future*
2008	*Harmonious Cities*
2007	*A safe city is a just city*
2006	*Cities, magnets of hope*
2005	*The Millennium Development Goals and the City*
2004	*Cities - Engines of Rural Development*
2003	*Water and Sanitation for Cities*
2002	*City-to-City Cooperation*
2001	*Cities without Slums*
2000	*Women in Urban Governance*
1999	*Cities for All*
1998	*Safer Cities*
1997	*Future Cities*
1996	*Urbanization, Citizenship and Human Solidarity*
1995	*Our Neighbourhood*
1994	*Home and the Family*
1993	*Women and Shelter Development*
1992	*Shelter and Sustainable Development*
1991	*Shelter and the Living Environment*
1990	*Shelter and Urbanization*
1989	*Shelter, Health and the Family*
1988	*Shelter and Community*
1987	*Shelter for the Homeless*
1986	*Shelter is my Right*

Building Resilience through Circular Economy

Dr. Nirmita Mehrotra *

Urbanization, economic growth and resource consumption are all intertwined with one another. By 2050 two third of global population might suffer from land and water scarcity as well as food insecurities. With cities are striving hard to meet Sustainable Development Goals, it's necessary to understand and assess resource inflow & outflow systematically (Mehrotra N. 2014, 2018). Focus of the world is shifting from linear to circular systems where former consumes an infinite supply of new resources; and later take input of used resources. As waste generated (output) in the circular system are recycled and recovered and reused as resource, implementation of circular pattern require fundamental change in our way of thinking.

It's high time to make urbanization sustainable and to avoid over extraction of resources and degradation of environment, which is possible through combined use of Circular Economy & Urban Metabolism. Circular cities are the system in which resources are looped in a way to regenerate ecosystem balance. Circular cities integrating the CE & UM approach can decouple environmental degradation from economic growth; address needs of poor through circularity. develop a indicators for urban resilience and sustainable cities.

Significance of Urban Metabolism

Current environmental goals for sustainability are resource efficiency and climate responsibility. Particularly the environmental stresses during extraction, processing and discard after processing and usages are adversely affecting global sustainability. It is important to reconfigure energy system through its production, consumption patterns and by-products to the immediate environment. High carbon embodied materials which have adverse environment impact may be omitted and replaced with local, less energy intensive and green materials. Our latest problem is not scarcity of materials but its abundance. Usage of recycled building material with cradle to cradle (C2C) approach can save not only on raw material; it also saves on GHG emissions released during extraction, manufacturing and transportation.

Table 1.0 - Current Per Capita Consumption Based GHG & CO_2 Emissions

Country/city	GHG emissions (tCO_2e/capita)	
India	**1.33**	**1994**
Ahmedabad	1.20	(1)
Bangalore	0.82	(1)
Chennai	0.91	(1)
Coimbatore	1.37	(1)
Delhi	1.50	2000 (8)
Faridabad	1.58	(1)
Gurgaon	2.13	(1)
Hyderabad	1.08	(1)
Jaipur	1.63	(1)
Kolkata	1.10	2000 (8)
Ludhiana	1.49	(1)
Mysore	0.72	(1)
Patna	0.83	(1)
Pune	1.31	(1)
Surat	0.91	(1)
Udaipur	0.76	(1)

Country	1990	2020
Australia	14.50	14.90
Canada	17.63	15.38
Germany	15.05	9.88
Hong Kong	15.31	14.55
India	0.66	1.76
Japan	10.62	10.15
Malaysia	3.65	8.33
New Zealand	7.97	8.38
Singapore	23.71	19.11
Saudi Arabia	11.94	18.83
Spain	6.76	5.83
Sweden	9.92	6.76
Switzerland	12.79	13.51

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Thailand	2.13	4.04
UAE	30.71	20.65
UK	11.70	7.71
US	19.96	17.10

Source: Adapted from Daneil H Et al 2011

Aggregation of Carbon dioxide equivalent emissions of GHG's) of CO_2 eq. respectively

City	GHG Footprint
Delhi	38,633.2 Gg
Greater Mumbai	22,783.08 Gg
Kolkata	14,812.10 Gg,
Chennai	22,090.55 Gg,
Greater Bangalore	19,796.5 Gg,
Hyderabad	13,734.59 Gg
Ahmedabad	91,24.45 Gg

Source: Ramchandra Et al 2015

Role of Cities

Cities are complex system and its complexity lies in the intertwined network of feedback relations among its elements. In this material recycling is important aspect of sustainable development which connects the loops of output to input. It is important to understand, define and regulate characteristics of feedback networks which acts as driver of self organization. In this context, the systems thinking and diagramming approach can be seen as a valuable tool to address the challenge of urban planning and management in the name of achieving long-term holistic sustainability. Presently positive results in urban system input output model of urban metabolism is evident, generally in form of pollutants as incorporation of waste to energy concepts is comparatively new at city level.

A circular economy (CE), with products designed to ease their recycling, reuse, disassembly, and remanufacturing, is currently expected to replace conventional, "linear" wasteful models used to drive the global economy. Resource constraints, as well as increasing volumes of waste and pollution, threaten urban welfare and well-being, as well as competitiveness, business continuity, profits, and jobs. Therefore, CE policy and technology solutions are proposed to achieve resource conservation and pollutant reduction. In order to deploy the CE framework, and for the general assessment of city sustainability, three main types of matter and energy flows at the urban/metropolitan area level need to be evaluated (Ghisellini et al., 2019):

i) primary material and energy resources (construction materials, fuels, food, goods, and water), with a focus on waste prevention, minimization of input flows, considering both non-renewable and renewable aspects of the flows and the relative efficacy of each;

ii) useful flows from one production sector to another (reuse, planning, transferring, exchanging); and

iii) waste and residues from production and consumption sectors (recycling, recovery, and disposal).

Urbanization's direct impact results from obvious changes in land use (Angel et al., 2005), but indirect and interlinked impacts exist as well. For instance, climate change and urbanization are ultimately linked as suggested by the unprecedented role cities took at the 2015 Climate COP in Paris. The International Energy Agency (IEA) estimates that 71% of energy-related global greenhouse gases can be assigned to cities (Hoornweg et al., 2011), and this proportion is expected to reach 76% by 2030. These rapid changes imply an increase in resource consumption so that it is expected that food production will increase by 70% between 2005 and 2050 (FAO, 2009), and become more energy demanding due to the intensification of agricultural practices (Bi et al., 2011). These may lead to modification in Building codes and other building regulations at municipal level, to emphasize zero waste and zero-footprint as a mandatory requirement.

Urban ecosystem comprises of material and energy flow through different processes of resource accumulation, transformation and depletion. In this respect, the four pillars of sustainability have to be looked forward which include Economics, Social Processes, Environment and Institutions as in Table 2.0.

a. Environmental Impact- through Energy and consumption patterns, transportation means, Waste management and recovery, emissions and treatment of Pollutants.

b. Social Processes– Responsible behaviors of community and individuals, Equity and Environmental Justice.

c. Urban Economy- Decoupling materialism and environmental degradation with economic growth, Shift from economy based on Industrial production to knowledge based economy.

d. Institutions- Participatory Metabolism and citizen's engagement, Network Governance & collaborations.

Table 2.0 - Four Pillars of Sustainability

Areas	Attributes of Circularity
Economics	Production Patterns, Resource consumptions, stocks & flows, Resource depletion, emissions, Pollutants.
Social Process	Society and individual Awareness, Capacity Building, Training, incentive and subsidies to modify behavior patterns.
Environment	Zero Carbon Building (ZCB), GHG emissions, CO_2 equivalent, Waste production and recycling, Zero Foot Print, Zero Emission by alternate Energy & Fuels.
Institutions	Participatory Metabolism, Citizens Engagement, Empowerment through network and collaboration.

Adapted from Geissdoerfer et al (2017)

Table 3.0 Linkages of Metabolic Concept to Urban sustainability

Dimension	Criterion	Urban Planning Interventions
Environmental	Resource Use	Renewable, Non Renewable, Reuse, Recycle, Recovery
	Water resource	Water Harvesting Efficiency of use, Waste Management, Metering, Recycling
	Waste disposal	Reuse, Waste reduction, Collection and Management, Green Infrastructure
Social	Green Coverage	Creation of green areas
	Open Space	Land Recycling, organized open spaces
	Public Health	Access to health infrastructure, Healthy life years
	Exposure to risk	Indoor Air Quality (IAQ), Safe Drinking Water etc
Economic	Energy Efficient	Alternate Energy Sources, Green Fuel
	Green Mobility	Pedestrian & Cycle Track, Mixed Use, Mass Transit , Transit oriented development
	Green Infrastructure	Green Investment, PPP Models, Flexibility of usage, Waste to energy, Sewage Treatment

Circular Economy & Resilience

Circular economy gained momentum in areas of clean production, resource conservation, recycling and sustainability. Based on resource efficiency and waste minimization, (Lucertini & Musco 2022) this sets path for Sustainable development Goals; mainly SDG-#12, SDG-#6,#7,#8,#11,#13. SDG 12 aims to ensure sustainable consumption and production patterns through the principles of circular economy, requiring application at different scales; from individual material to supply chains, household energy consumptions to waste management at neighborhood level, and zero footprint at regional level, by generating energy from alternate resources including waste.

Circular Economy (CE) emphasize on goals of resource efficiency; product designed to ease recycling, reuse, disassembly and remanufacturing and replace conventional linear wasteful models used to drive global economy. In order to deploy CE framework for general assessment of city sustainability three main types of energy and material flows at urban/ metropolitan level has to be evaluated (Ghisellini et al 2019)

a. Primary material and energy resources (Construction material, fuel, food, goods and water) with focus on waste prevention, minimum of input flow
b. Useful flow from one production sector to another (reuse, exchange).
c. Waste and residues from production and consumption sectors (Recovery & disposal).

Presently the concept of sustainability in urban planning and policy making has been focusing on urban metabolism mainly through water, carbon emission, energy and material flow within the city. Circular cities is a multi dimensional concept requiring trans-disciplinary approaches in which resources are looped in a way to regenerate ecosystem balance. Circular economy (CE) can be closed loop eliminating input of new resources and utilize all waste output from the system decoupling of economic growth from natural resource depletion.

Here analysis also requires in two overlapping approaches - systematic & hierarchical order (Gonzalez et al 2013). Former emphasize different levels in circularity whereas later identifies best practices at Micro, Meso and Macro Level (Ghiselline et al 2020).

1. Micro Level – eco design products, companies, consumer
2. Meso Level - Eco Industrial Parks, Corporate, Associations, Supply Chain
3. Macro Level- Eco-City, District, Municipal levels in sectors like food, construction, Power and production of goods

Applications at City Level

These Metabolism applications have been under varied uses around the world for engaging sustainable practices with actual assessment models to check material stocks and flows within the

Table 4.0 Relationship in Circular Economy & Resilience

Area	Sustainability	Circular Economy
Origin	Environmental & Economics	Cradle to Cradle, regulatory policy
Circularity Goals	Close ended. Non- linear.	No new input. Waste generated used as resource. Better use of resources
Motivation	Diffused and diverse	Incentive as core implementation tool
Integrative	Horizontal	Hierarchical focus on Economy
Beneficial	Environment, Economy & Society	Economic actors at core, Central role of Private Business
Time Frame	Open ended	Set optimization and threshold limits for fresh input and use of waste as resource.
Roles & Responsibilities	Actions & Roles exists in silos.	Policy makers, Innovative business Model possible for Industrial & Urban transformation. Inclusive & Participatory.
Commitment goals	Futuristic and resourceful.	Risk diversification, value creation opportunity. Integration eco-nomic and non- economic aspect into development

Source: Adapted from Geissoerfer et al 2017

urban agglomerations. Different scholars globally used the UM & CE concepts for various sectors

a. **Waste to Energy Simulation**- Waste Management has been a growing challenge in purview of climate crisis. Metabolic concepts used to analyze nexus of waste to energy production and other environmental policies for three Metro city, Tokyo, New York & Taipei.

b. **Efficiency in Building Material & Resource Use-** Urban Metabolism has recently being used for understanding impact of different projects and policy on environment and to emphasize more resource efficient strategies to urban development. Smart Urban Metabolism (SUM) Model by Shahrokni et al (2015) provide real time feedback on energy & material flow from level of household to urban district through case of Sweden & Stockholm. These frameworks used for assessment of water system and flow of key nutrients like phosphorous and nitrogen, study of heat accumulation in pavements and rooftop, and deposition of nutrients in soils or waste sites.Sankey diagrams used in Rotterdam to visualize emissions through construction and demolition (C&D) material waste, and dependency on fossil fuel in construction sector, design of buildings for renovation or disassembly rather than demolition.

c. **Web traffic Analysis -** Sankey diagrams are also recently used to display web traffic for customer's reaction and action through Links, nodes, drop off links and transaction; and may visualize the energy accounts on regional or national level including cost breakdown.

d. **Optimizing Settlement size based on Eco footprint** - Scholarly studies also conducted UM studies to determine threshold size of settlements in context of their eco-footprint and dependence on the hinterland for resources. This highlights unhealthy pattern of consumptions and discharges; and help identifying clusters of exchange, supporting circular economy which in turn will reduce the eco-footprint of cities.

e. **Environment Management -** UM identifies key processes that generate environmental burdens, explores its alternative solutions at early stage and deploy solutions; Setting priorities and action plan for new processes for environmental benefits.

f. **Building Resilience -** UM has power to earmark the causes of increasing vulnerability and inversely point on existing risk and directions, in order to enhance resilience. Kissinger & Stossel (2019) identify and confirm correlation between metabolic functions and evolv-

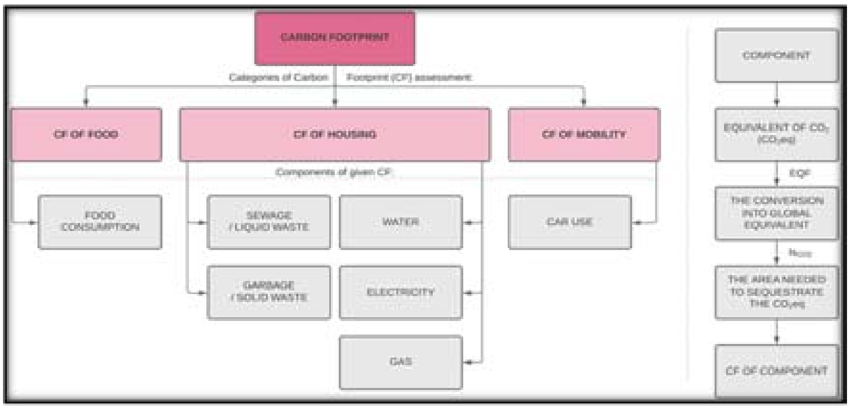

Table 5.0- Comparison of different UM Tools & Application

Method	Scale of Application	Remarks /Applications
Life Cycle Analysis (LCA)	Micro & Meso (Products, Supply Chain)	Production processes and their impact environment impacts at various stages.
Material Flow Analysis (MFA) (Exergy/emergy)	Macro (World, Country Region)	Account for stocks & Flow of resources, Ecological Balance.
Complex System (System Dynamics)	Macro/ Meso	Evaluate emerging Feedback loops of system structure, its reinforcement for self organization, connection to potential Market dynamics and opportunity for entrepreneurship.
Sankey Diagram	Meso to Micro Level	Carbon Accounting & GHG Emission, Energy input-output. C&D Waste monitoring
BRIDGE	Micro level	Integrating Urban Metabolism, Web traffic Analysis, & GIS Platform
MUSIASEM	Multi Scale Analysis	Ecological Foot Print by connecting environmental elements, Economic variables & structure of Society.

Source: Compiled by Author

ing vulnerability or building resilience by equity, efficiency, resource optimization and well being of community.

g. **Carbon Footprint -** The relevance of Carbon Footprint of products, processes & services to environment planning may appear unclear, but it form basis for estimate of GHG emission associated with major policy and planning areas such as energy and transport.

Significance of Study

With the looping Climate change crisis mainstreaming sustainability and environment concern has gained importance more than before. Urban Metabolism Tool can assess levels of sustainability and environmental impacts of urbanization around the world. It helps to delineate drivers of the resource flow, including the life styles and consumption patterns; increasing pollution levels and can help in policy formulation for implementation of circular economy in various sectors. Resource flow may be designed to be circular, fossil free and climate positive with assessment of eco footprint before undertaking any development project.

Urban Metabolism emphasize on goals of resource efficiency, generating opportunities for Circular Economy. For example, the consumption of construction materials has been growing exponentially with urbanization, where construction material contributes to 75% of the material which are mostly non-renewable in nature. In this respect, it's time to focus on investment shift on dematerialization strategies; reductions of consumptions of raw materials at regional & city scale. These tools for assessment of urban sustainability are likely to set new paradigm, conceptualizing cities through its metabolic pattern & circularity. This calls for structural transformation to organize flow of material, energy and people. Participatory Metabolism is next stage where co-design can take place with society in a bottom up approach. Implementation of urban metabolism tools may bring changes as follows-

i. **Optimal energy usage -** Using clean energy and improving

Table 6.0 Sustainability Assessment by Urban Metabolism

Criterion	Sub criterion	Indicator w/ units
Land Cover	Urban	Developed Areas in Hectare
	Landuse	Reconstructed urban areas
	Built Environment	constructed land in Percent of total area
	Open space	Green space per capita
Water	Consumption pattern	Per capita by residential sector Liter/number/day
	Wastewater production	Water consumption per capita by Liter/number/day
	Sewage Lines	Total Household units connected per capita
Air-pollution	SPM upto 10 microns	Per capita ton of CO2/SO2/ NiO2 emissions per annum
Material	Organic & Plastic Waste	Per capita of solid waste collected As M3/person/ yr
	Waste materials	Share of buried solid wastes Kg/person/yr
	Recycling	Per capita of waste production Kg/person/yr Total ton
	C&D Reuse	Vol. of CWD reused %
Energy	Transportation	Access to the public transport, Parking lots; Optimal / average distant
	Sources & Efficiency	Energy consumption per capita, Energy consumption per constructed area, Green Fuel in KWh Renewable Energy

Source : Author

energy efficiency.

ii. **Water Footprint -** Optimal water usage by Recycling and reuse, water harvesting and recharge of ground water.

iii. **Zero footprint-** Practice of reuse and recycling of materials for consumption and energy production, with no waste models.

iv. **Green field & Brownfield development-** Development of green spaces and optimal distribution in different areas, mixed use zonings, revival and reuse of dilapidated structures.

v. **Zero landfill model-** Circular economy uses of all waste as resource, encouraging zero landfill & net zero buildings (NZB). It should also create livelihood to people while generating wealth from waste.

Conclusion

It's high time to make urbanization sustainable and to avoid over extraction of resources and degradation of environment, which is possible through combined use of Circular Economy & Urban Metabolism. Unsustainable Consumption of resources is one of the society's major challenges today, which has been highlighted by Sustainable Development Goals particularly SDG 11 & SDG 12 where later aims to ensure sustainable consumptions and productions pattern. In this purview, UM has is a strong analytical tool where flow of materials can be visualized with volumes and weights. This chapter presents a comprehensive review of the methodological choices and outline common ground for environmental sustainability assessment through Urban Metabolism. By exploring fluxes of energy and resources, wasteful discharge in form of air pollutions, soil and water pollutions can be curbed.

Urban Metabolism has power to earmark the causes of increasing vulnerability and inversely point on directions to enhance resilience. This also requires focus on geographies beyond traditional city and district boundaries linking rural-urban as well global–local networks. Circular system are likely to replace existing linear solutions involving different stakeholders at corresponding level, with idealized solutions to reduce raw inputs as well as emission outputs from the system.

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Enhancing Sustainability in Indian Affordable Housing: A Path to Resilient Cities


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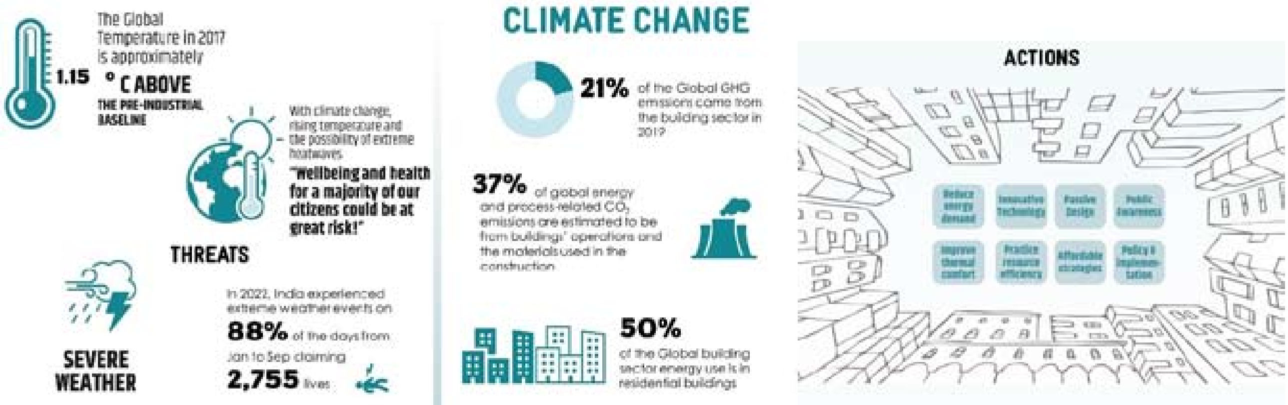
The rapid urbanization phenomenon is driving an unprecedented demand for the construction of buildings. Globally, buildings continue to be major energy consumers, responsible for a substantial portion of the world's energy consumption. Recent estimates from the UN environment indicate that in 2019, buildings and construction accounted for 35% of global energy consumption, along with 38% of associated CO_2 emissions, making it the largest contributor to final energy use. In India, a unique situation has emerged where two-thirds of the commercial and residential structures expected to exist in 2030 have yet to be built.

Urbanization has led to an exponential rise in housing demand, with nearly 95% of this demand concentrated in lower-income categories. The Pradhan Mantri Awas Yojna-Urban (PMAY-U), the Government of India's flagship affordable housing program, seeks to address this shortfall by focusing on Economically Weaker Sections (EWS) and Low-Income Groups (LIG). As a result of PMAY-U, approximately 12 million houses are being constructed in current mission plan, designed to last for at least 50-60 years. Such policies are needed for several more years to meet the entire demand in affordable housing sector in country. As India transform their lives by providing a pucca house, the beneficiaries of these houses will become a part of the structured infrastructure and demand all necessity linked with the infrastructure putting an exponential pressure on the existing situation of a city. But in pursuit to provide a pucca house, its important not to trap them in a thermally uncomfortable environment, looking desperately for solution and increase their dependency on active appliances. This would put pressure on electricity demand. It's important to note that beneficiaries of affordable housing may not demand for a new 5 star or a 3-star AC but would preferably adopt for no start or second hand AC to suit their purchasing power. This will give an unpreferable push to grey market and inefficient appliance installation in our country. Thus, a significant energy-saving opportunity lies in reducing the energy demand of these newly constructed affordable housing. These new constructions not only impact energy demand but also place strain on natural resources used in building materials.

The rapid growth in energy consumption within affordable



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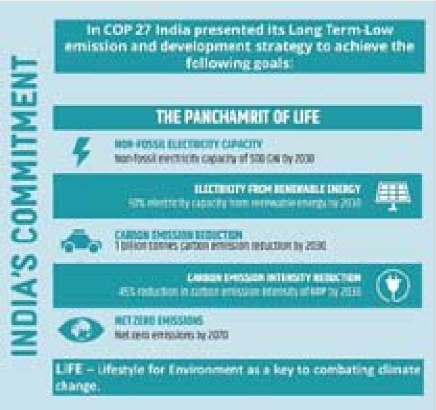

housing buildings is attributed to three factors:

- the need to address the current housing shortage due to rapid urbanization, particularly in tier-two and tier-three cities;
- the shift towards multi-storey housing in the formal sector, intensifying construction energy use due to a greater reliance on Reinforced Cement Concrete (RCC);
- and the rising demand for indoor thermal comfort met increasingly by room air-conditioning, affecting lower and middle-income groups and contributing significantly to increased energy consumption in this sector.

Its important to prioritize construction speed, ease, and cost, emphasizing new construction technologies and materials. This presents a significant opportunity to mainstream energy efficiency and environmental sustainability in housing projects, especially in the affordable housing sector, to offer thermally comfortable housing through passive means.

Addressing climate change and enhancing thermal comfort aligns with India's commitment to sustainable development and carbon emissions reduction, focusing on the building industry as a key area for future development. Lowering energy and emissions intensity in this sector, along with strategies to reduce life-cycle carbon emissions, is recognized as a cost-effective approach to combatting climate change. Initiatives led by Ministry of Housing and Urban Affairs, Building Material and Technology Promotion Council and GIZ, play a crucial role in implementing these measures and raising awareness among the masses.

The PMAY mission must extend beyond providing basic shelter to ensuring an improved living environment for enhanced quality of life. Occupant comfort, particularly thermal comfort, plays a pivotal role in this regard. With climate change and rising temperatures on one hand and increasing aspirational demands on the other, more households are likely to turn to air-conditioning in the coming years. To ensure sustainability and affordability for occupants, it is crucial to integrate thermal comfort into affordable housing today, aligning with the government's commitment to Sustainable Development Goals and climate change mitigation efforts.

To meet climate targets, the Ministry of Environment, Forest, and Climate Change launched the India Cooling Action Plan (ICAP) in 2019. ICAP sets a 20-year perspective with the aim of reducing cooling demand across sectors by 20%-25% and cooling energy requirements by 25%-40% by 2037-38. The plan emphasizes managing cooling demands through design, passive strategies, and adaptive thermal comfort standards. This shift moves away from rigid temperature set points toward thermal comfort ranges based on climate and context.

Multi-family apartments, being an efficient way to provide high-density affordable housing in urban areas where land is expensive, are gaining prominence. Cost and timely delivery are critical factors for these housing projects. Implementing energy efficiency in buildings constructed over the next decade presents an opportunity to reduce locked-in energy, reshape consumption patterns, and enhance cost savings for decades to come. As we prepare for climate change challenges, it becomes essential to ensure housing provides thermal comfort through passive design and sustainable building materials. Neglecting energy efficiency in design today could lead to a vicious cycle of greenhouse gas emissions, higher ambient temperatures, and increased demand for refrigerant-based cooling as these homes get occupied and living standards improve.

The Indo-German Energy Program – Climate Smart Buildings Project by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) and the Government of India, plays a vital role in increasing thermal comfort and energy efficiency in residential buildings. Initiatives such as Eco-Niwas Samhita 2018 & 2021 (ENS), labelling mechanisms, Energy Efficient Building Material Directory, and the Smart Home program have been instrumental in combating energy efficiency in residential sector. However, more efforts are needed to achieve the desired level of thermal comfort, raise awareness, and empower stakeholders.

The Climate Smart Buildings (CSB) program under IGEN extends technical assistance and cooperation to enhance climate resilience and thermal comfort through innovative passive measures and sustainable, low-embodied-energy materials, coupled with state-of-the-art construction technologies.

Fostering sustainability in the built environment is a priority, emphasizing the use of sustainable materials for thermal comfort, improving the environment, and climate conditions. This aligns with the government's Housing for All mission, supported by GIZ, the Federal Ministry of Economic Cooperation and Development (BMZ), and the Ministry of Housing and Urban Affairs (MoHUA).

Achieving thermal comfort in affordable housing is not only about providing mass housing but also improving the quality of life. Thermal comfort is essential for an enhanced standard of living and need not come at an additional construction or operational cost. Refrigerant-based HVAC systems are not the sole solution for achieving thermal comfort. Various efficient practices include optimizing building orientation, fenestration sizes, shading elements, efficient walling materials, insulation, and structured passive design techniques, alongside innovative local sustainable building materials. Capacity-building and awareness programs are necessary to emphasize the importance of thermal comfort and debunk the myth that it is expensive for affordable housing projects.

To enhance the thermal comfort in affordable housing, CSB strategized a 6 steps approach.

Step 1: Living Laboratory Experiments at Light House Projects:

Under the GHTC challenge, MoHUA has launched 6 Light House Projects as Live Laboratories to demonstrate not only innovative construction technologies but also to test the climate resilience of new age construction technologies with a single objective in mind - to provide a "liveable" pucca house to many people of this country, who deserve a better place to live. MoHUA has set up Climate Smart Building Cells at each of these LHPs to study the performance of these buildings in different climate zones in attaining the desired level of thermal comfort. Experiments were conducted in all LHPs to test the impact of various passive measures like orientation, window shading, window to wall ratio, natural & cross ventilation, mutual shading, cool & green roof, and thermal performance of the envelope etc to understand what works and what doesn't, along with the level of impact of each passive measure. The study was done to understand the level of comfortable hours achieved in a year inside a built environment, better indoor temperature compared to external environment or similar category of buildings that are not designed as per passive design principles and how passive measures supplemented the design objective to make a building thermally more comfortable.

Step 2: Mass Sensitization through Resilient, Affordable and Comfortable Housing Through National Action (RACHNA) training series

Thermal comfort in affordable housing many a times seems like a luxury in a scenario where government is putting all its effort to provide a pucca house. However, this luxury is a very basic right of a human being and is demanded by human ever since its birth. Thus, to sensitize the community for this action plan, a mass sensitization drive was carried out via RACHNA series of training which comprises of over 150 trainings to train over 11000 stakeholders in 37 cities and 5 climate zones. This series was conducted in 2022 to 2023 and have ensure a widespread penetration of the concepts of thermal comfort in all range of stakeholders.

Step 3: Extensive research on thermal comfort concepts, technical requirements, and application models:

Along with the sensitization of the stakeholders, it is important to

do a deep dive technical research on the concepts of thermal comfort and how stakeholders can apply the same. To do so, Catalogue of Climate Smart Building Designs for Affordable Homes initiative seeks to dispel the notion that achieving thermal comfort comes at an increased cost. It focuses on passive design measures, offering a range of thermally comfortable, energy-efficient house designs that consider various unit sizes and typologies for different climatic zones. A Handbook in thermal comfort is

also developed to further facilitate the technical understanding of this important concept. The handbook was launched by Prime Minister Narender Modi in Oct 2022.

Step 4: Demonstration project to test the concept in field:

The study has been further extrapolated to around 40 numbers of DHP, AHP, ARHC, and BLC projects across country to ascertain the findings and propose best solutions for thermally comfortable affordable housing design in India

focusing on economically viable solutions. It was important to extrapolate the findings in LHP's living laboratory experiments to diverse construction practices in affordable housing categories (both for public and private projects across country) to ascertain that the finding is relevant for the affordable housing segment overall and not limited to new age construction technology.

Step 5: Policy Document – Passive-design Response in Increasing Thermal Comfort with Viable Solution (PRiTHVi) – to guide on how to build for achieving thermal comfort.

A lot of work has been done in the past decade in this field and many codes and standards already exist for energy efficiency & sustainable building construction. However, these are understood by a limited number of professionals and not implemented vigorously at ground level. To fast-track adoption of these standards it is imperative that these are interpreted into easy to understand and simple to follow guidelines that can be adopted by the masses at various scales of construction.

PRiTHVi provides such viable solutions to achieve basic standards of thermal comfort through low-cost interventions which need to be adopted from the conception of a project, at various stages of design and construction.

Step 6: Incubation of new age technologies via Affordable Sustainable Housing Accelerator (ASHA India):

The Government of India launched the Pradhan Mantri Awas Yojana - Urban (PMAY-U) in 2015 with the goal of providing housing to all eligible families by 2022. The program aims to adopt innovative, sustainable technologies for faster and cost-effective construction of houses across different climatic conditions. Through the Affordable Sustainable Housing Accelerators-India (ASHA-India), 11 potential future technologies are being developed for upcoming affordable housing projects.

The CSB project encourages the use of passive measures and low embodied energy materials for sustainable construction in affordable housing. Under CSB initiative, technical mentorship are provided to the selected technologies in the incubation phase under ASHA-India to develop them into market-ready solutions.

The 6 steps strategy will provide a comprehensive solution to all domains ranging from Policy initiatives to field implementation and end user sensitization. The strategies are designed to ensure that appropriate steps are being taken at each level to ensure complete solution to address the thermal comfort in affordable housing and ensure a sustainable growth of our economy.

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19th Meeting of TAC under PACS

BMTPC operates Performance Appraisal Certification Scheme (PACS) through which innovative products, materials, technologies and processes are certified through performance based evaluation framework.

The 19th Technical Assessment Committee (TAC) meeting under the Chairmanship of ED, BMTPC was held on June 7, 2023 at BMTPC premises, New Delhi to consider certification to new products namely 3D Printing, Geopolymer Coarse Aggregates, Nano Aggregates, Alternate Manufactured Sand, uPVC Doors & Window frame based complete solutions, etc.

Resilient Urban Economies:
Leveraging Concrete 3D Printing for Sustainable Growth




*Dodda Srinivas** *Dhrutiman Dey** *Biranchi Panda** *T.G. Sitharam**

Abstract:

In this article, we explore the transformative potential of concrete 3D Printing as a catalyst for resilient urban economies. We delve into the concept of urban resilience, discuss economic challenges faced by cities, and demonstrate how advanced construction technologies like concrete 3D printing can play a pivotal role in driving economic growth and recovery.

Introduction:

In recent decades, the world has witnessed an unprecedented wave of urbanization, with more than half of the global population now residing in cities. This demographic shift has propelled cities into the epi-centres of economic activity, acting as engines of growth and recovery in a rapidly changing world. This urbanization trend is a testament to the magnetic pull that cities exert, promising the allure of economic prosperity, cultural diversity, and access to critical services. However, it is not just the population numbers that have grown; cities themselves have evolved into dynamic entities, driven by innovation, technology, and interconnectedness. As we embark on this exploration of resilient urban economies, it is crucial to understand that cities are not monolithic entities. They are diverse, complex, and reflective of the societies in which they are embedded.

Resilient urban economies are characterized by their capacity to bounce back from adversity, innovate in the face of challenges, and provide inclusive opportunities for all residents. The best example is the recent COVID-19 pandemic, which has not only challenged the resilience of urban economies but also questioned their significance in the context of recovery. The pandemic exposed vulnerabilities and disparities within cities, forcing us to rethink urban planning, economic strategies, and social cohesion. Now, more than ever, we must explore the intricate relationship between resilient urban economies and their role in not only surviving crises but thriving in their aftermath.

Resilient urban economies and challenges

In our rapidly evolving world, the term "urban resilience" has taken centre stage in discussions surrounding the future of cities. At its core, urban resilience refers to a city's ability to withstand and recover from a variety of shocks and stresses while maintaining its essential functions, structure, and identity. However, the true power and relevance of urban resilience emerge when we consider its deep connection to economic prosperity. In the context of economic growth, urban resilience means more than just the ability to bounce back from disasters; it signifies a city's capacity to adapt, innovate, and thrive amidst disruptions.

Urban areas, the vibrant hearts of economic activity, face a myriad of economic challenges that can hinder their growth and prosperity. These hurdles often stem from traditional construction practices, infrastructure deficiencies, and their associated costs. Conventional con-

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struction methods, while tried and tested for centuries, contribute to several economic challenges. One of the most significant issues is the generation of waste, particularly from formwork. Formwork, the temporary structures used to mold concrete during construction, is a major source of waste. It consumes materials, requires substantial labour, and generates significant waste when removed after use. This wasteful practice not only impacts the environment but also escalates construction costs. Furthermore, conventional construction heavily relies on manual labour, leading to high labour costs, inefficiencies, and delays. The construction industry often struggles to meet project timelines, resulting in financial overruns that affect urban development. Another adverse consequence of conventional construction is its environmental impact. The extraction of raw materials, energy consumption, and carbon emissions associated with traditional construction materials which contribute to pollution, deforestation, and climate change. The above reason highlights the pressing need for sustainable construction practices as an innovative solution to overcome these obstacles.

Cities and Government policies

Cities are engines of economic growth, and Housing is decisively rooted in an economic, social, and political sphere of any country. In the context of India, a nation marked by rapid urbanization, the census of India 2011 revealed that out of a total population of 1.21 billion, 377 million resided in urban areas, accounting for 31.15 percent of the country's population. As the higher growth of the urban population persists over the years, it is estimated that above 50 percent of the total population of India will be urban by 2050. This rapid urbanization presents a dual challenge: the need for sufficient housing to accommodate the burgeoning urban population and the necessity to ensure that this housing is both affordable and sustainable. To tackle these challenges head-on, the past government has formulated a series of policies and schemes, including Indira Awas Yojna (IAY), Rajiv Awas Yojna (RAY), Atal Mission for Rejuvenation and Urban Transformation (AMRUT), etc.

In spite of these above schemes, it is seen that housing affordability remains a formidable challenge, particularly for middle-income households. The critical problem and complexity involved in forming this policy is the heterogeneity of cost structure in housing markets in response to different locations and their submarkets. Hence, the major concentration on policy dimensions or policy framework mainly focused on managing the market by providing the supply-side (public housing or assistance to developers) and demand-side subsidies (periodic cash allowances or capital grants to support housing costs), enabling low-cost credit to low-income developers through Housing finance institutions and Housing Finance Companies (HFCs).

Recognizing the pivotal role of housing and urban development in its broader policy framework, the present government has undertaken significant initiatives to foster technological advancement in construction. One of the most prominent and ambitious programs in this regard is the Pradhan Mantri Awas Yojana (PMAY) - "Housing for All" initiative, which aims to provide affordable housing to all citizens by the year 2022. Government of India's approach in implementing PMAY reflects a forward-thinking vision that prioritizes technological advancement in construction over a purely subsidy-oriented approach. By promoting innovation, sustainable practices, and modern construction technologies, PMAY not only addresses the immediate need for affordable housing but also contributes to the long-term development and resilience of urban areas. This approach ensures that housing is not only accessible but also built to higher standards of quality, efficiency, and sustainability, ultimately benefiting both citizens and the nation as a whole.

Innovation and potential of concrete 3D Printing technology

In the quest for urban resilience, innovation stands as a cornerstone. The ability to think creatively, adopt cutting-edge technologies, and implement transformative solutions is what propels cities toward greater resilience and economic prosperity. In this context, advanced digital construction technology, particularly concrete 3D Printing, shines as a beacon of innovation. Concrete 3D Printing epitomizes the fusion of creativity and technology, offering unparalleled opportunities for urban development. This revolutionary construction method promises speed, precision, and sustainability, enabling cities to confront challenges with unprecedented efficiency. The innovation lies not only in the speed of construction but also in its ability to drastically reduce waste, lower carbon emissions, and create buildings that are energy-efficient. The process requires computer-aided design to build three-dimensional objects using a layer-by-layer approach as shown in (Figure 1) the recently completed project by IIT Guwahati researchers. The team 3D printed modular sentry post for Indian army and a security house as part of G20 summit programme using a special sustainable concrete mix, without the need of moulding work and much human intervention. Compared to conventional concrete casting, the team believes these projects will certainly gain more points in terms of productivity and sustainability, which are the pressing needs of construction industry.

Figure 1. 3D printed modular security house using sustainable concrete mix at IIT Guwahati
(From Left: Dhrutiman Dey, PhD student ; Professor P.K. Iyer, Professor T. G. Sitharam, Dr. Biranchi Panda, Dodda Srinivas, PhD student)

Socio economic impact of concrete 3D printing technology

The socio-economic impact of concrete 3D printing in construction, particularly in India is profound and multifaceted, influencing various critical aspects of housing, urban development, and the broader economy. First and foremost, this innovative technology's social impact is characterized by its remarkable ability to significantly reduce construction costs. This cost-efficiency is transformative, rendering homeownership attainable for low and middle-income families and effectively addressing the persistent issue of housing shortages and homelessness that have long plagued India's urban areas.

Moreover, the transformative potential of 3D-printed structures extends beyond affordability. In contrast to traditional low-cost housing, these innovative constructions are thoughtfully designed with modern amenities, leading to a marked improvement in the quality of life for residents who have endured subpar living conditions for too long.

Additionally, 3D printing technology has a profound impact on social sustainability. By drastically curbing material wastage and promoting the use of eco-friendly, sustainable materials, these structures align seamlessly with India's overarching goals of fostering environmentally responsible urban development. This not only reduces the environmental footprint of housing projects but also creates a more sustainable and liveable environment for communities, enhancing the long-term well-being of residents while preserving the planet's resources.

Furthermore, the economic impact of 3D printing in construction is significant. Firstly, the successful implementation of 3D-printed construction projects necessitates the cultivation of a skilled workforce proficient in operating and maintaining specialized equipment. This workforce development initiative not only addresses immediate employment needs but also brings about positive socio-economic transformations within local communities, offering opportunities for individuals to acquire valuable skills that enhance their employability and contribute to regional economic development.

The evolution of 3D printing has also benefited underwater engineers by allowing them to print complex coral reefs, underwater habitats and other facilities that involves challenging and unique engineering designs. With ocean resources worth trillions of dollars, this integration of 3D printing technology into the underwater construction has the potential to attract foreign investments, catalysing innovation and technological advancements, thereby contributing significantly to overall growth of the construction companies, fostering economic resilience and stability.

Conclusion

In conclusion, urban resilience, closely tied to economic growth, is vital in the face of challenges like the recent pandemic. Traditional construction methods in cities pose economic challenges, which have included factors like resource inefficiency and prolonged construction timelines. Government policies, like PMAY, emphasize technological advancement in construction for sustainable urban development. Concrete 3D printing significantly reduces construction costs, making homeownership accessible to low and middle-income families, improving living conditions, and positioning India as a leader in construction technology. In summary, 3D printing not only enhances housing affordability but also bolsters overall economic well-being, showcasing innovation's role in resilient and prosperous urban economies.

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World Blood Donor Day

Every year countries around the world celebrate World Blood Donor Day (WBDD). The event serves to raise awareness of the need for safe blood and blood products and to thank voluntary, unpaid blood donors for their life-saving gifts of blood. A blood service that gives patients access to safe blood and blood products in sufficient quantity is a key component of an effective health system.

June 14 being World Blood donor day, BMTPC organised Blood Donation Camp in association with Divine Charitable Trust at India Habitat Centre, Lodhi Road, New Delhi. The World Blood Donor Day theme this year was "Give Blood, Give Plasma, Share Life, Share Often", emphasising the importance of blood and plasma donations for lifelong transfusion patients and to encourage donating blood or plasma often to ensure a safe and sustainable global supply of blood to all who are in need. BMTPC family enthusiastically participated & donated blood.

Earthquake & Fire Safety – An assessment of the Vulnerability of Indian Buildings after Türkiye Earthquake

Dr. Deepak Bansal [1]

India is severely prone to earthquakes (more than 50% of the land area of India is prone to medium to severe intensity of earthquakes) and has witnessed several severe earthquakes in the past, resulting in the loss of several thousand of human lives and several million INR worth of properties. The earthquake of Uttarkashi (1991), Latur (1993), Jabalpur (1997), Chamoli (1999), Bhuj (2001), Kashmir (2005), Nepal (2015) and many more, have devasted the local population & infrastructure very badly. The country has been seismically mapped and 4 (four) earthquakes zones have been defined by BIS (Bureau of Indian Standards) as Zone II to Zone V, depending upon on probability & intensity of occurrence of low to high-magnitude of earthquakes. Detailed guidelines have been issued by BIS, to plan, design & construct various facilities in these zones according to the expected resilience of these facilities in their service life span and many of these guidelines have been incorporated into local building by-laws of many state governments. These are fairly good guidelines and it is felt from the lessons learned from previous disasters, that major loss of lives & properties happened due to non-adherence of these guidelines in the fields and not because of technical flaws in these guidelines, further these guidelines keep on updating as per latest scientific knowledge & technology.

However, in practice/fields, we see the construction of several buildings nonconforming from these guidelines and unauthorized modifications in the structural systems of conforming buildings (structural columns/beams and slabs are cut to do modifications/ interiors/extra construction) coupled with misuse of defined buildings uses (residential buildings are converted into shops, hospitals, educational facilities, guest houses, warehouses, etc.) is happening at a large scale. This is very common in almost all the urban/suburban areas of India and nobody seems to be bothered about it (as the public at a large scale is involved in these activities and because of public pressures, these are either ignored or regularized at a later stage without analysing their effect on infrastructure and disaster resilience). It is estimated that less than 10% (very rough estimate) of total residential buildings in urban areas are engineered (and they too had gone through major changes afterward through these unauthorized construction activities, hence may not be categorized in the engineered category), and the rest 90% (approx.) buildings are non-engineered (especially in Lal Dora, Slums and peri-urban areas), which are highly vulnerable and may collapse like pack of cards in case of occurrence of even low to moderate intensity of an earthquake. This is a big challenge, as this is happening not because of a lack of planning, designing, or construction knowledge but because of poor monitoring of construction in the fields. The building stability certificates desired by statuaries authorities are also an eyewash, as generally these certificates are issued without any detailed calculations or technical investigations based on established scientific methodology. India is progressing toward becoming a superpower, but its infrastructure is flawed. The situation will be totally unimaginable in case of an earthquake having severity (Magnitude on Richter scale and intensity on MMI scale) like Türkiye.

In case of an earthquake having a magnitude more than 7.0 on the Richter scale (at shallow depth having high intensity), strike any

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urban area of India, which has may very high population density and weak buildings/infrastructure, the damage will be unimaginable. The rescue operations will be severely affected due to narrow lanes and the high density of buildings. Our lifeline buildings may not be functional as most of them are not designed for earthquake safety and even if they are designed, their services like oxygen supply lines and other auxiliary support systems may not be in working conditions. Further, houses of the staff working in these hospitals may have been affected by the earthquakes, resulting in a shortage of staff. Hence, collateral damages will be much more (which can be avoided). It is hoped that the agencies like NIDM/NDMA/SDMA/DDMAs may have done risk assessments of such situations, specific to cities, and may have prepared a strategy to deal with such situations.

Unlike an earthquake, which are mostly natural threats, fires are manmade (most of the time in urban areas) threats, which are killing humans & animals and destroying properties. In the recent past, there have been several reported cases of fires in public buildings in national media, like a fire in coaching centre at Surat & Delhi, Hospitals & Restaurants in Mumbai/Delhi, Guest houses, Hotels & Factories in Delhi, etc., where public including teenaged children suffered badly, including loss of many precious lives. These are generally not government buildings, but commercial/institutional buildings, which are used by public/users/customers/patrons/patients, after paying money for the usages (shops, restaurants, hotels, malls, cinema halls, factories, coaching centers, hospitals, etc.), hence needs to be planned, designed, constructed and maintained with the utmost care, to provide safety inside to the intended users. If students die in schools due to fire or building collapse, what kind of civil society are we? What is the fault of the people, who used these buildings, after paying money, believing that these buildings are doing legitimate business as per approved building plans in accordance with the legal framework of the country? Where are the enforcement agencies? They wake up only after a disaster and go to slumber again after a few weeks after the disaster. What lessons are learned from the failure of much talked about buildings in Lalita Park at Yamuna bank, Delhi, and Shaberi village at Greater Noida, UP? No. If yes, these are not in public domain to be replicated for the larger interest of the public.

There are detailed guidelines in National Building Code of India (NBC) 2016 and Bye-Laws of various cities to plan, design, construct, and maintain different types of buildings as per their uses or business, footfall, and importance, for Loading, Earthquakes, Cyclone, Fire, Ventilation, PHE, Electrical, etc. It is expected that concerned local statutory authorities will ensure these provisions, but a quick reconnaissance survey will reveal its massive violations in any city in India. After every disaster only owners & contractors are held responsible and bigger operators like responsible officials, police, politician and middlemen are spared to operate again with impunity. Now, when we talk about sustainability and differently able people-friendly buildings in India, are we not making fun of ourselves, with our current state of affairs of our built environment?

If a person pays to get coaching, the responsibility of his/her safety is to be ensured by the person taking money and providing coaching in the buildings, but he/she claims further innocence/victim, as the concerned building is either hired or built & maintained by someone else. He/she may be right to some extent, as if he/she try to fulfil all the safety requirements in the buildings, as envisaged in NBC 2016 or local building bye-laws, he/she will not find a place in any urban centres to operate in all likelihood, as most of the buildings are defying approved building use, Loading, Fire, EQ, Cyclone, Electrical and do not have a proper escape route. If escape routes are there, they are often locked up or encroached upon. The basements in the buildings are being used to run cafeterias or storing inflammable goods, which is further adding woes. Even streets/footpaths are encroached upon and Fire Tenders cannot move in case of emergency. The availability & capacity of Fire tenders in cities is also doubtful as have been seen in most of the cases mentioned above that fire tenders reached late and do not have ladder of sufficient heights.

There is another dimension that is further complicating this issue, which is that, even best planned, designed, and constructed buildings are violating approved building use and many times staircases are locked, giving the impression that our civil society is not well-educated and doesn't care. Author recently visited the CBSE (Central Board of Secondary Education) office in Patparganj Area, Delhi and found that this building in fact has taken a few clues from NBC and displayed allowed loads on every floor of this building. However, such practices, although being mentioned in NDMA (National Disaster Management Committee) is rarely followed in India.

Now the question is this, where public, who is a consumer also, should go where, for shopping, education, recreation, dining, offices, and medical treatment? Most of the buildings, pavements, lanes/roads are unsafe. People construct floors on top of shops/houses and cut beams/columns to extend balconies horizontally, even in posh DDA/planned colonies (by government bodies like Development Authorities, Housing Boards, etc.,) without any fear, then what can be said about urban villages in Delhi, as they get few privileges/immunities being located in village area (Lal Dora). There is no one to listen/act on such issues as all stakeholders are hands in gloves, but in case of any earthquake, even these so-called modified engineered buildings will behave like non-engineered buildings as their vital structural columns, beams & slabs have been cut. When such types of greed-based modifications/extensions will stop? When concerned authorities will act on such large-scale violations? In recent times, we have seen one more type of manmade disaster i.e., terrorism, where the public is targeted with explosives in the markets or public places, which affects buildings & services also.

There is a well-defined set of guidelines in National Building Code of India (NBC) 2016 to conduct periodic safety audits of all buildings, every 3 to 5 years as stated clearly in chapter II in the administration part of this code. These multi-disciplinary audits will expose the vulnerability of existing buildings in terms of Fire Safety, Structural Safety as well as of Electrical Installations, etc. In fact, these post-construction audits will also be useful to know how unsafe the buildings are, vis a vis the revised norms laid down in National Buildings Code 2016, for buildings constructed based on older NBC. The authorities have completely ignored these provisions and may cite reasons for inadequate technical manpower with them as a possible cause for these violations. In such a case, NBC clearly recommends that technically qualified professionals from the market/field may be engaged to carry out the desired task and recommend strengthening/retrofitting measures. Only after the same is incorporated, the buildings should be allowed to be operated for the approved building use. These audits will ensure compliance with building Bye-Laws and also the specific approved building use of the buildings whether commercial, institutional, industrial, or residential. Hospitals are now governed by NDMA hospital safety guidelines, which extensively cover all design provisions for new and existing hospital buildings for Loading, Earthquakes, Cyclones, Fire, Ventilation, PHE, Electrical, etc.

Local authorities must gear up to ensure the recommendations of NBC, local building bye laws and guidelines of NDMA are followed in totality. The technical audits, as recommended by law (When local building By-laws incorporate NBC, NBC becomes Law), must be carried out every 3 to 5 years, and measures to enhance safety must be adopted. The author strongly feels that these steps will bring about tremendous improvement in safety levels in the entire built environment. Professional associations like the Indian Association of Structural Engineers (IAStructE), Bureau of Indian Standards (BIS), Institution of Engineers (IEI), CEAI (Consulting Engineering Association of India), COA (Council of Architecture), etc., may also be roped in for professional inputs, wherever required. This exercise needs to be diligently carried out in every city in India. India, being the fastest growing economy and having urbanization of more than 30%, needs to address these issues on top priority, as we cannot afford to put our own people in these death traps. It is high time to wake up and act, especially aftermath of the Türkiye earthquake. We have to increase monitoring and stop all illegal/unauthorized construction, especially construction in Lal Doras, and practice of additions/alterations/modifications in DDA/Government/Planned buildings, as this is a very common practice in almost all the cities, which not only weaken those buildings, but also neighbouring buildings in case of occurrence of earthquakes and/or fires.

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Sustainable and Greener Construction Materials – A Scientific Low-Cost Solution towards Mass-Housing

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Abstract

The rapid economic rise of the developing country like India requires extensive construction activities which can put a negative threat on the environment through due to the requirement of large amount of conventional Portland cement. The highly energy-intensive synthesizing process of Portland cement utilizes natural resources and releases Greenhouse gases. In contrast, geopolymer binder utilizes agro-industrial wastes and produces a low-cost, sustainable cementitious product, which has impressive engineering properties and in addition, help to alleviate climate change issues. However, till date, Geopolymer technology is majorly limited to laboratory-level application in India. In this article, an overview of geopolymeric materials, its applications, current research trends, major barriers and challenges associated with geopolymer concrete (GPC) are presented. Consequently, the possible strategies to overcome those barriers and to bring the newer material from the scientific laboratory scale to practical application are discussed. In that context, the individual contribution of research institutions, government bodies and industries are discussed. The research institute's primary role would be on developing the standard mix-design guidelines of GPC under variable environmental conditions. Whereas a strategical plan is required to be implemented by the government and industries to promote GPC. With the development and commercialisation of a sustainable low-cost building material (GPC), India's infrastructural growth will reach a new height along with putting another step towards the net zero emissions by 2070.

Keywords: Sustainable construction; Low-cost building material; Cement, Waste utilization; Geopolymer concrete.

1. Introduction

Urbanisation, in terms of constructing buildings, bridges etc., has led to an increased demand on the production of Portland cement in developing countries, like India [1]. In fact, production of cement globally has increased by more than 3 times (from 1.39 to 4.4 billion tons) in last 25 years [2] and is projected to increase upto 6 billion tons by 2050 [3]. Production of one-ton cement generates around 0.89 tons of carbon-di-oxide (CO_2), which is around 7% of the global CO_2 emissions [4]. Various efforts were made to lower the CO_2 emissions for mitigating the adverse effects of climate change [5]. Further, incorporation of green taxes to restrict the emissions of green-house gases could lead to doubling the prices of cement by 2030 [6,7]. In addition, another major challenge for the cement industry is the depletion of natural resources that is used as raw material in cement production [8]. Consequently, searching for an alternate solution for cement is of utmost importance, which in one hand should have no or less CO_2 emissions, but also should be low-cost and doesn't require natural resources for its production. Geo-polymer based cementitious binder, which utilizes various agro-industrial wastes, could be the one of the promising answers to the above three questions: negligible CO_2 emissions, low-cost and conservation of natural resources. Fig. 1 presents the various benefits of geopolymer concrete (GPC) than

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conventional Portland cement-based concrete.

The infrastructural development of India in recent times has seen a considerable growth. In the Union Budget 2021, various initiatives such as 'Housing for All', 'Smart Cities Mission' etc., were announced by the government and a fund of Rs. 13,750 crores were allocated to Smart Cities Mission and AMRUT. Towards the mass housing mission and development of smart cities, geopolymer concrete could be one of the low-cost, sustainable choice of building materials in India.

It is Prof. Joseph Davidovits who first introduced the term "geopolymer" in the year 1970 which resembles a wide range of materials in which chains of several inorganic molecules represent the binding material [9]. Production of geopolymer binder is a result of the geo-polymeric reaction (the primary difference in the production mechanism of GPC from conventional Portland cement-based concrete) that occurs between alumino-silicate based waste materials and alkali activators [10–12]. Among different alumino-silicate based agro-industrial wates, fly ash, Ground Granulated Blast Furnace Slag (GGBFS), Rice husk Ash etc., were successfully utilised in synthesizing geopolymer binder. Owing to the utilization of the various agro-industrial wastes in the production of GPC, the environmental impact that could occur from the landfilling of the wastes, could reduce significantly [13,14]. In addition to various advantages associated with GPC, the improved engineering properties such as strength, durability [15] etc., makes it more attractive to the Civil Engineering community in terms of adopting geopolymer concrete (GPC) as an alternate construction material.

This article presents an overview of geopolymeric materials and its applications in the current context of infrastructural growth without affecting the environment. The associated current research trends of the GPC along with its major barriers and challenges in its popularisation are also presented. After that, the possible strategies in overcoming those barriers and to bring the newer material from the scientific laboratory scale to practical application are discussed. Consequently, the role of research institutions, government bodies and industries are discussed. With the development and commercialisation of a sustainable low-cost building material (GPC), India's infrastructural growth will reach a new height along with achieving the net zero emissions by 2070.

2. Geopolymeric Materials and its Applications

Exploration of the ancient structures reveals that geopolymer materials were used as construction materials during 2630 BCE to 2611 BCE in Egyptian pyramids [12]. However, in terms of first residential structures, it is the building with 20 floors at Lipetsk, Russian Federation in 1989 that was made of alkali-activated geopolymer concrete i.e., no Portland cement was used [16]. Later, Global Change Institute (GCI) of the University of Queensland, Toowoomba Wellcamp Airport were also built with geopolymer concrete [17]. In India, CSIR-Central Building Research Institute, Roorkee, built a 50-meter-long and 4-meter-wide roads which is made with fly ash-based geopolymer concrete in accordance with the standards of Indian Road Congress (IRC). After that, another 1.2km long road was built in NTPC Ramagundam [18]. Further, geopolymer concrete has also been utilised in the Delhi Metro Project.

Various such application of geopolymer concrete highlights the possibility of increased utilisation of GPC in coming days which attract the attention of different public and government sectors. Other than in new construction, GPC could possibly be utilised on repairing potholes on pavements, bridges, tunnels, sewer pipe etc., owing to its improved durability properties over the conventional concrete [19]. Hence, it can be stated that GPC could rapidly replace Portland cement-based concrete.

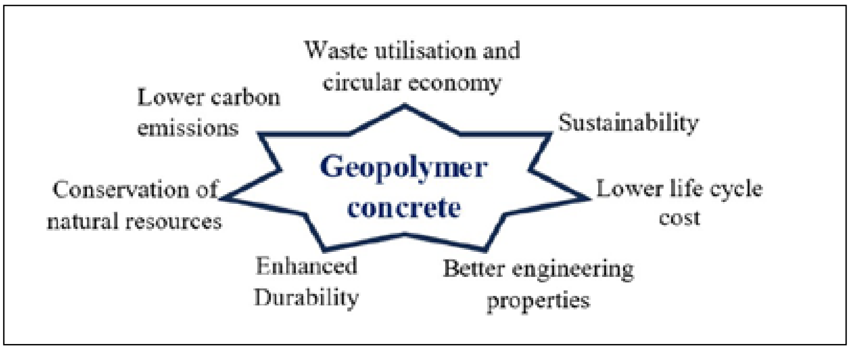

Fig. 1. Advantages of geopolymer concrete than conventional Portland cement concrete.

3. Geo-polymer concrete and its current research trends

Although several advantages are offered by geopolymer concrete over the conventional one, however, the majority of the construction activity using GPC is bounded to lab-scale or precast applications, such as railway sleepers, sewer pipes etc. The primary reason behind the non-popularisation GPC could lies in its production process. In the conventional or 'two-part' based geopolymer, solid aluminosilicate-based waste materials are mixed with a highly alkaline solution or activator. However, due to highly hazardous and corrosive nature of activator solution [20,21], the transportation and handling of large quantity of alkali solutions require special care. Further, the storage and transportation cost of the huge amount of alkali solution further limit the utilization of GPC in an in-situ construction.

Hence, at current times, researchers are focussing in producing a geopolymer binder, where the alkali solution can be replaced with solid alkali activator. Such type of geopolymer binder is known as "single component geopolymer (SCG)", in which only water is required to be added at site, a synthesising process like the OPC. Consequently, the handling difficulties of a large amount of alkali solution, transportation costs, etc., are reduced. Hence, it can be stated that SCG brings the advantages of both the traditional concrete production process along with the low-cost and sustainability of geopolymer binder. Thus, SCG could bring higher market viability [22] than both conventional two-part geopolymer and Portland cement-based concrete.

However, the utilization of a solid alkali activator in synthesizing GPC (i.e., SCG) could results in alteration of the resultant chemical reactivity. Consequently, the evolution of engineering properties of the SCG concrete could significantly vary from the conventional two-part GPC. Hence, in last few years, researcher have attempted in utilizing various solid alkali activators along with different agro-industrial wastes to synthesize SCG based concrete. In current times, other than FA and GGBFS, materials like metal industry-based wastes, sewage ash, meta-kaolin, etc., has also been employed as binary or ternary mixes with different other wastes in producing SCG concrete [23–25]. Similarly, research efforts are also being made in synthesizing low-cost solid alkali activator that require lesser energy in production [26]. The various solid activators that are under investigation in terms of its production or with respect to utilizing it in producing SCG concrete are Sodium silicates (Na_2SiO_3), Sodium Hydroxide (NaOH), Sodium sulphate (Na_2SO_4), Sodium carbonate (Na_2CO_3), etc. Consequently, such research works focus on evaluating various engineering properties, like compressive strength, tensile strength etc., of the developed SCG concrete where the above-mentioned wastes and solid alkali activators were used. A research works conducted in [15] highlights that utilisation of FA and GGBFS as wastes materials and solid Sodium Metasilicate as alkali activator can produce a SCG binder with the 28-day compressive strength of more than 100 MPa. Such a higher value of compressive strength of SCG binder under ambient curing highlight the suitability of SCG based concrete under various practical application. Apart from compressive strength, research efforts are being envisaged in evaluating other properties like flexural strength, durability etc. of SCG. The flexural or durability property of concrete is very crucial in assessing long-term performance of any concrete structure.

Hence, the current research trends in GPC or more specifically in the area of SCG based concrete is on developing standard guidelines of utilising various agro-industrial waste using single component geopolymer technology so that in practical application, one can confidently choose the suitable waste materials and alkali activators that meet the site requirement. Further, research efforts are also made in utilising SCG binder in 3D concrete printing application. A combination of 3D printing and SCG based technology could undoubtedly uplift the possibilities of commercialisation of geopolymer concrete in large-scale construction [27,28].

4. Market Trends

Due to rapid urbanisation and infrastructural development, extensive growth of geopolymer market is expected in coming days. In addition, the increased repair and rehabilitation of the existing structures would further increase the market size of geopolymer due to its improved durability properties. However, lack of standard design guidelines could hinder the growth of geopolymer market. Globally, market size of geopolymer has reached 5 billion USD in 2021 and is expected to rise 15.8 billion USD by the year 2027 [29]. Based on various application, the market can be categorised into several segments, such as, buildings, bridges, tunnels, repair and rehabilitation of existing structures, etc.

In the various above-mentioned sectors, it is expected that North America and Europe will lead the global geopolymer market in the next few years and will hold a key share. On other side, Asia Pacific region is also expected to see significant growth in the geopolymer market with the increasing infrastructural activities [30], especially in India and China. Wagner's, Geopolymer Solutions LLC, Clock Spring NRI, and Schlumberger Limited, etc [29] are expected to be the major players in the geopolymer market. However, the commercialisation of geopolymer product is still limited to few parts of the world, hence, further research and developmental work is needed.

5. Barriers and challenges of geopolymer technology in India

Adoption of geopolymer materials in construction sectors faces several barriers and challenges which include both technical and administrative issues. Below are the details of various such barriers and challenges behind the popularisation of geopolymer technology:

Lack of appropriate design standards: One of the primary causes behind non-adoption of geopolymeric materials in construction sectors lies in its non-availability of appropriate standard design guidelines. Variability in the quality and chemical compositions of different waste materials (e.g., fly ash, GGBFS, metakaolin, mine tailings, etc.) produced in different parts of the country, could results in different engineering properties of geopolymer concrete. Like waste materials, source and production process of solid alkali activators also strongly effect the performance of GPC. Hence, any standard design guidelines should include all the variability aspects mentioned above along with the composition, curing conditions etc.

Lack of awareness and government support: Lack of awareness about the low-cost, sustainability, improved engineering properties of geopolymer is another barrier behind its popularisation in the construction sector in India. Consequently, the role of governments to achieve customers' acceptance of GPC (over conventional concrete) with sufficient convincing facts is become crucial. Further, appropriate policy making, and government support is required in the adoption of newer technology in the construction sector over the conventional one. In this direction, MOEF issued guidelines of utilising 100% fly ash without which a penalty would be levied [31].

Lack of handling and safety issues: Another challenges associated with conventional geopolymer (or two-part technology) is the handling of corrosive and hazardous alkaline solution. However, with the current research efforts of utilising solid activator i.e., single component geopolymer (SCG) technology, such things can be overcome.

6. Recommendations for commercialising GPC

To overcome the various barriers and challenges associated with GPC (or more specifically SCG concrete), it is the first and foremost duties of government agencies, industries, research institutions to create awareness among the public about the huge problems of waste management and consequent environmental impact. Such awareness could be conducted through media engagements, or by conducting seminars, conferences, etc. These awareness programmes would be the first step in popularising GPC in India. Consequently, the more specific roles of the research organisations, government and industries can be separated as:

Role of Research Institutes: To overcome the technical barriers associated with the commercialisation of GPC, the role of country's research institutions becomes very important. First, it is required to characterise (in terms of chemical, mineralogical properties) the various agro-industrial wastes sourced from different parts of the country. Thereafter, utilizing such wastes in various mix-proportions along with suitable alkali activator for evaluating the different mechanical, physical, durability properties of the developed GPC under wide variety of environmental and loading conditions. Based on the extensive experimental and/or modelling framework, design standards are required to be prepared so that a practical engineer can easily use such guidelines. Here, the role of BIS and CPWD becomes crucial in preparing the guidelines. Although a few guidelines related to geopolymer concrete exist, yet such standards are limited to specific constituent type or mix-proportion.

Role of Government bodies: Along with research institutions, the role of governments bodies also become very important in implementing geopolymer technology in India. Firstly, in accordance with the provisions of research institutes, government should implement a suitable waste management policy for managing various agro-industrial wastes. In this context, the government should promote the utilization of GPC in construction sector through which the waste dumping issues, and its consequent adverse effect can be mitigated. By utilising GPC in various government projects such as bridges, highways, railway sleepers, marine structures, etc., confidence can be brought in public on utilising GPC successfully.

Role of the Construction Industries: In parallel with the research institutions and government bodies, construction industries also play the pivotal role in commercialising GPC in constructions sector. With the available standard guidelines and government's awareness, builders and contractors can promote the application of GPC in their client structures by highlighting the fact of low-cost, environment friendly, improved quality of GPC.

7. Conclusions

Reduction in carbon-footprint, waste utilization, sustainability and circular economy are some the utmost concerns in current times of many countries in the world. To achieve that goal, synthesis and utilization of single component geopolymer (SCG) concrete in the infrastructure development could serve as one of the crucial steps. The low-cost features of geopolymer concrete than conventional concreting has further attracted the attention of most of the developing countries for their urbanisation and mass housing projects. In addition, the excellent mechanical and durability properties of GPC than conventional concrete highlights the applicability of GPC.

However, utilization of newer developed geopolymer concrete replacing the conventional concrete in the construction industry have several technical and non-technical barriers. Lack of standard mix-design guidelines of GPC under variable curing conditions, constituents' type etc., is the major technical barriers. Consequently, the role of research institutions become very important in conducting the associated research activities through which the respective standards can be prepared. Similarly, the role of government and the construction industries also becomes crucial to overcome the different legal and non-technical obstacles of popularising GPC in the construction sector which is cost effective, sustainable and environment-friendly material as an alternative to conventional Portland cement concrete.

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Vulnerability Atlas of India – an effort towards Resilient Cities

Dr. Shailesh Kr. Agrawal *

Introduction

As per prevalent geo-climatic conditions, Indian sub-continent is prone to natural hazards such as earthquakes, wind storms & cyclones, landslides, floods, thunderstorms. India has witnessed several disasters leading trail of destruction, irreparable loss of lives and properties. Recognizing the vulnerability of Indian sub-continent, Disaster Management Act was enacted in 2005 followed up by National Policy for Disaster Management in 2009 and National Disaster Management Plan in 2016. Internationally also, 1990-2000 was declared as International Decade for Natural Disaster Reduction (IDNDR) by UN General Assembly, which was subsequently supported by Yokohama Strategy for Safer World in 1994, Hygo Framework for Action (2005-2015) and Sendai Framework for Disaster Risk Reduction in 2015-2030. All these policy frameworks brought paradigm shift in disaster risk management from post disaster relief centric measures to pro-active pre-disaster preventive measures.

As per National Disaster Management Authority (NDMA) report, about 58.6% land area of India is vulnerable to earthquakes of modern to very high intensity; about 12% of land (over 40 million Ha) is prone to floods and river erosion; 5700 km of coast line out of 7516 km long coast line is prone to cyclones, wind storm surges and tsunamis; 68% of cultivable area is vulnerable to drought and hilly area are at risk from landslides and avalanches. As such the vulnerability to these natural phenomenon exist and one cannot do much about it, however it is the man made habitat which pose much danger and cause irreparable losses to life and property. This is more aggravated by exponential rise in population, urbanization and hackneyed construction practices. Occurrence of natural hazards adversely affect the existing housing and building stock and it is estimated that about 1.2 to 1.5 million houses get damaged by one natural hazard or the other every year.

It is high time that we recognize the risk to the existing housing and infrastructure and at the same time take preventive measures in the future constructions. Under the umbrella of Ministry of Housing and Urban Affairs, Govt. of India, one of the major contribution of BMTPC i.e., bringing out Vulnerability Atlas of India which till date is the only document existing on damage risk to housing stock in India w.r.t. natural hazards i.e., earthquake, wind & cyclone and flood. The atlas was first published way back in 1997, and then second edition in 2006, based on 2001 Census data. The third edition of the Vulnerability Atlas of India based on 2011 Census data was brought out in 2019 which includes hazard maps of earthquakes, wind/cyclones, floods, landslides, thunderstorms and vulnerability risk tables based on available latest data in order to help in enhancing preparedness of Governments and various other agencies in mitigating natural disasters. The Atlas is a useful tool not only for public but also for urban managers and National & State Authorities dealing with disaster mitigation and management.

VULNERABILITY ATLAS OF INDIA : INTRODUCTION

Vulnerability Atlas of India, 1997

BMTPC in 1997 brought out the *first of its kind* Vulnerability Atlas of

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India covering whole country with respect to earthquakes, cyclones and floods. The Atlas contains State and UT-wise hazard maps showing the degree of vulnerability right up to the district levels and also district-wise tables of housing stock indicating the risk against the forces of natural hazards which may strike in a particular region.

Nearly 80% of the housing stock in the country belongs to non-engineered category, thereby leading to much higher risk of damage and destruction on account of natural hazards like earthquake, cyclones, floods, landslides, etc.

This Atlas has been a benchmark contribution of the BMTPC and has been commended nationally and internationally. The formulation of the Vulnerability Atlas can be claimed as the first example of its type not only in India but in the whole developing world. As a result, the International Jury set up by IDNDR Secretariat ranked this work of BMTPC at the 4th position out of the 41 international projects of such kind. The Vulnerability Atlas of India was also recognized as GOOD PRACTICE amongst the cases received for Best Practices by the UN-HABITAT under Dubai International Awards for the year 2006.

Vulnerability Atlas of India, 2006

With increasing emphasis by the Central Government on proactive, preventive and mitigation measures by all States and Union Territories (UTs), availability of latest information about hazards and vulnerability in a user friendly manner has become a necessity. Since the publication of the Vulnerability Atlas in 1997, hazard scenario especially with respect to earthquakes and floods has undergone changes. At the same time more information are available on seismo-tectonic feature of the country, tsunami effect of earthquakes, storm surge, rainfall data and landslides. Housing scenario has also changed and latest information available through Census 2001. Politically also new States were formed and number of districts were created. Keeping all these in view, under the guidance of the Ministry of Housing and Urban Poverty Alleviation, Government of India, BMTPC was entrusted the task of revising the Atlas of 1997 through a Peer Group.

Accordingly, the second edition Vulnerability of India was brought out by BMTPC in 2006 based on Census 2001 data using GIS tools and digitized maps were developed for the first time providing hazard and seismo-tectonic information upto district level. Based on Census Housing Stock data, housing risk tables upto districts were also published based on distribution of houses by predominant material of roof and wall.

Vulnerability Atlas of India, 2019

Since the publication of Vulnerability Atlas of India in 2006, there has been invaluable feedback from users on the Atlas. Also, Vulnerability Atlas of India was brought out in digitized CD form in 2008 and was also uploaded on National Informatics Centre (NIC) platform. National Institute of Disaster Management (NIDM), Government of India also used the Atlas for training SAARC countries so as to prepare the region towards disaster risk reduction.

There have been subtle changes in the available knowledge and information in the area of disaster mitigation and management. New datasets with respect to earthquake occurrence, cyclones, wind storms, landslides, thunderstorm etc. have been brought out by nodal government agencies. There are demographic changes also on account of formation of new States and new districts. During this period, the country has also experienced some damaging earthquakes, cyclones, floods and landslides. Thunderstorms, urban flooding, flash floods have also caused significant damages to lives and properties.

BMTPC brought out the third edition of the Vulnerability Atlas of India based on 2011 Census data in 2019 which includes hazard maps of earthquakes, wind/cyclones, floods, landslides, thunderstorms and vulnerability risk tables based on available latest data in order to help in enhancing preparedness of Governments and various other agencies in mitigating natural disasters. Hon'ble Prime Minister of India, released the digital version of Third Edition of Vulnerability Atlas of India on the occasion of Global Housing Technology Challenge - India (GHTC-India), Construction Technology India 2019 Expo-cum-Conference on 2nd March, 2019 at New Delhi organized by Ministry of Housing & Urban Affairs. The Hon'ble Prime Minister, while releasing the Atlas, emphasized the need to formulate & implement various schemes of the Central & State Governments keeping in view the vulnerability of the region & indicative risk assessment as given in Vulnerability Atlas of India and suitable provisions should also be included in the tender documents.

The digital version of Third Edition of the Vulnerability Atlas of India has been made available at https://vai.bmtpc.org for wider access by various stakeholders.

Hazard Maps

The monitoring of hazards in the country is being carried out by (a) Seismic occurrence and cyclone hazard monitoring by IMD and (b) flood monitoring by the CWC. In addition, noteworthy contributions are made by Geological Survey of India in mapping of seismic hazard and landslide hazard prone areas and the Department of Earthquake Engineering, Indian Institute of Technology Roorkee (DEQ), on all aspects of engineering concerning seismic risk. It is pertinent to mention here that the Bureau of Indian Standards Committees on Earthquake Engineering and Wind Engineering has already prepared a Seismic Zoning Map and the Wind Velocity Map including cyclonic winds for the country, and the Central Water Commission has prepared a Flood Atlas of India. BMTPC has also published a Landslide Hazard Zonation Atlas of India.

BMTPC used these hazard maps to prepare 1:2 million scale maps by superimposing the above available data on Survey of India map of this scale as the base map. The earthquake, wind storm and flood hazard maps are drawn for each State and Union Territory separately in which the various district boundaries are clearly shown for easy identification of the hazard risk prone areas. The seismic zones of India based on intensities of earthquakes on MSK scale and intensity of the wind hazard related with wind speed are shown on the maps clearly identifying the various intensity zones.

Earthquake Hazard Maps

The Indian subcontinent has a history of recurrent occurrence of earthquakes with moderate to high intensities. The latest version of seismic zoning map of India as given in IS 1893 (Part 1): 2002 assigns four levels of seismicity for India in terms of zone factors. In other words, the earthquake zoning map of India divides India into 4 seismic zones (Zones II, III, IV and V). According to the present zoning map, Zone V expects the highest level of seismicity whereas Zone II is associated with the lowest level of seismicity. The general basis of the zones as deliberated in the code is as follows:

Zone V: Covers the areas liable to seismic intensity IX and above on MSK (1964) Intensity Scale. This is the most severe seismic zone and is referred here as Very High Damage Risk Zone.

Zone IV: Gives the area liable to MSK VIII. This zone is second in severity to zone V. This is

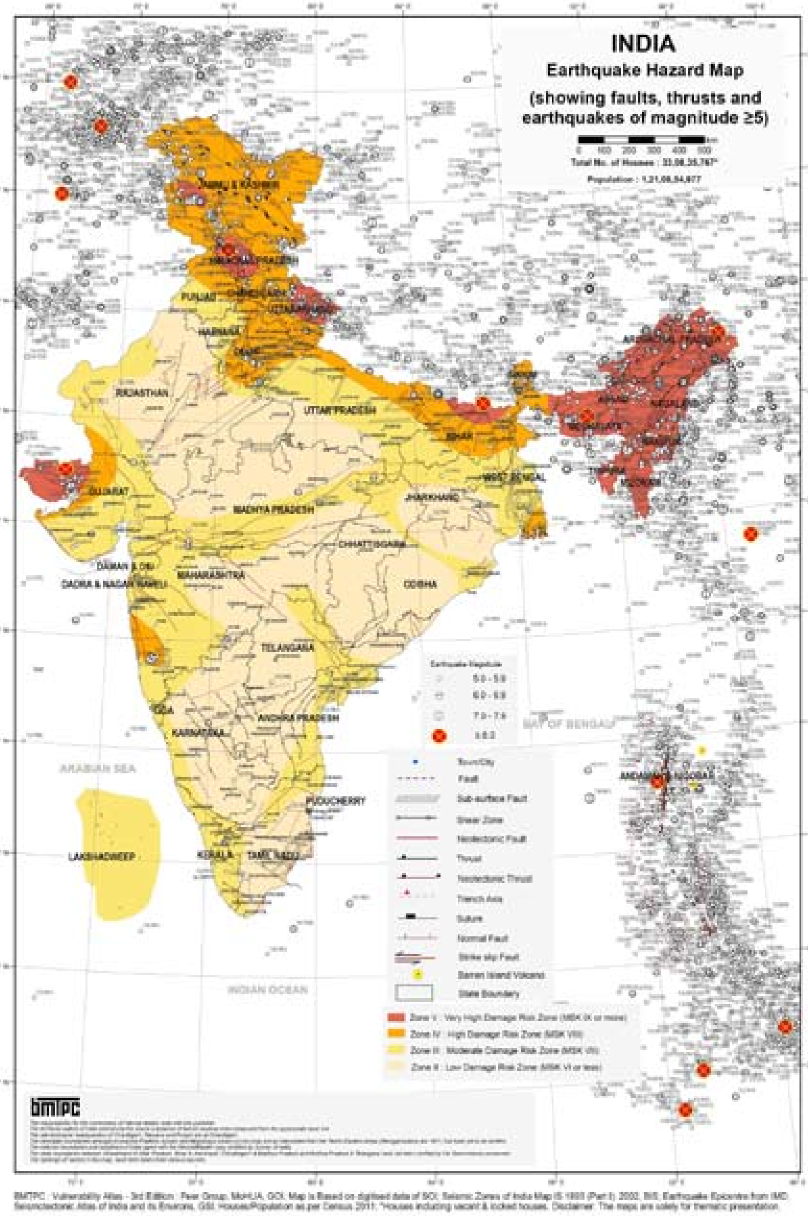


Fig.1: Earthquake Hazard Map of India

referred here as High Damage Risk Zone.

Zone III: The associated intensity is MSK VII. This is termed here as Moderate Damage Risk Zone.

Zone II: The probable intensity is MSK VI or less. This zone is referred to as Low Damage Risk Zone.

The Earthquake Hazard Map of India, States and Union Territories includes the seismic zonation of India, faults and thrusts, epicenters of earthquakes from IMD besides giving administrative boundary of States and districts (**Fig.1**).

Wind/Cyclone Hazard Maps

The country level as well as state-wise wind hazard maps contain the following information:

Basic Wind Speed Zones : The macro-level wind speed zones of India have been formulated and published in IS 875 (Part 3):1987 entitled "Indian Standard Code of Practice for Design Loads (other than earthquakes) for Buildings and Structures, Part 3 Wind Loads". There are six basic wind speeds V_b considered for zoning, namely 55, 50, 47, 44, 39 and 33 m/s. From wind damage view point, these could be described as follows:

55 m/s (198 km/h) - Very High Damage Risk Zone - A

50 m/s (180 km/h) - Very High Damage Risk Zone - B

47 m/s (169.2 km/h) - High Damage Risk Zone

44 m/s (158.4 km/h) - Moderate Damage Risk Zone - A

39 m/s (140.4 km/h) - Moderate Damage Risk Zone - B

33 m/s (118.8 km/h) - Low Damage Risk Zone

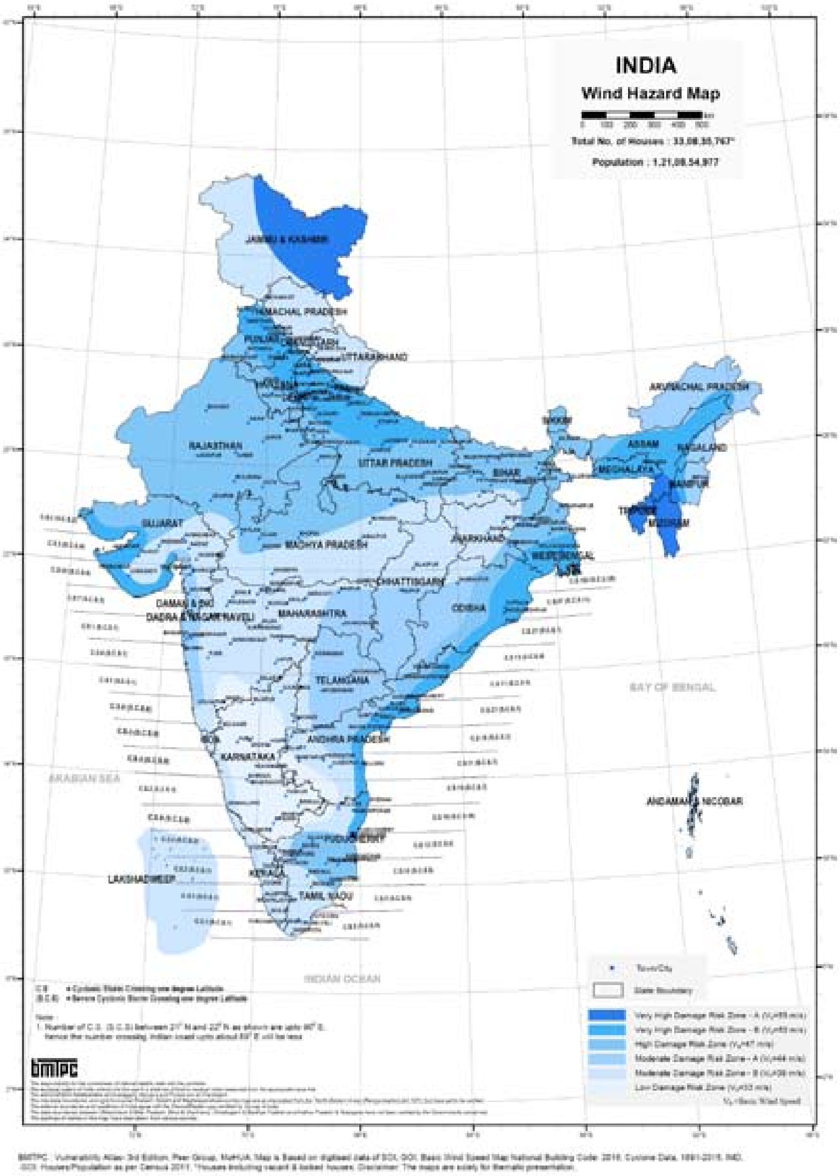


Fig.2: Wind Hazard Map of India

The basic wind-speed zones are plotted in statewise maps which show the district boundaries as well as the district towns for their easy identification. The Wind Hazard Map of India is given in **Fig.2**.

Flood Hazard Maps

The flood hazard maps (**Fig.3**) in the Vulnerability Atlas are based on the Flood Atlas of India (1987), and updated flood prone areas of Assam and other neighboring States including Bihar, West Bengal and Eastern Uttar Pradesh included in the Task Force Report (2004). These maps mark the areas which are liable to flooding. Since these maps given herein also show the district boundaries and the location of the district towns along with the rivers, districtwise identification of the vulnerable areas will be easy. As regards latest data on flood prone areas is concerned, the scientific assessment of flood prone area in India is under progress by CWC. The existing flood maps presented here are of 2006 Atlas and will be updated as and when the data is made available by CWC.

Landslide Incidence Maps

In the third edition of the Vul-

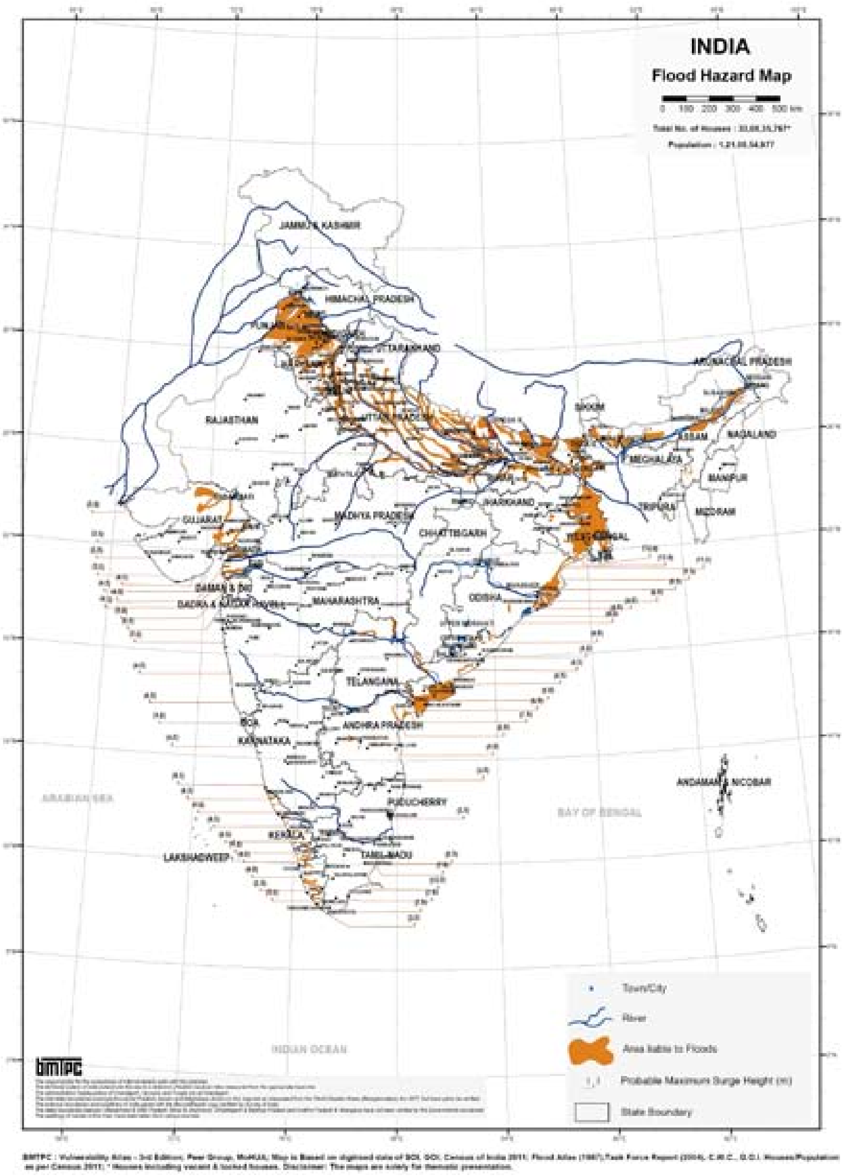


Fig.3: Flood Hazard Map of India

nerability Atlas of India, 9883 nos. historic landslide data, that have been mapped and field validated till 2016 by the Geological Survey of India (GSI) – the nodal department of landslide studies in India, are incorporated to depict the landslide vulnerability of the various States of India. The distribution of such historic landslide incidences indirectly shows the relative densities of landslides in different such landslide prone States in the map as well as also in the associated textural database, indicating their types of movement, material type and dimensions, and in some cases their initiation years and damage details, wherever such information are available. However, landslide incidences demonstrated in this Vulnerability Atlas (**Fig.4**) are time-dependent and dynamic features, therefore, its signatures in cases of many smaller landslides cannot always be recognized on ground on present day because of rapid land use and vegetation changes in time. Besides, in the Landslide Incidence Map, the annual state rainfall normal as provided by IMD has also been shown.

Thunderstorm Incidence Map

Thunderstorm is a severe weather phenomenon, the impact of which is felt by all the sectors of society including aviation service; it occurs all over the world. In general, the orographically dominant regions as well as the coastal areas are more prone to thunderstorm activities. In Indian scenario, most thunderstorm prone area is north-eastern states and adjoining east India. Thunderstorm is popularly known as 'Nor'westers' over these regions because most of them move from northwest to southeast over these regions. Frequency of thunderstorms is the maximum during pre-monsoon season (April-May). It is accompanied with lightning, squalls and sometimes heavy rain and hailstorms. Thunderstorm incidence map showing number of thunderstorm at a station during the period 1981-2010 have been presented in **Fig.5**.

State-Wise Maps

The State wise maps of various hazard such as Earthquake Hazard Maps of Gujarat (**Fig.6**), Wind Hazard Map of Odisha (**Fig.7**), Flood Hazard Map of Bihar (**Fig.8**) and Landslide Map of Uttarakhand (**Fig.9**) are given here.

Vulnerability and Risk Assessment

It is noted that preliminary effort toward vulnerability assessment of buildings under seismic and cyclone intensities has been made by the Deptt. of Earthquake Engineering, Indian Institute of Technology, Roorkee and Structural Engineering Research Centre (SERC), Chennai, respectively. Taking guidance from this work, the types of housing as existing in each district has been taken from the Census of India, 2011 and categorised from vulnerability

Fig.4: Landslide Incidence Map of India

Fig.5: Thunderstorm Incidence Map of India

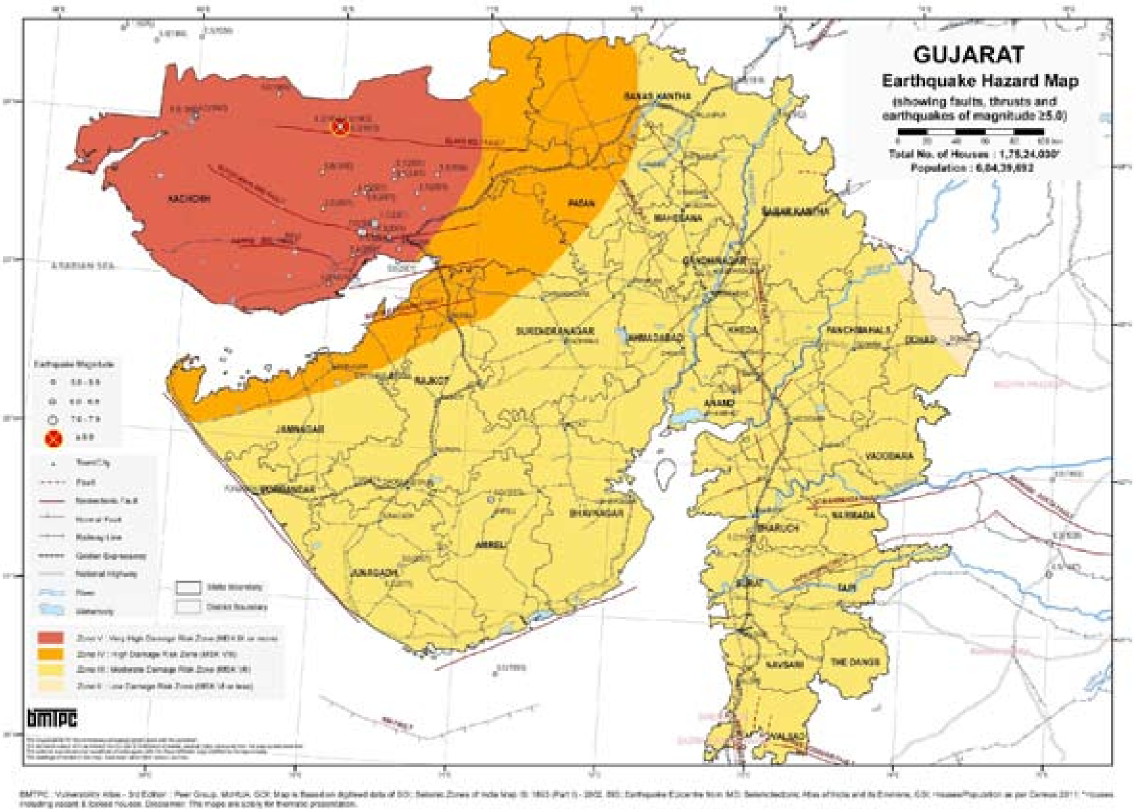


Fig.6: Earthquake Hazard Map of Gujarat

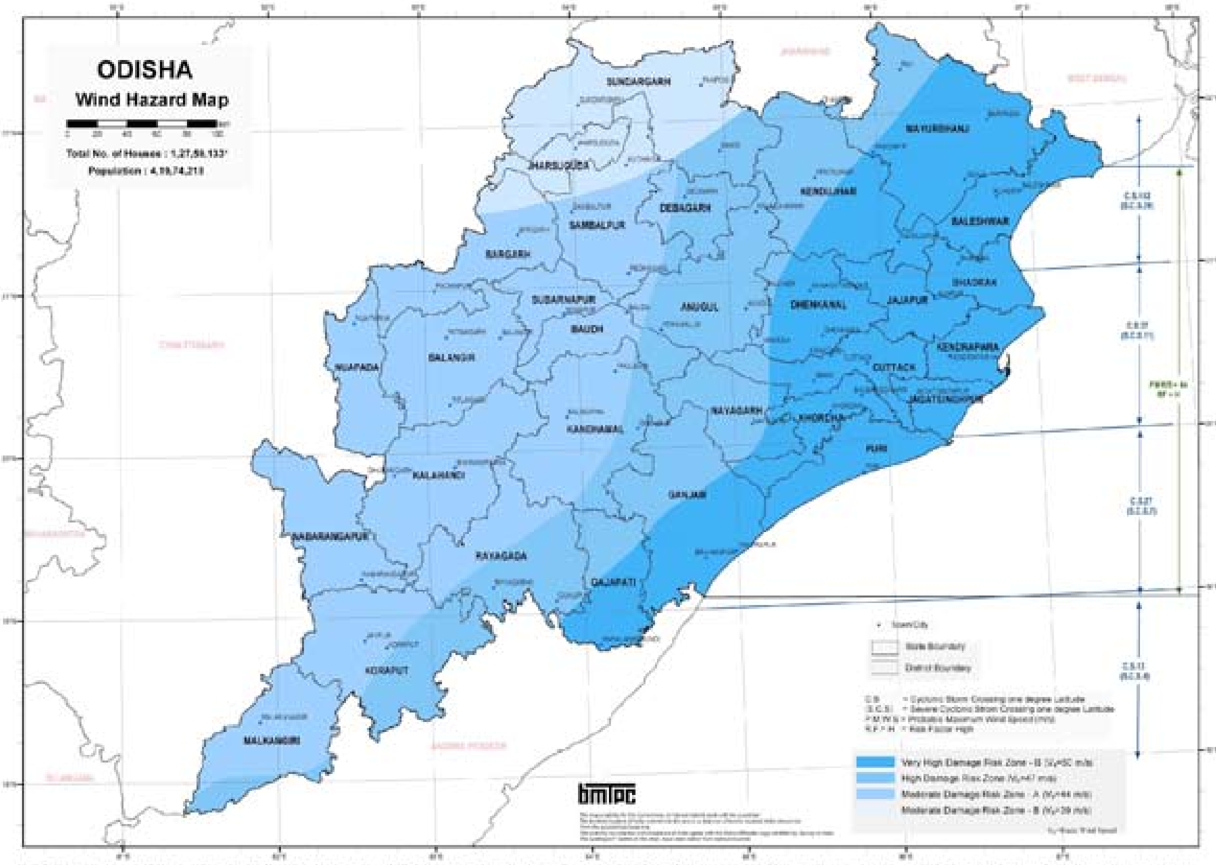


Fig.7: Wind Hazard Map of Odisha

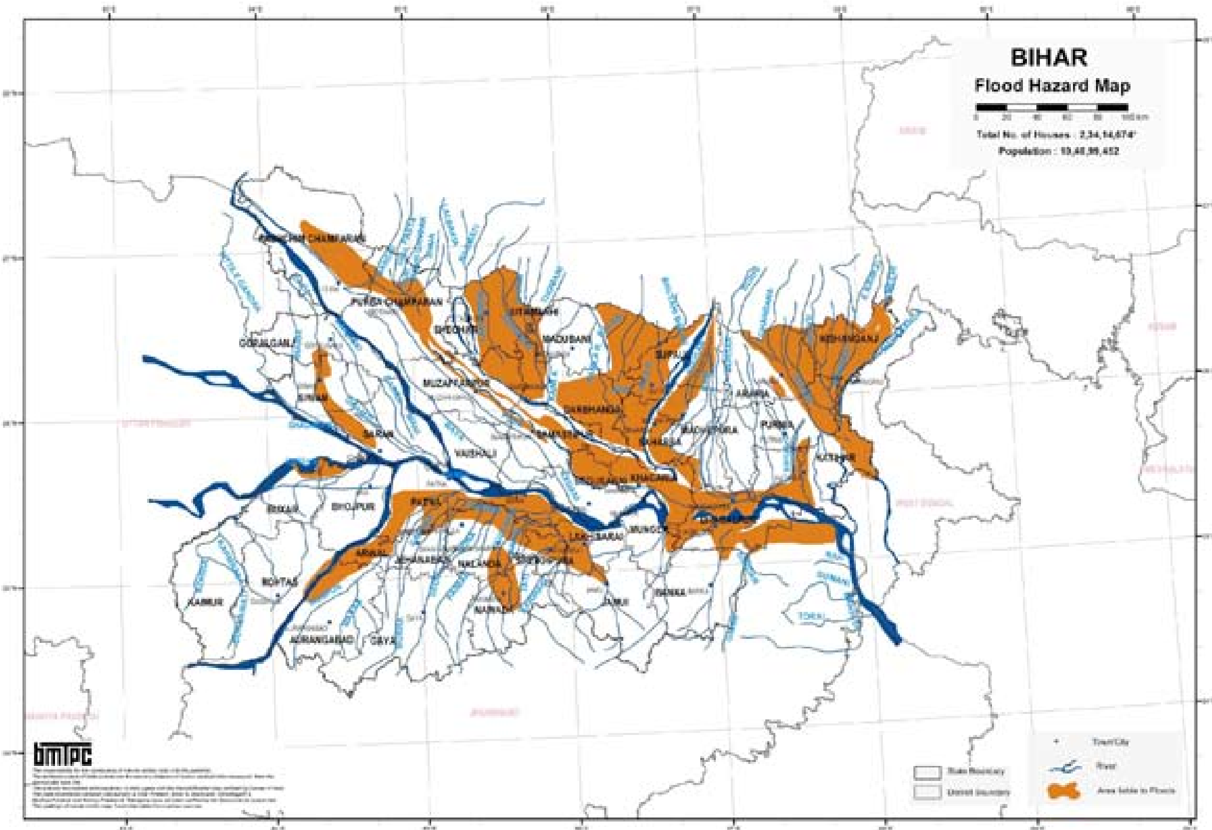
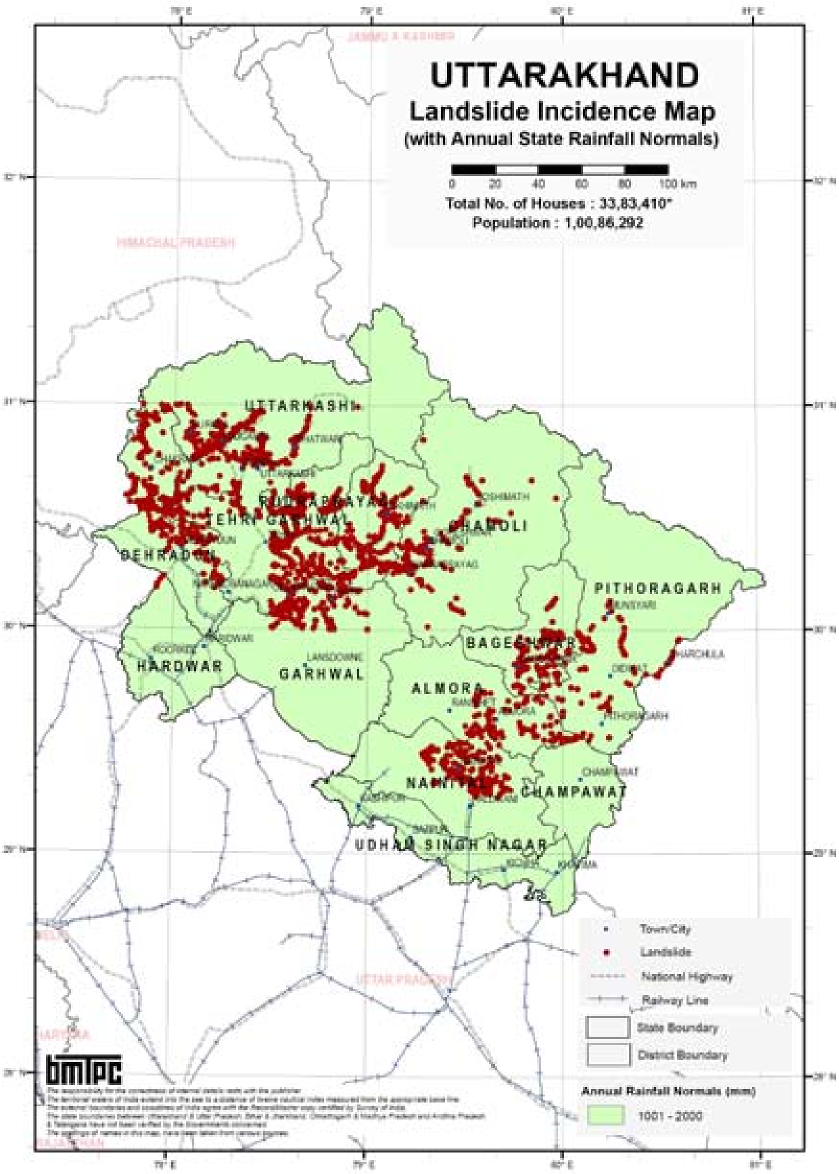


Fig.8: Flood Hazard Map of Bihar



BMTPC: Vulnerability Atlas - 3rd Edition: Peer Group, MoHUA,GOI: Map is Based on digitised data of SOI: Landslide Incidence data GSI: Annual Rainfall data IMD. Houses/Population as per Census 2011; * Houses including vacant & locked houses. Disclaimer: The maps are solely for thematic presentation.

Fig.9: Landslide Incidence Map of Uttarakhand

consideration. The vulnerability of these types to various intensities of the hazards including floods was estimated based on knowledge gained in past disaster damage surveys, and the damage risk present in each district is presented accordingly in a separate table for each district wherein the area of the district prone to various hazard intensities has also been shown.

The distribution of houses based on Predominant materials of roof and wall over whole of India according to 2011 Census is shown in Table-1. From the point of view of vulnerability to the earthquake, wind or flood hazards, it was seen that the type of flooring had hardly any significance, hence omitted from consideration, and that the roof types and wall types could not be grouped together. The appropriate grouping for the whole of India is shown in Table-2, wherein the wall and roofing groups have been categorized.

With these groupings, the vulnerability of each subgroup could be defined separately for any given intensity of earthquake, wind or flood hazard. The risk levels of the various categories of houses for the three hazards are shown in Table-3.

Table 1: Distribution of houses by predominant materials of roof, wall and floor over whole of India as per 2011 Census

Houses by Material of Roof in India (Census of India 2011 – Housing Data)

	Total number of census houses	Grass/ Thatch/ Bamboo/ Wood/ Mud, etc.		Plastic/ Polythene		Hand made Tiles		Machine made Tiles		Burnt Brick		Stone/Slate		G.I./ Metal/ Asbestos sheets		Concrete		Any other material	
		No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%
Rural	206,563,690	42,727,900	20.7	1,459,766	0.7	34,822,769	16.9	20,092,484	9.7	14,860,852	7.2	19,119,151	9.3	34,381,089	16.6	38,238,079	18.5	861,600	0.4
Urban	98,318,758	4,259,769	4.3	613,607	0.6	5,453,980	5.5	6,332,576	6.4	5,394,029	5.5	7,862,543	8.0	15,955,314	16.2	52,005,804	52.9	441,136	0.4
Total*	304,882,448	46,987,669	15.4	2,073,373	0.7	40,276,749	13.2	26,425,060	8.7	20,254,881	6.6	26,981,694	8.8	50,336,403	16.5	90,243,883	29.6	1,302,736	0.4

Houses by Material of Wall in India

	Total number of census houses	Grass/ Thatch/ Bamboo etc.		Plastic/ Polythene		Mud/ Unburnt brick		Wood		Stone not packed with mortar		Stone packed with mortar		G.I./Metal/ Asbestos sheets		Burnt brick		Concrete		Any other material	
		No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%
Rural	206,563,690	26,417,331	12.8	762,256	0.4	58,330,614	28.2	2,132,342	1.0	7,751,666	3.8	20,934,124	10.1	1,269,359	0.6	83,618,436	40.5	3,699,096	1.8	1,648,466	0.8
Urban	98,318,758	2,530,263	2.6	335,575	0.3	8,119,213	8.3	648,929	0.7	2,689,476	2.7	12,107,666	12.3	1,062,510	1.1	62,927,369	64.0	7,284,583	7.4	613,174	0.6
Total*	304,882,448	28,947,594	9.5	1,097,831	0.4	66,449,827	21.8	2,781,271	0.9	10,441,142	3.4	33,041,790	10.8	2,331,869	0.8	146,545,805	48.1	10,983,679	3.6	2,261,640	0.7

Houses by Material of Floor in India

	Total number of census houses	Mud		Wood/ Bamboo		Burnt Brick		Stone		Cement		Mosaic/ Floor tiles		Any other material	
		No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%	No. of Houses	%
Rural	206,563,690	127,431,172	61.7	2,088,961	1.0	5,345,565	2.6	12,290,562	6.0	51,436,407	24.9	7,434,415	3.6	536,608	0.3
Urban	98,318,758	11,254,774	11.4	486,629	0.5	2,511,582	2.6	11,685,210	11.9	46,620,799	47.4	24,836,212	25.3	923,552	0.9
Total*	304,882,448	138,685,946	45.5	2,575,590	0.8	7,857,147	2.6	23,975,772	7.9	98,057,206	32.2	32,270,627	10.6	1,460,160	0.5

** Excluding locked/vacant houses*

Note : Percentage (%) is calculated with respect to the respective Total Census Houses given in column one

Table 2: Distribution of houses by predominant materials of roof and wall and level of damage risk

INDIA

Wall / Roof		Census Houses: No. of Houses	Census Houses: %	Level of Risk under EQ Zone (Area in %): V	IV	III	II	Wind Velocity m/s (Area in %): 55 & 50	47	44 & 39	33	Flood Prone Area in %
INDIA				11.3	14.4	31.1	43.2	18.0	30.3	45.1	6.6	7.3
WALL												
A1 - Mud & Unburnt Brick Wall	Rural	58,330,614	19.1									
	Urban	8,119,213	2.7									
	Total	***66,449,827***	***21.8***	*VH*	*H*	*M*	*L*	*VH*	*H*	*M*	*L*	*VH*
A2 - Stone Wall not packed with mortar	Rural	7,751,666	2.5									
	Urban	2,689,476	0.9									
	Total	***10,441,142***	***3.4***	*VH*	*H*	*M*	*L*	*H*	*M*	*L*	*VL*	*VH*
Total - Category - A		***76,890,969***	***25.2***									
B - Burnt Bricks Wall & Stone wall packed with mortar	Rural	104,552,560	34.3									
	Urban	75,035,035	24.6									
	Total	***179,587,595***	***58.9***	*H*	*M*	*L*	*VL*	*H*	*M*	*L*	*VL*	*H/M*
Total - Category - B		***179,587,595***	***58.9***									
C1 - Concrete Wall	Rural	3,699,096	1.2									
	Urban	7,284,583	2.4									
	Total	***10,983,679***	***3.6***	*M*	*L*	*VL*	*VL*	*L*	*VL*	*VL*	*VL*	*L/VL*
C2 - Wood wall	Rural	2,132,342	0.7									
	Urban	648,929	0.2									
	Total	***2,781,271***	***0.9***	*M*	*L*	*VL*	*VL*	*VH*	*H*	*M*	*L*	*H*
Total - Category - C		***13,764,950***	***4.5***									
X - Other Materials	Rural	30,097,412	9.9									
	Urban	4,541,522	1.5									
	Total	***34,638,934***	***11.4***	*M*	*VL*	*VL*	*VL*	*VH*	*H*	*M*	*L*	*VH*
Total - Category - X		***34,638,934***	***11.4***									
TOTAL HOUSES*		**304,882,448**										
ROOF												
R1 - Light Weight Sloping Roof	Rural	79,430,355	26.1									
	Urban	21,269,826	7.0									
	Total	***100,700,181***	***33.1***	*M*	*M*	*L*	*VL*	*VH*	*VH*	*H*	*M*	*VH*
R2 - Heavy Weight Sloping Roof	Rural	74,034,404	24.3									
	Urban	19,649,099	6.4									
	Total	***93,683,503***	***30.7***	*H*	*M*	*L*	*VL*	*H*	*M*	*L*	*VL*	*H*
R3 - Flat Roof	Rural	53,098,931	17.4									
	Urban	57,399,833	18.8									
	Total	***110,498,764***	***36.2***	*Damage Risk as per that for the Wall supporting it*								
TOTAL HOUSES*		**304,882,448**										

Housing Category : Wall Types

Category - A : Buildings in field-stone, rural structures, unburnt brick houses, clay houses

Category - B : Ordinary brick building; buildings of the large block & prefabricated type, half-timbered structures, building in natural hewn stone

Category - C : Reinforced building, well built wooden structures

Category - X : Other materials not covered in A,B,C. These are generally light.

Notes: *1. Flood prone area includes that protected area which may have more severe damage under failure of protection works. In some other areas the local damage may be severe under heavy rains and chocked drainage.*

2. Damage Risk for wall types is indicated assuming heavy flat roof in categories A, B and C (Reinforced Concrete) building

3. Source of Housing Data : Census of Housing, GOI, 2011

Housing Category : Roof Type

Category - R1 - Light Weight (Grass, Thatch, Bamboo, Wood, Mud, Plastic, Polythene, GI Metal, Asbestos Sheets, Other Materials)

Category - R2 - Heavy Weight (Tiles, Stone/Slate)

Category - R3 - Flat Roof (Brick, Concrete)

EQ Zone V : Very High Damage Risk Zone (MSK > IX)

EQ Zone IV : High Damage Risk Zone (MSK VIII)

EQ Zone III : Moderate Damage Risk Zone (MSK VII)

EQ Zone II : Low Damage Risk Zone (MSK < VI)

Level of Risk : VH = Very High; H = High; M = Moderate; L = Low; VL = Very Low

* Total No.of Houses excluding Vacant/Locked Houses

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Table 3: Damage risk to housing under various hazard intensities

Category Type of Wall		Level of Risk: Seismic Zone: V	IV	III	II	Wind Velocity m/s: 55 & 50	47	44 & 39	33	Flood Prone
A1	Mud and Unburnt Brick	VH	H	M	L	VH	H	M	L	VH
A2	Stone Wall	VH	H	M	L	H	M	L	VL	VH
B	Burnt Bricks Wall	H	M	L	VL	H	M	L	VL	H/M
C1	Concrete Wall	M	L	VL	VL	L	VL	VL	VL	L/VL
C2	Wood wall	M	L	VL	VL	VH	H	M	L	H
X	Other Materials	M	VL	VL	VL	VH	H	M	L	VH
Category Type of Roof										
R1	Light Weight Sloping Roof	M	M	L	VL	VH	VH	H	M	VH
R2	Heavy Weight Sloping Roof	H	M	L	VL	H	M	L	VL	H
R3	Flat Roof	Damage Risk as per that for the Wall supporting it								

Table 3...contd.

Building Category : (By Wall Material)

Category - A :	Buildings in field-stone, rural structures, unburnt brick houses, clay houses
Category - B :	Ordinary brick building; buildings of the large block and prefabricated type, half-timbered structures, building in natural hewn stone
Category - C :	Reinforced concrete building, well built wooden structures
Category - X :	Other materials not covered in A,B,C. like light sheets and biomass materials

Note : Damage Risk is indicated assuming heavy flat roof in cases A, B and C (Reinforced Concrete) building

Building Category : (By Roof Material)

Category - R1 :	Light Weight Sloping Roof (Grass, Thatch, Bamboo, Wood, Mud, Plastic, Polythene, GI Metal, Asbestos Sheets, etc)
Category - R2 :	Heavy Weight Sloping Roof (Tiles, Stone/Slate)
Category - R3 :	Flat Roof (Brick, Concrete)

EQ Zone V : Very High Damage Risk Zone (MSK > IX)
EQ Zone IV : High Damage Risk Zone (MSK VIII)
EQ Zone III : Moderate Damage Risk Zone (MSK VII)
EQ Zone II : Low Damage Risk Zone (MSK < VI)

Level of Risk : VH = Very High; H = High; M = Moderate; L = Low; VL = Very Low

Notes:

1. *Flood prone area includes that protected area which may have more severe damage under failure of protection works. In some other areas the local damage may be severe under heavy rains and chocked drainage.*
2. *Source of Housing Data : Census of Housing, GOI, 2011*

Epilogue

The Vulnerability Atlas of India presented through this chapter is a tool to understand the overall hazard scenario and risk to the existing building stock for earthquake, wind & cyclone and floods at macro-level. It is unique in a sense that no other document is available for projecting risk to existing building stock till date. However, it is just an initiative and for better preparedness and mitigation, the studies at micro level are required. There have been number of studies by academic and other institutions, but still, it is a long way to go before the hazard and risk maps at micro level are published officially for public use.

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Influence of Quick Lime Addition in the Fly Ash based Geopolymeric Mortar and Concrete for improvement of Compressive Strength at Ambient Atmosphere




Manish Mudgal [1] *J.S Chauhan* [2] *Akash Nageshwar* [3] *R. K. Chouhan* [4]

Abstract

In this present investigation Class F fly ash based Geopolymeric mortar and concrete have been developed using fly ash collected from Satpura Thermal Power station, Sarni Distt. Betul, M.P. (India).

The studies conducted for assessing Influence of Quick Lime Addition in the Fly Ash based Geopolymeric Mortar and Concrete for improvement of Compressive Strength at Ambient Atmosphere. Fly Ash based geopolymer binder have been developed using sodium hydroxide and sodium silicate as alkaline activators.

The quick lime has been added at dosages of 0,1, 2, 3, 4, 5, 6, 7, 8, 9, and 10% by weight of fly ash, and the standard consistency and setting time were tested for specimens cured at room temperature. The results showed that the addition of optimized dose of 7 to 9 wt.% calcium oxide (Quick Lime) with fly ash dramatically decreased the room-temperature Setting time and increased the compressive strength of fly ash-based geopolymer mortar and concrete. X-ray fluorescence (XRF), X-ray diffraction (XRD) and Field emission scanning electron microscopy (FE-SEM) test techniques were performed to get insight into the binder microstructural phases and their chemical characteristics.

Keywords: Fly ash; Quick Lime Geopolymer; Setting time; compressive strength.

Introduction

Cement is an important raw material in building. It is used in concrete and cement mortar as a binder. The production of OPC emits significant volumes of carbon dioxide (CO_2), which contributes to greenhouse gas emissions. One ton of carbon $_{dioxide}$ is discharged for every ton of cement produced. Currently, the world's annual OPC output is 1.6 billion tons, accounting for around 7% of worldwide CO_2 emissions. Furthermore, one ton of OPC necessitates the computation of 1.5 tons of limestone, which not only contributes to global warming but also consumes a large quantity of natural resources and energy. As a result, another source as a substitute for cement is urgently required.

Geopolymers are being used in a variety of applications due to their properties better than the properties of conventionalmaterials. Fast setting and attaining high compressive strength, resistance against fire and acids, and low CO_2 production is the main property of geopolymers. Geopolymers are employed in a range of applications because their qualities outperform those of traditional materials. The major attribute of geopolymers is their rapid setting and high strength under compression, resistance to fire and acidic substances, and minimal CO_2 generation.

Geopolymers are a type of alkaline-activated aluminosilicate material developed through acti-

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vating aluminosilicate raw materials with alkali. Geopolymers are synthesized using metakaolin, fly ash, and slag as aluminosilicate materials, sodium hydroxide and potassium hydroxide as alkali solutions, and/or sodium and potassium silicates as silica sources. Fly ash is a byproduct of coal-fired power stations that contains significant levels of silica and alumina. The use of fly ash in the synthesis of geopolymers results in environmental advantages as well as economic benefits from the sale of by-products for the synthesis of valuable goods [1]. Many elements influence the features of the final geopolymer in both macrostructure and microstructure throughout the manufacturing process, including raw materials or precursors, calcination temperature/ thermal treatment, particle size, activating solution/activator, and treatment technique. In addition to these variables, the molarity concentration of the NaOH activator solution might influence the properties of geopolymer binders. [2]. The use of fly ash as a precursor containing more than 50% silica and alumina activated by an alkaline activator can yield compressive strength greater than ordinary cement, according to research. [2–3]. Because of the high silica content of rice husk ash, ceramic and glass waste, kaolin, and clay, geopolymer binders with compressivestrengths greater than 20 MPa may be produced. [4–5].

In addition to compressive strength, the initial and ultimate setting times of geopolymer binders are key parameters to consider. With increasing ratios of fly ash precursors and ground granulated blast furnace slag (GGBS), the setting time increased. The optimal GGBS/fly ash ratio of 40% resulted in an initial setting time of 5-58 minutes and a final setting time of 65- 105 minutes [6]. The processing time of geopolymer binders may be affected by the weight of the precursor as well as the composition of the alkaline activator. The use of sodium silicate as an alkaline activator can reduce the initial and final setting time of the geopolymer. When the water/solid (W/S) ratio increases, so do the compressive strength and bonding time of geopolymer binders. In addition, increasing the Silica/ Alumina (Si/Al) ratio can improve compressive strength while lowering bonding time. [7].

Compared to the previous research on the alkali-activation of fly ash, the enhanced mechanical properties of fly ash- based geopolymer enquired elevated curing temperature. The main thrust of the work reported herein is to investigate the use of calcium oxide addition on the alkali-activated fly ash-based geopolymer to enhance the mechanical properties.

1. Materials and Methods

The aluminosilicate precursor used for the production of fly ash-based geopolymers was Class F fly ash. The fly ash was collected from m Satpura Thermal Power Station, Sarni, the deposit which is located 150 km from Bhopal city. The fly ash was received in particle sizes ranging from 10 to 100 µm. The fly ash was dry before use in the process. XRF was used to determine the chemical composition which is (presented in Table 1) showed that the fly ash mainlyconsisted of silica and alumina with a total content of 74.7 wt.% of fly ash.

Calcium oxide was added at percentages of 0,1, 2, 3, 4, 5, 6, 7, 8, 9, and 10% by weight of fly ash, For the standard consistency and setting time of geopolymer binder. Fly ash-based geopolymers were synthesized using sodium hydroxide and sodium silicate flakes solution. It was purchased from Central Drug House (Pvt.) Ltd. for Laboratory Supplies, with purity of 96.0%. In order to enhance the room-temperature and residual compressive strength of the fly ash-based geopolymer mortar and concrete, calcium oxide was added at percentages of 0 and 8 % by weight of fly ash. Two batches were cast for geopolymer mortar and geopolymer concrete.

The calcium oxide (CaO) was purchased from Central Drug House (Pvt.) Ltd. for Laboratory Supplies with a purity of 96%.

Standard River sand (obtained from local resources located in Bhopal City, India) was used to prepare mortar specimens. The fineness modulus (FM), specific

Table 1: Chemical compositions of the fly ash (wt.%) obtained via XRF analysis

Silicon Dioxide	Aluminium Oxide	Ferric Oxide	Calcium Oxide	Potassium Oxide	Sodium Oxide	Sulphur Trioxide	Magnesium Oxide	Titanium Dioxide
(SiO_2)	(Al_2O_3)	(Fe_2O_3)	(CaO)	(K_2O)	(Na_2O)	(SO_3)	(MgO)	(TiO_2)
47.1	27.6	19.2	1.57	1.27	0.118	0.459	0.698	1.35

gravity and absorption for River sand was determined upon, IS 383: 2016 [41]. Their values were found to be 2.658, 2.55, and 1.09%, respectively. Coarse aggregate (obtained from local resources located in Bhopal City, India) was also used to prepare concrete specimens.

The samples were prepared by mixing fly ash with the alkaline additives at 12.5 molar ratios. These mortar mixtures were prepared with a ratio of 1:2 (Fly ash/River sand). The resulting mortar was transferred to 70.6 X 70.6 X 70.6 mm cubic moulds, then cured at room temperature, and then stored for compression tests per IS 4031-6 (1988)[23]. A flexural strength test using a Jinan testing equipment WDW-50 (UTM) universal testing machine witha capacity of 50 kN and a loading rate of 50 N/s till failure, was also carried out for geopolymer mortar using ASTMC348 [14]. The compressive strength of the cubes is evaluated using a compression machine and the average of three specimens from each batch were tasted at 3 days, 7 days, 14 days, and 28 days for geopolymer mortar using a 3000 kN capacity compressive testing machine, manufactured by Hydraulic and Engineering Instruments popularly known as HEICO.

Field Emission Scanning electron microscopy (FE-SEM) observations on paste specimens were performed and the specimens were coated with a 20-nm thick carbon layer in an SC7640 Auto/Manual High-Resolution Sputter Coater. The mineralogy of specimens was assessed via x-ray diffraction (XRD) using (an Ultima IV X-ray Diffractometer machine) with Cu x-ray radiation operating at 40 kV and 40 mA.

2. Results and Discussions

2.1 Geopolymer Paste

Fig. (1) compares the FE-SEM images for the fly ash-based geopolymer binder without added calcium oxide (Fig. 1 a) and after adding 8% calcium oxide into the geopolymer binder (Fig. 1b). The as-received fly ash-based geopolymer without added calcium oxide appeared in a plate-like structure with particle size mostly smaller than 10 µm. The as-received fly ash-based geopolymer binder structure is pseudo-hexagonal along with plates which could decrease the reactivity of fly ash-based geopolymer binder. After adding 8% calcium oxide, the fly ash-based geopolymer binder sheets appeared to be more deformed and locally condensed into bundles with less crystalline shapes (Fig. 1b).

Fig. (2) compares the XRD patterns of fly ash-based geopolymer binder without added calcium oxide before and after adding 8% calcium oxide fly ash-based geopolymer binder. The as-received fly ash-based geopolymer binder is composed of Calcite (C), mullite (M) and quartz (Q) as the major minerals.

2.2 Mechanical Properties

2.2.1 Effect of Calcium oxide on the standard consistency and Initial and Final setting on Fly ash based-geopolymer

The best result obtained from the initial and final setting time of geopolymer paste was 8 %. Which has a standard consistency of 26% wt. of fly ash. All 11 tests have standard consistency of 25-30% wt. of fly ash. All the test was performed at room temperature. Fig.3. Effect of Calcium oxide on

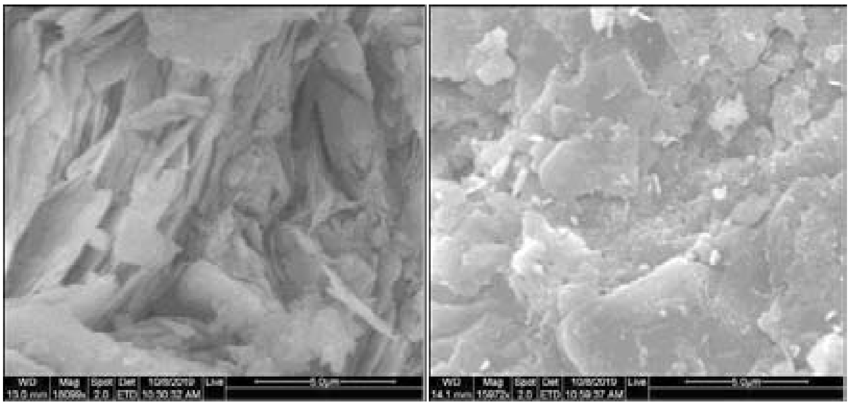

Figure 1. FE-SEM images for the (a) fly ash-based geopolymer binder without added calcium oxide and (b) adding 8% calcium oxide into the geopolymer binder.

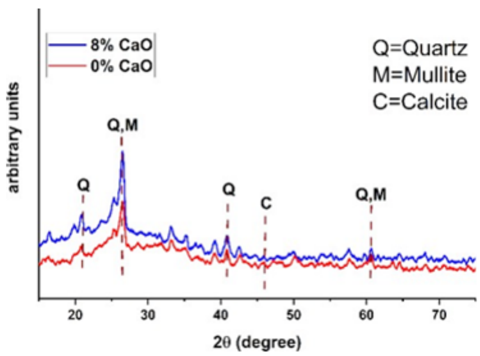

Fig. 2. X-Ray Diffraction Analysis for the fly ash-based geopolymer binder without added calcium oxide and after adding 8% calcium oxide flyash-based geopolymer binder.[3]

the standard consistency and Initial and Final setting on Fly ash based-geopolymer. The initial setting time without added calcium oxide was 1365 minutes and thefinal setting time was 7200 minutes. After adding calcium oxide with fly ash, the best result was obtained from 8 % which has an initial setting time of 120 minutes and the final setting was 330 minutes.

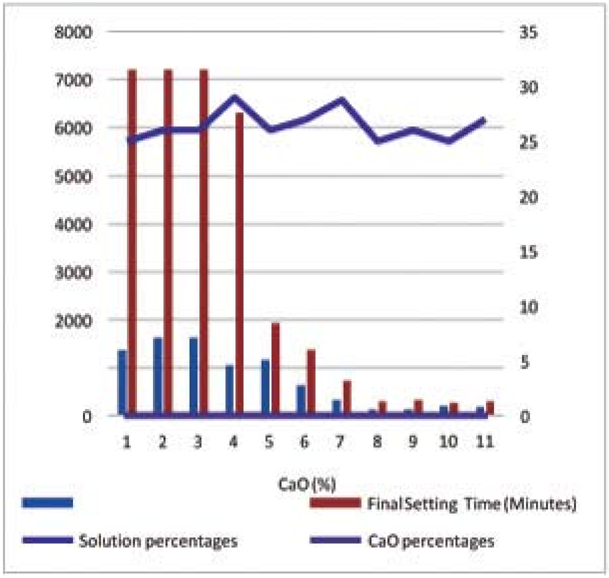

Fig.3.Effect of Calcium oxide on the standard consistency and Initial and Final setting on Fly ash based-geopolymer.

2.2.2 Effect of CaO on the mechanical properties of fly ash based-geopolymer mortar

The effect of CaO addition on the compressive strength of the *fly ash-based-geopolymer mortar* mixes is shown in Fig. (4). The addition of 8 wt.% of CaO increased the compressive strength to 49.91 MPa, respectively, compared with control specimens. While without the addition of 8 wt.% of CaO, the compressive strength is about 45.75 MPa. Geopolymer mortar flexural strength was tested on the 28th day. The maximum flexural strength obtained from geopolymer mortar without added CaO (GPM, B1) was 4.21 MPa on the 28th day and for the geopolymer mortar with added CaO (GPM, B-2) was 5.56 MPa on the 28th day. The results show that the effect of the addition of CaO with room temperature curing conditions had a significant influence on the compressive strength of fly ash-based-geopolymers mortar. The added CaO could react with the silica (in the sodium silicate and/or in the fly ash) forming C-A-S-H hydrates.

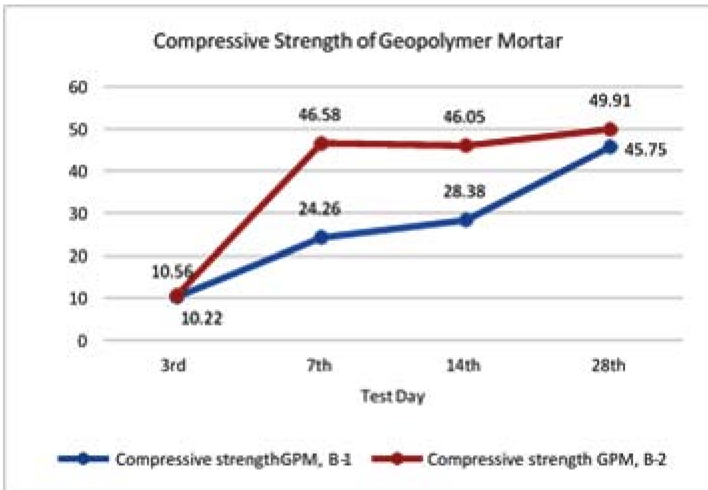

Fig.4. Effect of CaO on the mechanical properties of fly ash based-geopolymer mortar.

2.2.3 Effect of CaO on the mechanical properties of fly ash based-geopolymer concrete

The effect of CaO addition on the compressive strength of the

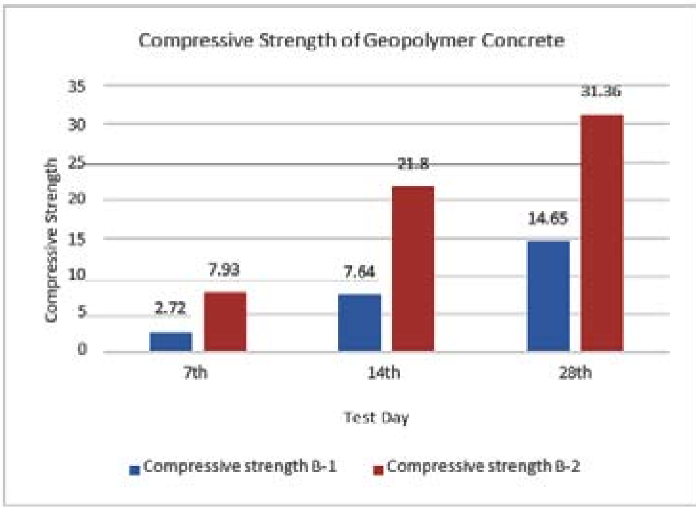

Fig.5. Effect of CaO on the mechanical properties of fly ash-based-geopolymer concrete.

fly ash-based-geopolymer concrete mixes is shown in Fig. (5). The addition of 8 wt.% of CaO increased the compressive strength to 31.36 MPa, respectively, compared with control specimens. While without the addition of 8 wt.% of CaO, the compressive strength is about 14.65 MPa. The results show that the effect of the addition of CaO with room temperature curing conditions had a significant influence on the compressive strength of fly ash-based-geopolymers concrete. The added CaO could react with the silica (in the sodium silicate and/or in the fly ash) forming C-A-S-H hydrates.

3. Conclusions

The result of the engineering properties also indicated the effect of CaO and the effect of ambient curing and compressive strength of geopolymeric mortar and concrete.

- Standard consistency of geopolymeric paste tested for 11 different samples as per IS 4031 (Part 4) (1988)[19]. Cement has 25-35% standard consistency. All the test results were between 25 to 30% wt of fly ash for geopolymeric paste.
- For the initial and setting time of geopolymer paste 11 different samples were also tested. Geopolymer paste which has 0% CaO has an initial setting of 1365 minutes and 7200 minutes for the final setting time, with added 7 to 9 wt.% calcium CaO we have obtained an initial setting time of 120 minutes and a final setting time of 330 minutes, which is much less than without added CaO.
- Flow table tests were also used to determine the workability of geopolymer mortar, The flowability of geopolymer mortar Batch-1 (without added CaO) was greater than that of geopolymer mortar Batch-2-(added CaO). GPM, B-1, has a flowability of 45%, whereas GPM, B-2, has a flowability of 35%. The slump test was also used to determine the workability of geopolymer concrete. Geopolymer concrete batch-1 has a 140 mm slump and added geopolymer concrete batch-2 has an 80 mm slump.
- Compressive strength of geopolymer mortar and concrete was also tested. Geopolymer mortar 28th-day compressive strength for GPM, B-1 has 45.75 MPa and for GPM, B-2 has 49.91 MPa. Geopolymer concrete 28th-day compressive strength for GPC, B-1 has 14.65 MPa and GPC, B-2 has 31.36 MPa, which is double of GPC, B-1. The flexural strength of geopolymer mortar was also tested, the maximum flexural strength obtained from geopolymer mortar without added CaO (GPM, B1) was 4.21 MPa on the 28th day and for the geopolymer mortar with added CaO (GPM, B-2) was 5.56 MPa on the 28th day.

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

Under Global Housing Technology Challenge – India (GHTC-India), proven innovative and alternate construction technologies along with future potential sustainable technologies were shortlisted. A basket of 54 proven technologies were shortlisted in six broad categories, and distinct technologies from each of these broad categories are being showcased through execution of six Light House Projects (LHPs) across six regions of the Country namely, Indore, Rajkot, Chennai, Ranchi, Agartala and Lucknow. BMTPC is regularly monitoring and interacting with the construction agencies in close coordination with the Ministry for any query resolution and smooth operationalization of LHPs. These LHPs are projected as live laboratories to establish innovative and green construction practices across India and will help in replication of these systems in future construction projects in the country.

These LHPs are pilot housing projects which will pave the way for further adaption and use of these innovative technologies in the construction sector. The projects are showcasing construction of ready-to-live houses which are sustainable, cost-effective, resilient and built in much lesser time from the conventional cast-in-situ RCC framed construction.

The Light House Projects at Chennai & Rajkot have already been completed & handed over to the beneficiaries. The LHP at Indore is ready for inauguration, while LHP at Lucknow & Ranchi are at advanced stage of completion. The current status of these LHPs are shown with the help of actual site photographs.


LHP Lucknow


LHP Indore


LHP Ranchi


LHP Ranchi

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

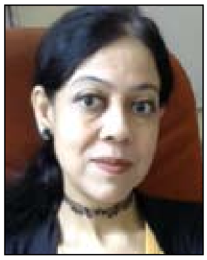
No. of Dwelling Units: 1040 Nos. (S+13)
No. of Block/ Tower: 4 Blocks
Units in each Block/ Tower: A(494), B(130), C(208) & D(208)
Technology Name: PVC Stay in Place Formwork System with Pre-engineered Steel Structural System

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

Impact of Rental Housing in improving Urban Resilience





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Introduction

India, a nation characterized by its vast diversity and immense potential, finds itself at the forefront of an unprecedented urban revolution. As per the 2018 United Nations World report[1] on Urbanisation Prospects, India is poised to contribute significantly to the global surge in urban population. An astonishing 416 million individuals are expected to join the ranks of urban dwellers, effectively doubling India's urban populace from 2018 to 2050. This demographic transformation underscores India's rapid urbanization, a phenomenon with profound implications. However, beneath the surface of this extraordinary shift lies a monumental challenge: the urgent demand for affordable and adequate urban housing. As urbanization sweeps across the country, over half of India's population grapples with a fundamental dilemma—how to secure housing that is not only financially accessible but also capable of providing a secure and dignified urban life.

According to data from the National Sample Survey Office (NSSO) in 2019, a staggering 31 million households in urban India currently reside in rental accommodations with majority of these households in informal housing arrangements, fraught with uncertainty and often lacking essential amenities. This informal rental landscape hints at the intricate web of housing challenges that urban India confronts. While issues of housing deprivation and affordability remain formidable hurdles, a more recent and disconcerting trend that has emerged is increase in the number of vacant houses over the past decade. This perplexing phenomenon casts a shadow over the housing landscape, exacerbating the stark divide between those in desperate need of housing and those who possess a surplus of empty dwellings. It signifies not just a housing issue but also the tangible manifestation of growing inequality within India's urban fabric.

Historical Issues in Housing Sector:

The housing sector in India has faced persistent imbalance between demand and supply in the past. The formal housing supply has struggled to match the escalating demand witnessed in Indian cities. The unresponsiveness of the formal housing market has resulted in a concerning statistic: approximately 17.4% of urban households in India find themselves residing in slum settlements[2]. Furthermore, as per Technical Group-12 Report on Urban Housing Shortage a substantial shortfall of 96% in the category of Economically Weaker Sections (EWS) and Lower Income Groups (LIG) was noted (refer Table 1). This data underscored the magnitude of the housing crisis and the urgent need for innovative solutions to bridge the gap between housing demand and supply, particularly for those with modest incomes.

The supply side of affordable housing in India has been dealing with several challenges, such as scarcity of developed and unencumbered urban land, rising construction costs, a growing informal housing sector, the absence of a viable and regulated rental market and constraints imposed by master plans. These factors collectively

1 United Nations, Department of Economic and Social Affairs, Population Division (2019). World Urbanization Prospects: The 2018 Revision

2 MoHUPA, NBO (2015) Slums in India: A Statistical Compendium

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Table 1 Urban Housing Shortage based on Income Groups

Category	Shortage (Millions of Units)	Shortage (%)
EWS (economically weaker section)	10.55	56%
LIG (low income)	7.41	39%
MIG (middle income)	0.82	4%
HIG (high income)	0	0%
Total	18.78	100%

hindered the growth potential of the formal affordable housing market. Simultaneously, the demand side had its own obstacles such as limited purchasing power, lack of accessible and affordable lending options and the limited reach to government subsidies. These factors have historically made formal housing less affordable for a significant portion of the population.

Land-use plans often struggle to keep pace with the rapid growth of urban populations and urban development. This lag in planning has led to the proliferation of slum settlements, which in turn, face challenges related to insecure land tenure, legal disputes, and inadequate infrastructure. Additionally, outdated DCRs characterized by lower FAR, along with inappropriate values for setbacks, building heights and access road widths constrain building development and limit the full realization of permitted FAR/FSI. These regulations has resulted in the creation of substandard and inadequate housing units that find little demand in the market, contributing to a surplus of vacant housing stock. While homeownership has been promoted, rental housing has often been overlooked, resulting in a scenario where landlords hold significant power and exploit vulnerable tenants by imposing exorbitant rents for substandard and crowded accommodations, frequently leading to evictions.

This article elaborates on the need to provide decent housing and living conditions for the urban poor, particularly migrant workers focusing on the necessity for comprehensive reform and improved urban management.

Housing and Urban resilience

In addition to the quantitative shortages, there had been issues with the quality of housing. Housing quality and stability are integral to the well-being of urban populations and urban resilience. Adequate and well-maintained housing not only ensures the physical safety and health of residents but also fosters social cohesion within communities. When individuals have secure and comfortable homes, they are more likely to engage with their neighbors and form supportive networks. These social bonds become invaluable during times of crisis, enabling communities to come together, share resources, and provide mutual aid. As a result, housing quality directly contributes to a city's ability to withstand shocks and stresses, creating a foundation of resilience that extends beyond the physical aspects of housing.

Furthermore, housing plays a vital role in economic stability and growth within urban areas. A stable housing market underpins financial security for individuals and families, allowing them to maintain stable employment and contribute to the local economy. Housing construction and related industries are also significant drivers of urban economies. Therefore, resilient housing practices not only bolster individual financial stability but also fortify the economic foundation of cities. Housing affordability and equity are also central to urban resilience, ensuring that all residents have access to safe and affordable housing, reducing vulnerability during times of crisis, and fostering inclusive urban environments that are better prepared to face a wide range of challenges.

Linkages in Housing

The housing sector continues to serve as the most prominent catalyst for economic expansion, characterized by robust forward and backward linkages. It has a multiplier influence on the economy, invigorating not only the primary sector, responsible for raw materials but also the manufacturing sector (construction materials) and the service sector (professionals such as architects and engineers, skilled laborers and financial institutions). Housing sector has a trickle-down effect on more than 270 industries of all scales, few of them are listed below:

Backward Linkages:

- Construction Industry: In India, the construction sector is a significant contributor to GDP. It accounted for approximately 8.6% of India's GDP in 2019-2020, according to the National Statistical Office (NSO).
- Manufacturing: The housing sector drives demand for various manufacturing industries, including cement, steel, and building materials. For example, over 370 Lakh metric tonne cement and 84 Lakh metric tonne steel has been utilised under PMAY-U till 2022, as reported by the MoHUA[3].
- Labour Force: Skilled and Unskilled workers for masonry, plumbing, carpentry and electrical work.
- Retail and Consumer Goods: The retail sector in India benefits from increased consumer spending on home goods and appliances.

Forward Linkages:

- Finance and Banking: The housing finance sector in India has grown substantially. As of March 2020, housing finance companies in India had assets worth approximately INR 24.5 trillion, as reported by the National Housing Bank (NHB)[4].
- Real Estate Services: Real estate and related services, contributing approximately 7% to the country's GDP in 2020 are vital for housing transactions (IBEF)[5].
- Infrastructure Development: Housing projects also lead to infrastructure development such as roads, utilities and transport network.
- Legal and Regulatory Services: Legal and regulatory services are critical in property transactions such as Home insurances.

These facts and figures illustrate the significant impact of housing on India's economy, including contributions to GDP, employment, and various related industries. Housing is not just a basic need but it also serves as a cornerstone for economic growth and development in the country.

Longitudinal study of Rental Housing in India

Rental housing plays a vital role in facilitating both horizontal and vertical mobility by providing individuals with access to suitable housing without the need for immediate home purchase. It serves as a significant entry point into urban areas for newcomers across various income levels, allowing them to reside in the city until they are financially prepared or willing to invest in their own homes. This is especially crucial for rural migrants, as their financial resources may already be allocated to assets like land and livestock, making access to shelter a priority over acquiring additional assets that may be vulnerable to local market fluctuations. As per Centre for Social and Economic Progress (CSEP), New Delhi rental units in urban India has experienced a decline, decreasing from 53% in 1971 to 28% in 2011, as depicted in Panel B of Figure 1. According to data from the Census of India, 26.3% of households reside in rental accommodations within slum areas, while 27.8% do so in formal housing.

Table 2 provides insights into the occupancy status across various income groups in urban India. Employing monthly per capita expenditure (MPCE) as an indicator of income, it becomes evident that renting is prevalent across all income brackets.

Although the highest share of rentals is observed among households in the final quintile, it's noteworthy that renting remains a significant choice for middle-income households as well.

While the decline in rental housing is evident across most regions of the country, it is not consistent. Figure 2 presents a district-level comparison of the share of urban rental housing between 1961 and 2011. These maps illustrate a particularly significant decline in the northern states, excluding the mountainous regions.

Numerous social issues are tied to rental housing, including the exclusion of low-income populations due to rising rent prices, resulting in settlement in problematic slums and informal areas with limited access to amenities like clean water, sanitation, electricity and more (Kumar 2015b). Additionally, the broker-landlord-tenant relationship is often fraught with challenges. Brokers, motivated by commissions may deceive prospective tenants with incomplete or false information. Landlords, typically living away from rental properties prioritize rent collection over property maintenance, leaving tenants to address problems like space constraints, drainage issues and dilapidated conditions.

3 PMAY-Urban Newsletter, Issue 42, 15 July 2022
4 NHB, Annual Report 2019-20
5 India Brand Equity Foundation (IBEF), Real Estate Industry Report, 2022

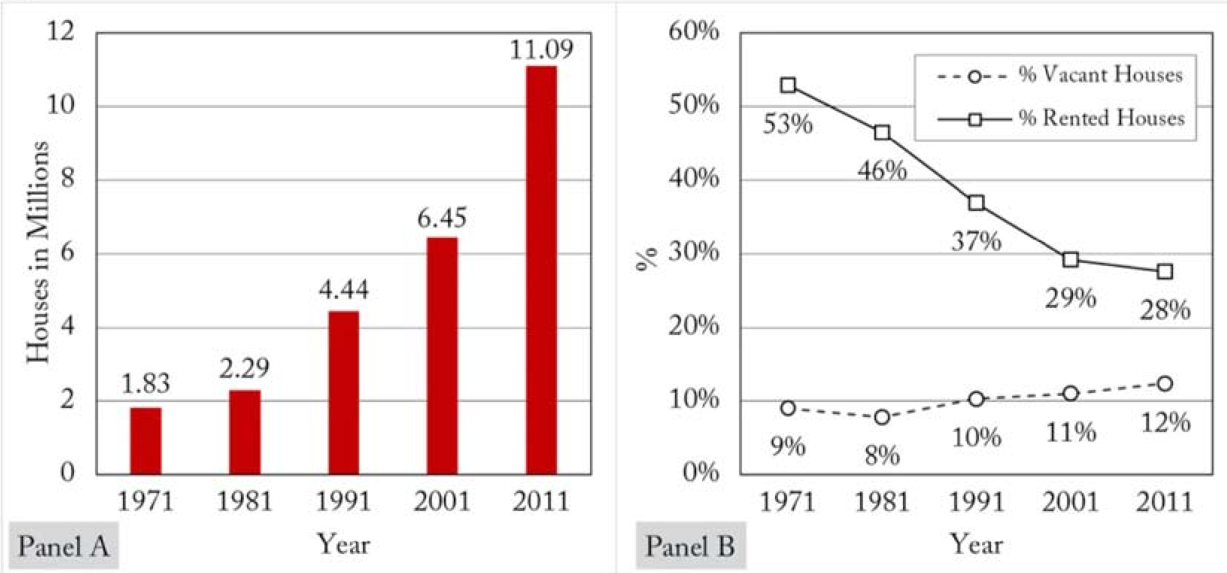
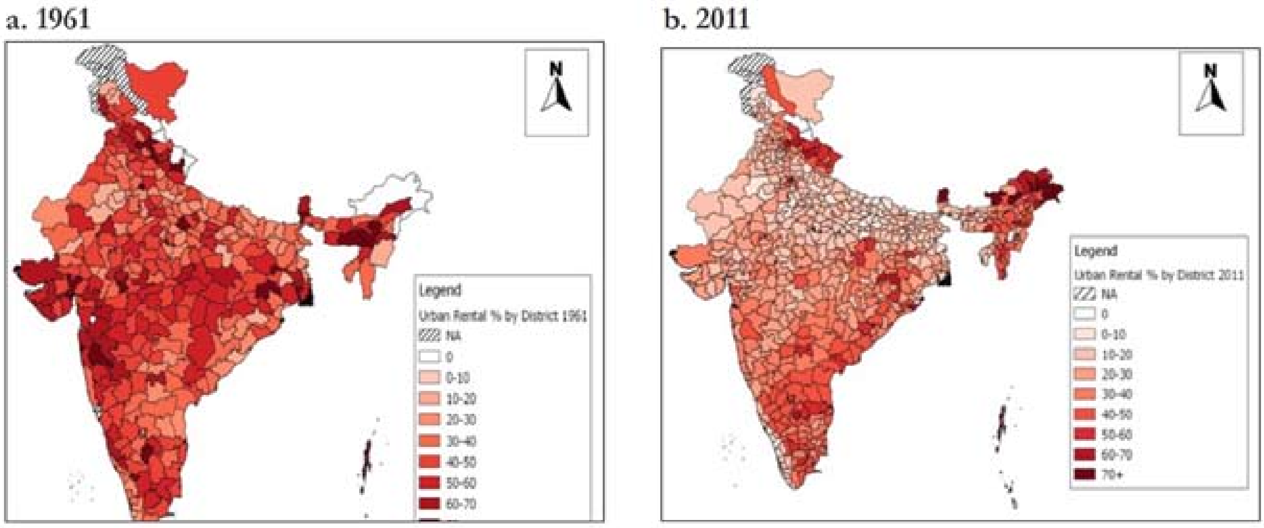


Figure 1 Percent Rental and Vacant Houses in Urban India (Source: CSEP, New Delhi)

Table 2 Tenure Status and Income Quantile based on Monthly Per Capita Expenditure in Urban India
(Source: CSEP, New Delhi)

Income quintiles						
Tenure	0-20	20-40	40-60	60-80	80-100	Total
Owned	24.0	20.5	20.6	17.7	17.2	100
Rented	13.2	16.1	22.8	23.0	24.8	100



Source: Tandel, V., Patel, S., Gandhi, S., Pethe, A., & Agarwal, K. (2016). Decline of rental housing in India: the case of Mumbai. Environment and Urbanization.

Figure 2 Rental Housing in Urban India 1961 and 2011

Table 3 Contracts in Slums and Non-Slums Dwellings

(Source: CSEP, New Delhi)

Type	Formal	Slum	Total
Rented: Employer quarter	11.6	2.4	10.7
Rented: With written contract	18.6	14.1	18.1
Rented: Without written contract	69.8	83.5	71.1
Total Rental	100	100	100

Table 3 outlines different rental contract arrangements. Only 14.1% of slum households and 18.6% of formal rental households have written contracts[6]. The relatively small proportion of slums is anticipated because of their informal characteristics, while the comparatively modest figure for formal housing may be linked to landlords trying to bypass rent control regulations or lessen the duration and expenses connected with official agreements.

Vacant Housing Stock

Vacant housing is often perceived as a result of impediments in the market (referred to as "unintentional" vacancy) and as a strategic choice by landlords to remove their property from the market (referred to as "intentional" vacancy). In India, during the year 2011, there were 24.7 million unoccupied census houses, constituting 7.5% of the total census houses. Among these, 13.6 million (6.2% of the rural census houses) were in rural areas, and 11.1 million (10.1% of the urban census houses) were in urban areas (Table 6). The proportion of vacant census houses in relation to the overall number of census houses experienced a slight increase from 6.3% in 2001 to 7.5% in 2011 across India, encompassing both rural and urban sectors. The count of vacant census houses rose by 8.9 million (56%) from 15.8 million in 2001 to 24.7 million in 2011. The decade-long escalation in the count of such houses was 45.1% in rural sectors and 71.9% in urban sectors.

Approximately 60% of the vacancies can be attributed to activities tied to construction, finalization procedures and allocation.

In this context, the Government of India's announcement in May 2020 regarding the nationwide rental housing program garnered significant approval.

The Affordable Rental Housing Complexes (ARHC) scheme was introduced as part of the Rs 20 lakh crore Atmanirbhar Bharat relief package. The goal of the ARHC scheme is to create a viable setup for economical rental housing, providing migrants and the urban impoverished the opportunity to reside in "dignified living spaces with necessary civic amenities conveniently located near their workplaces." This initiative is incorporated as a component of the Pradhan Mantri Awas Yojana - Urban (PMAY-U).

Affordable Rental Housing Complex

Residential rental housing markets exhibit localized variations, shaped by regional economic, political, and regulatory factors (UN-Habitat and UNESCAP 2008). Under the Constitution of India, housing is a state subject, and hence, the enactment and enforcement of laws become the responsibility of the states.

Gandhi S., Green, K. R. & Patranabis, S. 2021. India's housing vacancy paradox: How rent control and weak contract enforcement produce unoccupied units and a housing shortage at the same time. *CSEP Research Foundation Working Paper.*

Figure 3 Percent Vacant and Rental Houses in Urban India

6 Gandhi, S., Green, K. R., & Patranabis, S. (2021). India's Housing Vacancy Paradox: How rent control and weak contract enforcement produce unoccupied units and a housing shortage at the same time (CSEP Working Paper 4). New Delhi: Centre for Social and Economic Progress.

The benefits of promoting rental housing are noteworthy. Tenants increase population density, reducing urban sprawl and lessening the demand for costly infrastructure in peri-urban areas. It can also deter poor families from engaging in land invasions or purchasing plots in illegal subdivisions. Higher rental rates may facilitate public transport organization, given the concentration of people in a small area, with most tenants opting for locations near bus or train routes (UN-Habitat 2004).

Analyzing the distribution of rental housing requires assessing demand and supply. On the demand side, there are three primary segments: permanent households unable to purchase a home, transient households (including migrants and students), and captive households living in employer-provided tenements. Meanwhile, the supply side includes individual landlords, institutional landlords, hostels/dormitories, and corporate/captive housing (MoHUPA 2013). Several factors influence residential rental housing, such as location, household income and affordability, access to socio-economic opportunities, mobility, homeownership affordability, household life cycle stage, tenure requirements, house size, legal status, house quality, available amenities and services, and rent prices, among others.

The ARHC operational guidelines outline two delivery modes. The first mode involves converting existing government-funded public housing into rental units, with public agencies or public-private partnerships (PPPs) responsible for this transformation. In 2020, MoHUA instructed state governments to repurpose vacant and under-construction houses previously funded by schemes like BSUP, IHSDP under the JNNURM and the RAY for this aspect of the program. The second mode involves the construction, operation, and maintenance of rental housing by private entities on their own land. This initiative is directly overseen by MoHUA.

Conclusion

In India, the promotion of home ownership is a key element of socio-economic policy. While there are valid reasons for encouraging home ownership, it's imperative to acknowledge that the rental market plays a crucial role in the urban ecosystem. Challenges like rent control, unclear property rights and difficulties in enforcing contracts have historically imposed significant limitations on the Indian housing market in recent years. Addressing these issues is essential not only for facilitating both horizontal and vertical mobility but also for combatting the related problem of high vacancy rates.

Rent control measures and the state of contract enforcement in India have contributed to an alarmingly high number of vacant houses, surpassing the typical frictions encountered in housing markets. To put this issue into perspective, in 2011, there were a staggering 11.09 million vacant urban housing units constituting 12 percent of the total urban residential stock. This surplus housing capacity could potentially accommodate up to 50 million people which is equivalent to 13 percent of the urban population.

In light of these stark statistics, the Model Tenancy Act (MTA) was introduced in 2021. It is a landmark piece of legislation designed to bring much-needed reform and structure to India's rental housing market. MTA offers standardized rental agreements, regulates rent increases and ensures tenant rights and protection against arbitrary eviction. By doing so, it aims to strike a fair balance between the interests of landlords and tenants, fostering a more transparent and efficient rental market. Additionally, the act establishes Rent Courts and Rent Tribunals for quicker dispute resolution, encourages digital documentation and limits security deposits making it easier and more affordable for tenants to access rental properties. The MTA represents a significant step forward in addressing the challenges within India's rental housing sector, with the potential to reduce vacancy rates and provide more secure and organized housing options for millions of Indians.

Introduction of MTA stands as a pivotal initiative to streamline the rental market, enhance tenant-landlord relations and reduce the number of vacant houses, ultimately contributing to the growth and sustainability of India's housing ecosystem and optimizing utilization of existing housing stock along with inclusivity in the housing market.

Apropos, rental housing is a cornerstone of urban resilience offering accessibility, economic stability and adaptability. It provides a lifeline for urban residents including those with fluctuating incomes, fostering economic mobility and labor flexibility. The diversity and inclusivity of rental options promote social equity, while its concentration in urban areas enhances infrastructure efficiency and resource allocation. In times of crisis, rental housing serves as a vital safety net offering shelter and fostering community cohesion. Additionally, affordable housing initiatives within the rental sector contribute to social equity and environmental sustainability making it an indispensable element in building resilient cities.

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Session on New Construction Technologies

NAREDCO NextGen in association with TIMES Group organised Realty Conclave & Icon awards to identify top Real Estate leaders from heritage in realty categories of profession, who have not just made immense contributions to the Indian economy but have also made an impact through contributions to their respective society on April 26, 2023. During the Conclave, a Session on New Construction Technologies was organised in which Dr. Shailesh Kr. Agrawal, ED, BMTPC elucidated various emerging construction systems and initiatives taken by MoHUA for mainstreaming these technologies.

Pilot Survey for Assessing Adoption of Innovative Technologies by Private Builders, Developers and Other Agencies

Dr. Shailesh Kr. Agrawal [1]

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Background

Building Materials and Technology Promotion Council (BMTPC) is mandated to promote resource-efficient, climate resilient, disaster resistant construction practices including emerging building materials and construction technologies for field level applications.

BMTPC provides an inter-disciplinary platform to various agencies under Central and State Governments and the private sector for scaling up proven technologies to enhance their wide-spread use and for assisting commercial production as well as dissemination of appropriate technologies for the benefit of the construction agencies and society at large.

The Council in recent years has reoriented its approach towards promotion of not only sustainable technologies through identification, evaluation & dissemination but also propagating emerging industrialised housing systems from within the country and abroad for affordable mass housing.

It has been constant endeavour of the Council to be updated about the new developments in the housing sector especially in the field of innovative Construction technologies which are affordable, resource efficient, disaster resilient, environment friendly and sustainable.

During the recent years, there has been very rapid developments in terms of introduction of new technologies in the market and construction of more projects including residential, commercial, institutional using these new technologies. Although, Council has been aware of the latest developments in the field, however it has been realised at times that adequate compilation of data about use of these new innovative technologies is required to understand which technologies are used more by the private agencies, applicability of technology in type of buildings, acceptability by user etc.

With the above background in mind, it was decided to study the requirement of innovative technologies in the market, market trends, what are the innovative materials, technologies & products being adopted by the companies so that BMTPC align its activities for effective dissemination and mainstreaming of innovative technologies. It is also required to create a database on innovative technologies being adopted Pan India by private builders, developers, agencies as these agencies might be implementing innovative technologies. .

In view of the above, a pilot study was decided to be undertaken for preparation of database of new technologies being used by private builders, developers, agencies in their projects. In this pilot survey, those cities were identified on all India level where maximum construction is going on.

To take up this pilot survey, Indian Institute of Architects (IIA), which is a National body of Architects in the country having more than 25,000 members and having its local chapters in most of the major was engaged through their Northern Chapter-IIA. The Indian Institute of Architects has also signed an agreement with BMTPC to work jointly in the areas of promoting new building system/ technologies for better Buildings.

Northern Chapter, IIA appointed team of Professionals deliberated on the subject and finalized the format of Study including conduct-

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ing the Survey across the areas selected by BMTPC and identification of issues in compilation of the required database. The details of the draft format as discussed and finalised with BMTPC was used as a basis for seeking data from secondary sources for a detailed study of the issues involved. Projects having been completed recently / ongoing were identified for listing out a city wise list for the Builders / Developers for reaching out to them for more specific information. Secondary Sources such as popular websites were identified for creating the base data for Project identification.

The pilot study was conducted for data compilation in the format by either or all of the following methods:

a. Assessment of the data uploaded on the RERA portal.

b. By directly calling up Developers.

c. By calling up the Project Architects where the required information could not be provided by the Developers.

d. The data from secondary sources and the developers was not following the technical terminologies being followed by BMTPC and hence interpretation was done by the Survey Team for compilation of the above findings for relating to the identified technologies.

e. The data available from the Secondary Sources is mostly for the Residential Properties.

f. For other typologies, efforts were made for generation from primary Sources as a part of the targeted Survey to be taken up as a part of the Second Round

Fig. 1: Identification of the 19 Cities for the Pilot Study

Table-1: List of 19 Identified Cities

S. No.	Cities	Tier Type
1	**North**	
1.01	Delhi NCR	Tier-I
1.02	Chandigarh	Tier-II
1.03	Dehradun	Tier-II
1.04	Lucknow	Tier-II
2	**East**	
2.01	Kolkata	Tier-I
2.02	Patna	Tier-II
2.03	Bhubaneswar	Tier-II
2.04	Guwahati	Tier-II
3	**West**	
3.01	Mumbai	Tier-I
3.02	Ahmedabad	Tier-I
3.03	Pune	Tier-I
3.04	Jaipur	Tier-II
4	**South**	
4.01	Hyderabad	Tier-I
4.02	Bangalore	Tier-I
4.03	Chennai	Tier-I
4.04	Kochi	Tier-II
5	**Central**	
5.01	Raipur	Tier-II
5.02	Indore	Tier-II
5.03	Bhopal	Tier-II

of Survey. However, as the companies were large and project specific information was not usually available.

Challenges faced for gathering of required data

For the developers having multiple projects across the country, challenges are being faced for getting the required information. The Connects identified from the company's domain is usually not the technical person capable of providing the required information in the prescribed format. In most cases, as the Project implementation is decentralized or outsourced, it has been difficult to connect with the specific person.

Identified Projects shortlisted City wise

The required information about 387 Projects out of 495 Projects identified has been compiled in the Report as given in the Table-2.

Findings from the data collected:

Detailed analysis of the data collected was conducted. The Projects using innovative technologies were identified and highlighted for distinct identification. The complete collected data was analysed with respect to the following parameters:

a. Zone wise segregation of identified Projects with details of Use type and number of Units

The data collected was analyzed with respect to the proposed number of units in each Project along with the use type of the Project. The identified Projects were listed in the following three categories namely Residential Projects having dwelling units, Commercial Projects having saleable units as

Table-2 : The total number of identified Projects shortlisted City wise

S.No.	City	Total Projects	Climate Type	Seismic Type
1	**North**	**167**		
1.01	Delhi NCR	139	Composite	ZONE IV
1.02	Chandigarh	9	Composite	ZONE IV
1.03	Dehradun	8	Composite	ZONE IV
1.04	Lucknow	11	Composite	ZONE III
2	**East**	**41**		
2.01	Kolkata	15	Warm & Humid	ZONE III
2.02	Patna	7	Composite	ZONE IV
2.03	Bhubaneswar	13	Warm & Humid	ZONE III
2.04	Guwahati	6	Warm & Humid	ZONE V
3	**West**	**135**		
3.01	Mumbai	63	Warm & Humid	ZONE III
3.02	Ahmedabad	17	Hot & Dry	ZONE III
3.03	Pune	35	Warm & Humid	ZONE III
3.04	Jaipur	20	Hot & Dry	ZONE II
4	**South**	**134**		
4.01	Hyderabad	20	Composite	ZONE II
4.02	Bangalore	63	Warm & Humid	ZONE II
4.03	Chennai	35	Warm & Humid	ZONE III
4.04	Kochi	16	Warm & Humid	ZONE III
5	**Central**	**18**		
5.01	Raipur	8	Composite	ZONE II
5.02	Indore	4	Composite	ZONE II
5.03	Bhopal	6	Composite	ZONE II
	TOTAL	**495**		

Table-3: Zone wise list of Projects and Units based on project type

S. No.	City	Residential		Commercial		Mixed Use	
		Projects	Units	Projects	Units	Projects	Units
1	**North**						
1.01	Delhi NCR	124	138427	14	14	1	1
1.02	Chandigarh	8	6189	1	1	-	-
1.03	Dehradun	6	4121	1	1	1	1
1.04	Lucknow	7	6487	3	3	1	1
2	**East**						
2.01	Kolkata	14	13836	1	1	-	-
2.02	Patna	7	384	-	-	-	-
2.03	Bhubaneswar	12	4473	1	1	-	-
2.04	Guwahati	6	1084	-	-	-	-
3	**West**						
3.01	Mumbai	47	160855	15	15	1	1
3.02	Ahmedabad	14	14473	3	3	-	-
3.03	Pune	31	28544	3	3	1	1
3.04	Jaipur	17	19983	3	3	-	-
4	**South**						
4.01	Hyderabad	15	95282	5	5	-	-
4.02	Bangalore	59	49499	4	4	-	-
4.03	Chennai	34	32622	1	1	-	-
4.04	Kochi	13	3334	3	3	-	-
5	**Central**						
5.01	Raipur	8	8936	-	-	-	-
5.02	Indore	4	1343	-	-	-	-
5.03	Bhopal	6	1392	-	-	-	-
	TOTAL	**432**	**591264**	**58**	**58**	**5**	**5**

Shops & Mixed Use Projects having Residential and Commercial. The zone wise list with information regarding the Units segregated based on the above use types is given in Table-3.

b. Identification of Projects using innovative Technologies

Out of the Projects identified in the above list, the Projects using innovative technologies were segregated. The list of Projects using innovative Technology, the zone wise list with information regarding the Units using Innovative Technologies was then segregated based on the above use types - residential, commercial and mix use is given in Table-4.

Table-4: Zone wise list of Innovative System Projects and Units based on project type

S. No.	City	Projects using innovative technology	City Tier	Residential		Commercial		Mixed Use	
				Project	**Units**	**Project**	**Units**	**Project**	**Units**
1	**North**	67							
1.01	Delhi NCR	60	I	52	64878	7	7	1	1
1.02	Chandigarh	1	II	1	1500	-	-	-	-
1.03	Dehradun	2	II	2	3722	-	-	-	-
1.04	Lucknow	4	II	4	5069	-	-	-	-
2	**East**	13							
2.01	Kolkata	9	I	9	8646	-	-	-	-
2.02	Patna	-	II	-	-	-	-	-	-
2.03	Bhubaneswar	3	II	3	1463	-	-	-	-
2.04	Guwahati	1	II	1	40	-	-	-	-
3	**West**	28							
3.01	Mumbai	17	I	14	138385	3	3	-	-
3.02	Ahmedabad	2	I	2	8822	-	-	-	-
3.03	Pune	9	I	8	17871	1	1	-	-
3.04	Jaipur	-	II	-	-	-	-	-	-
4	**South**	33							
4.01	Hyderabad	7	I	7	87232	-	-	-	-
4.02	Bangalore	12	I	11	21225	1	1	-	-
4.03	Chennai	14	I	14	13471	-	-	-	-
4.04	Kochi	-	II	-	-	-	-	-	-
5	**Central**	5							
5.01	Raipur	3	II	3	7848	-	-	-	-
5.02	Indore	1	II	1	1024	-	-	-	-
5.03	Bhopal	1	II	1	40	-	-	-	-
	TOTAL	**146**		**133**	**381236**	**12**	**12**	**1**	**1**

The above data establishes that 146 projects having about 3,81,249 units out of 387 Projects having about 5,91,327 units have been identified to be using innovative technologies.

The data regarding the residential units was available for all the Projects using Innovative technologies and hence the analysis has been carried out in unit terms. However, for many Commercial and Mixed Use projects using innovative technologies, the data on units was not available. Hence, the analysis related to Commercial and Mixed use Projects has been represented in terms of number of projects.

The data collected for the identified Projects has been reorganized City tier-wise for further evaluation of technology adaptation in various parts of the Country. The data is further categorized into residential project units, Commercial Project

Table-5: List of Tier 1 cities for Innovative System Projects and Units based on project type

S.No.	City	No. of Projects	Residential		Commercial		Mix	Use
			Project	Units	Project	Units	Project	Units
	Tier 1							
1	Delhi NCR	60	52	64878	7	7	1	1
2	Kolkata	9	9	8646	-	-	-	-
3	Mumbai	17	14	138385	3	3	-	-
4	Ahmedabad	2	2	8822	-	-	-	-
5	Pune	9	8	17871	1	1	-	-
6	Hyderabad	7	7	87232	-	-	-	-
7	Bangalore	12	11	21225	1	1	-	-
8	Chennai	14	14	13471				
	Total	**130**	**117**	**360530**	**12**	**12**	**1**	**1**

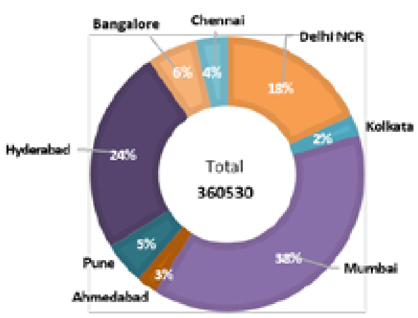

Fig.2: Residential Units for T1 Cities

Table-6: List of Tier 2 cities for Innovative System Projects and Units based on project type

S.No	City	No. of Projects	Residential		Commercial		Mixed Use	
			Project	Units	Project	Units	Project	Units
	Tier 2							
1	Chandigarh	1	1	1500	-	-	-	-
2	Dehradun	2	2	3722	-	-	-	-
3	Lucknow	4	4	5069	-	-	-	-
4	Patna	-	-	-	-	-	-	-
5	Bhubaneswar	3	3	1463	-	-	-	-
6	Guwahati	1	1	40	-	-	-	-
7	Jaipur	-	-	-	-	-	-	-
8	Kochi	-	-	-	-	-	-	-
9	Raipur	3	3	7848	-	-	-	-
10	Indore	1	1	1024	-	-	-	-
11	Bhopal	1	1	40	-	-	-	-
	Total	**16**	**16**	**20706**				

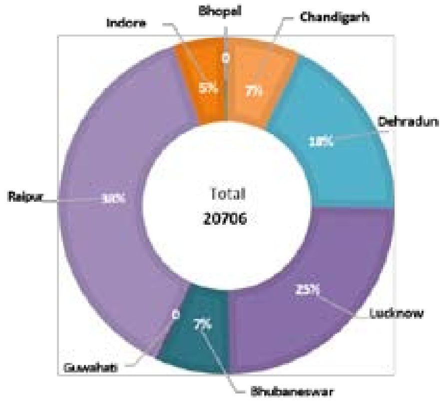

Fig.3: Residential Units for T2 Cities

numbers and Mixed use project numbers. For a better understanding of the data acquired given in Table-5 & Table-6 and charts (Fig.2 & 3) have been created for Tier 1 and Tier 2 cities respectively.

In assessment of the use of Innovative technologies in Tier 1 cities, Mumbai with 38% of the total units tops the list followed by Hyderabad with 24% and Delhi NCR with 18%. The same is attributable to the ever growing nature of these cities as they are providers of good job opportunities.

In assessment of the use of Innovative technologies in Tier 2 cities, Raipur with 38% of the total units tops the list followed by Lucknow with 25% and Dehradun with 18%.

The analysis of the above data indicates the following:

a. As per the above list, the maximum Projects using innovative technologies are located in Delhi NCR followed by Mumbai. For Delhi NCR, this could be attributed to many factors such as more awareness amongst the professionals, readiness to adapt to new technologies and a better access to technology infrastructure. The trend of using the innovative technologies as per the above data indicates that the use is more prevalent in Tier I at this time the reason can be associated to the increasing population and the need to provide shelter and jobs in these City is higher compared to others.

b. The use percentage is highest in Residential Buildings, followed by mixed use Building types and commercial projects.

c. The most used innovative technologies/material used in projects are as follows –
   - MIVAN Construction/Monolithic Concrete Construction,
   - Steel Structure with Infill panels/ Flyash bricks/ AAC Blocks/Concrete block/ Bricks/Hollow Concrete Blocks
   - RCC Precast Construction Technology
   - 3D Printing

The reasons as provided by the Developers for using the new and innovative technologies/material were as below:

- Its more structurally safe specially for high-rise and skyscrapers.
- The replacement for the conventional bricks is much lighter and stronger.
- The construction is much faster.
- Less Labour is required.
- The shuttering can be used repeatedly (10-15 projects) and is also re-sellable at 50% of its actual price.

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नवरीतिः NAVARITIH – Certificate Course on Innovative Construction Technologies

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

The Course has received very good response so far and in 15 batches conducted so far, 1045 participants e.g. civil engineers, architects, faculty & students from various engineering and architectural colleges successfully attended the Course.

RACHNA 3.0 : One-Day Training cum Consultation Programme on "Innovative Construction Technologies & Thermal Comfort for Affordable Housing"

75 RACHNA training programmes each during RACHNA 1.0 and 2.0 were successfully conducted across India during 2022, covering vast stakeholders. RACHNA - Resilient, Affordable, Comfortable Housing through National Action - is a collaborative effort of MoHUA, BMTPC and GIZ. Different group of stakeholders, ranging from urban practitioners, Central/State Government officials, Urban Local Body (ULB) officers, architects, engineers, builders, professors, students and construction workers, were included in the online/offline trainings programmes and workshops. The RACHNA aimed to impart knowledge on importance of thermal comfort, building materials, methods of construction for affordable housing and technology.

In continuation, RACHNA 3.0 is being conducted now. The One-Day Training cum Consultation Programme on "Innovative Construction Technologies & Thermal Comfort for Affordable Housing" took place on September 1, 2023 at the Chandigarh. The event was organized by Climate Smart Buildings (CSB), GIZ, in collaboration with BMTPC & MoHUA. Professionals and State engineers from Punjab attended the programme.

The program's objective was to empower and engage senior government officials, policymakers, professionals in the built-environment sector, and stakeholders from relevant government departments. The primary focus is on exploring innovative construction technologies, both globally and domestically, to expedite and streamline the construction of affordable housing. Additionally, the goal is to achieve thermally comfortable, resilient, and cost-effective homes.

The program commenced with an inauguration by Shri M. P. Singh, Director of PEDA. It was followed by address of Dr. Shailesh Kr. Agrawal, Executive Director, BMTPC, who discussed emerging construction technologies for mass housing. While Mr. Nitin Jain, Program Head at CSB, GIZ, provided an overview of CSB's various initiatives, Mr. Govinda Somani, Energy Advisor at CSB, GIZ, introduced the Passive and Resilient Thermal Comfort Standard based on Viable Solutions. Technology providers from Light House Projects (LHP) also presented the technologies used in LHPs. The event concluded with sessions on climate-responsive buildings and thermal comfort in buildings, delivered by Dr. Jyotirmay Mathur, MNIT, Jaipur and Dr. Jit Kumar Gupta.





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

BMTPC is entrused to promote 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 using emerging construction systems shortlisted through GHTC-India & certified under PACS of BMTPC.

These DHPs are pilots which help 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 sustainable. Earlier, BMTPC completed DHPs at Nellore, Andhra Pradesh; Bhubaneswar, Odisha; Lucknow, Uttar Pradesh; Biharshariff, Bihar; Hyderabad, Telangana; Panchkula, Haryana and Agartala, Tripura. Recently, DHPs at Bhopal, Madhya Pradesh and Ahmedabad, Gujarat have also been completed. The Demonstration Housing Projects at Tiruppur, Tamil Nadu; Guwahati, Assam; Ayodhya, Uttar Pradesh; Dimapur, Nagaland and Jammu, J&K are at finishing stages.

The construction of demonstration housing projects in different parts of the country aims to facilitate wide spread dissemination and adoption of both existing proven, emerging and sustainable building materials and technologies replacing conventional construction and create eco-system for mainstreaming such materials & technologies in the construction sector & adapt them as future technologies for construction. During the construction of demonstration houses, training to professionals, artisans & students is also being imparted.

The detials of the ongoing DHPs are as given under:

1. DHP AT AYODHYA, UTTAR PRADESH

State Urban Development Authority (SUDA), Lucknow allotted land measuring 3600 sqm.at Village Malikpur, Pargana Avadh,

Recently completed Demonstration Housing Project (DHP) at Bhopal, Madhya Pradesh using Stay In Place Formwork System - Insulating Concrete Forms (ICF)

Recently completed Demonstration Housing Project (DHP) at Ahmedabad, Gujarat using
Precast Concrete Construction System - Integrated Hybrid Solution-One

Tehsil Sadar, Janpad, Ayodhya, Uttar Pradesh owned by Mahila Kalyan Vibhag/ Siksha Vibhag, Ayodhya to be used as Destitute Widow Ashramand Orphanage for construction of DHP. The layout plan, architectural plans, etc. were approved by the Ayodhya Development Authority, Ayodhya. The DHP is in G+2 configuration with other provisions and a community centre (G) and being constructed using LIGHT GAUGE STEEL STRUCTURAL SYSTEM - Light Gauge Steel Framework System (LGSF) with Cement Fibre board on both side of walls and infill of rock wool.

Project Profile:

- Location: Village Malikpur, Pargana Avadh, Tehsil Sadar, Janpad, Ayodhya
- State Level Nodal Agency : State Urban Development Authority (SUDA), Lucknow
- Land Allotted by: Mahila Kalyan Vibhag/Siksha Vibhag, Ayodhya
- Usage : Destitute Widow Ashram and Orphanage
- Plot area of project : 3600 sqm.
- No. of houses : 40 (G+2); Other provisions includes Dining Hall with Kitchen & store, Common Room with toilet, General office, Medical Room with toilet, Care Taker Room, Activity Rooms and Laundry
- Community Centre having built up area of 342 sqm. consist of Single storey Multipurpose Hall with Kitchen, office, green room, shops and toilet.
- Carpet area of each unit : 29.47 sqm.
- Built up area of each unit : 34.34 sqm.
- Total built up area : 2661 sqm. including community centre
- Technology Used: LIGHT GAUGE STEEL STRUCTURAL SYSTEM - Light Gauge Steel Framework System (LGSFS)
- Each unit consist of a room with attached toilet, pantry and balcony
- Infrastructure facilities : CC Road, pathways with concrete pavers, water supply work, UGT, septic tank, horticulture work, boundary wall, tube well, drainage & disposal and external electrification using solar panels, rain water harvesting, fire fighting system, etc.
- Includes Earthquake Resistant Features.

About the Technology

Light Gauge Steel Framed Structures (LGSF) is based on factory made galvanized light gauge steel components, designed as per codal requirements. The system is produced by cold forming method and assembled as panels at site forming structural steel framework of a building of varying sizes of wall and floor. The assembly is done using special types of screws and bolts. LGSF is a well-established technol-

Demonstration Housing Project (DHP) at Ayodhya, Uttar Pradesh being constructed using
Light Gauge Steel Framework System (LGSF) with Cement Fibre board on both side of walls and infill of rock wool.

ogy for residential construction in North America, Australia and Japan and is gaining ground in India. LGSF is typically ideal for one to three storey high buildings, especially for residential and commercial buildings. Due to its flexibility, fast construction and durability, this technology has great potential for counties like India. LGSF can be combined with composite steel / concrete deck resting on light steel framing stud walls.

In this project, the total thickness of wall is 124mm having 89mm thickness of LGSF and 9mm & 6mm thick fibre cement board with vapour barrier on outside wall and 8mm thick fibre cement board with 12mm gypsum board inside of wall. Rock wool have been used as infill material.

2. DHP AT TIRUPPUR, TAMIL NADU

The Tamil Nadu Urban Habitat Development Board, Chennai, Tamil Nadu allotted land measuring 2000 sqm. through District Collector, Tiruppur at Survey No.24/3, Village Sempiyanallur, Taluk Avinashi, Tiruppur District, Tamil Nadu for the Demonstration Housing Project to be used as Working Women Hostel & Widow Home. The layout plan, architectural plans, etc. is being approved by the District Town and Country Planning Office, Tiruppur. The DHP is in G+3 configuration with other provisions and being constructed using Precast Concrete Construction System –Precast Components Assembled at Site.

Project Profile:

- Location: Survey No.24/3, Village Sempiyanallur, Taluk Avinashi, Tiruppur District, Tamil Nadu
- State Level Nodal Agency : Tamil Nadu Urban Habitat Development Board, Chennai
- Land Allotted by: District Collector, Tiruppur
- Usage : Working Women Hostel & Widow Home
- Plot area of project : 2000 sqm.
- No. of houses : 40 (G+3); 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
- Carpet area of each unit : 26.66 sqm.
- Built up area of each unit : 31.51 sqm.
- Total built up area : 2044 sqm.
- Technology Used: Precast Concrete Construction System –Precast Components Assembled At Site
- Each unit consist of a room with attached toilet, kitchen and balcony
- Infrastructure facilities : CC Road, pathways with concrete pavers, water supply work, septic tank, tube well, horticulture work, boundary wall, drainage & disposal and external electrification using solar panels, rain water harvesting, fire fighting system, etc.
- Includes Earthquake Resistant Features.

About the Technology

Precast construction technology is a system of casting concrete

Demonstration Housing Project (DHP) at Tiruppur, Tamil Nadu being constructed using Precast Concrete Construction System –Precast Components Assembled at Site

in a reusable mould or "form" which is then treated in a controlled environment, conveyed to the construction site and lifted to the place. Precast Construction Technology consists of various precast elements such as walls, beams, slabs, columns, staircase, landing and some customized elements that are standardized and designed for stability, durability and structural integrity of the building. Precast residential building construction involves design, strategic yard planning, lifting, handling and transportation of precast elements. This technology is suitable for construction of high rise buildings resisting seismic and wind induced lateral loads along with gravity loads. The building framing is planned in such a way that maximum number of repetitions of moulds is obtained. These elements are cast in a controlled factory condition. The factory is developed at or near the site which provides an economical solution in terms of storage and transportation.

Use of Precast Concrete Construction System –Precast Components Assembled at Site - at Tiruppur, Tamil Nadu

In this project, the system has been used as load bearing wall panels. The total thickness of wall is 150mm and precast slab of 100mm.

3. DHP AT GUWAHATI, ASSAM

Mission Director, PMAY-HFA(U)-Assam, Guwahati has allotted the land measuring 1600 sqm. owned by Guwahati Municipal Corporation (GMC) at Fatashil Ambari, Guwahati to be used as rental accommodation for Contratual Safai Karamchari of GMC. The Guwahati Municipal Corporation approved the plan and layout consisting of 40 Dwelling Units with other provisions and a community centre. The houses under DHP are in G+3 configurations and community centre (G) are being constructed using LIGHT GAUGE STEEL STRUCTURAL SYSTEM - Light Gauge Steel Framework System (LGSFS) with V-infill walls and Pre-engineered

Use of Light Gauge Steel Framework System (LGSFS) with V-infill walls and
Pre-engineered Building (PEB) steel structure at DHP Guwahati, Assam

Building (PEB) steel structure.

Project Profile:

- Location: Fatashil Ambari, Guwahati
- State Level Nodal Agency : Mission Director, PMAY-HFA(U)-Assam, Guwahati
- Land Allotted by: Guwahati Municipal Corporation (GMC)
- Usage : Rental accommodation for Contratual Safai Karamchari of GMC
- Plot area of project : 1600 sqm.
- No. of houses : 40 (G+3)
- Community Centre having built up area of 336 sqm. consist of Single storey Multipurpose Hall with Kitchen, office, green room, shops and toilet.
- Carpet area of each unit : 31.06 sqm.
- Built up area of each unit : 36.09 sqm.
- Total built up area : 2190 sqm. including community centre
- Technology Used: LIGHT GAUGE STEEL STRUCTURAL SYSTEM - Light Gauge Steel Framework System (LGSFS) with V-infill walls
- Each unit consist of a living room, a bed room, a kitchen, a bath room, a W.C., a lobby and a balcony.
- Infrastructure facilities : CC Road, pathways with concrete pavers, water supply work, UGT, septic tank, horticulture work, boundary wall, tube well, drainage & disposal and external electrification using solar panels, rain water harvesting, fire fighting system, etc.
- Includes Earthquake Resistant Features.

About the Technology

Light Gauge Framed Steel Structure (LGFSS) is based on factory made galvanized light gauge steel components produced by the cold forming method assembled as panels at site forming structural steel framework of a building and varying wall and floor construction. The panels are assembled on site with screws and bolts to form the internal and separating walls and inner leaf of the external walls of a building and floors & ceiling. The building is completed by the installation of V-Infill Wall elements.

V-Infill Wall is an innovative emerging building and construction technology using factory made 8/10mm fibre cement boards (Vboard) on either side of GI studs and erected to produce straight to finish walls which are filled with light weight concrete made of EPS, cement, sand and additive. 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.

In this project, the total thickness of wall is 124mm having 89mm thickness of LGSF and 9mm & 6mm thick fibre cement board with vapour barrier on outside wall and 8mm thick fibre cement board with 12mm gypsum board inside of wall. V-infill wall material have been used as infill material

Use of Prefabricated Sandwich Panel System - EPS core Panel
using Quikbuild Panels at DHP Bhalwal, Jammu

with Pre-engineered Building (PEB) steel structure.

4. DHP AT BHALWAL, JAMMU

The J&K Housing Board, Government of J&K allotted land measuring 4048 sqm. at Bhalwal, Jammu for the Demonstration Housing Project to be used as Sports Hostel. The layout plan, architectural plans, etc. were approved by the J&K Housing Board, Government of J&K. The DHP is in G+2 configuration with other provisions and being constructed using Prefabricated Sandwich Panel System - EPS core Panel using Quikbuild Panels.

Project Profile:

- Location: Bhalwal, Jammu
- State Level Nodal Agency : J&K Housing Board, Government of J&K
- Land Allotted by: J&K Housing Board, Government of J&K
- Usage : Sports Hostel
- Plot area of project : 4048 sqm.
- No. of houses : 40 (G+2); Other provisions includes a Office with Toilet, Dining Hall with Kitchen & store, Activity Room cum Gym, Medical Room with toilet and store, Care Taker Room with toilet, Laundry Room.
- Carpet area of each unit : 28.57 sqm.
- Built up area of each unit : 35.35 sqm.
- Total built up area : 2054 sqm.
- Technology Used: Prefabricated Sandwich Panel System - EPS core panel using Quikbuild Panels
- Each unit consist of 2 Rooms, Kitchen, Toilet & Balcony
- Infrastructure facilities : CC Road, pathways with concrete pavers, water supply work, septic tank, tube well, horticulture work, boundary wall, drainage & disposal and external electrification using solar panels, rain water harvesting, fire fighting system, etc.
- Includes Earthquake Resistant Features.

About the Technology

EPS core panel using Quikbuild Panels as walling (Prefabricated Sandwich Panel System)and EPS roof/slab Panel with concreting - QuikBuild panel system consists of a welded wire space frame integrated with a polystyrene insulation core. The wall panel is placed in position and a wythe of concrete is applied to both sides. The wall panel receives its strength and rigidity from the diagonal cross wires welded to the welded-wire fabric on each side. This combination produces a truss behavior, which provides rigidity and shear terms for a full composite behavior. Steel trusses are pierced through the polystyrene core and welded to the outer layer sheets of galvanized steel mesh to form a rigid panel.

The shell of the structure is built by manually erecting the panels directly onto the slab with reinforcement rods. Desired utilities like doors, windows and ventilators may be pre-built while plumbing, electrical conduits may be added onsite. The wall is then finished by plastering with cement using the traditional method or by shotcreting machine to create a monolithic structure. These panels are used in the construction of exterior and interior loadbearing and non-load bearing walls and floors of buildings of all types of construction.

In this project, the system has been used as load bearing wall panels. The total thickness of wall is 180mm with EPS thickness of 80mm and 50mm shortcreting/ plastering on both side of the wall.

5. DHP AT DIMAPUR, NAGALAND

The Works & Housing Department and Municipal Affairs Department, Government of Nagaland allotted land measuring 2819 sqmts. at PWD Housing Complex Sematila, Dimapur, Nagaland for the Demonstration Housing Project to be used as Working Women Hostel. The layout plan, architectural plans, etc. were approved by the PWD Housing, Kohima, Nagaland. The DHP consists of a Hostel Block in G+2 configuration and a community centre being constructed using Prefabricated Sandwich Panel System-EPS Cement Sandwich Panels with steel structure.

Project Profile:

- Location: PWD Housing Complex Sematila, Dimapur, Nagaland
- State Level Nodal Agency : Municipal Affairs Department, Government of Nagaland
- Land Allotted by: Works & Housing Department, Government of Nagaland
- Usage : Working Women Hostel
- Plot area of project : 2819 sqm.
- No. of houses : 40 (G+2); Other provisions includes a Dining Hall with Kitchen, Activity Room, Medical Room with toilet, Office with Toilet, Care Taker Room with toilet.
- Community Centre having built up area of 272 sqm. consist of Single storey Multipurpose Hall with Kitchen, office, two shops, two toilets & one toilet for physically handicapped.
- Carpet area of each unit : 25.21 sqm.
- Built up area of each unit : 28.60 sqm.
- Total built up area : 2050 sqm. including community centre
- Technology Used: Prefabricated Sandwich Panel System-EPS Cement Sandwich Panels with steel structure
- Each unit consist of a room, a pantry, Toilet & Balcony
- Infrastructure facilities : CC

Use of EPS Cement Sandwich Panels with steel structure at DHP Dimapur, Nagaland

Use of EPS Cement Sandwich Panels with steel structure in Community Centre at DHP Dimapur, Nagaland

Road, pathways with concrete pavers, water supply work, septic tank, horticulture work, boundary wall, drainage & disposal and external electrification using solar panels, rain water harvesting, fire fighting system, etc.

- Includes Earthquake Resistant Features.

About the Technology

Prefabricated Sandwich Panel System-EPS Cement Sandwich Panels with steel structure are lightweight solid core sandwich panels made of 5mm non-asbestos fiber cement boards on both sides of panels as facing sheet and the core material of expanded polystyrene beads, admixture, cement, sand, fly ash and other bonding materials in mortar form. The core material in slurry state is pushed under pressure into preset molds. Once set, it is moved for curing and ready for use with RCC or steel framed structure. These panels may be installed without any structural support up to 5m only. Due to the sheets, the panels do not require plastering and water curing. These panels are joined with tongue & groove jointing system.

These are non–load bearing panels and should be used as walling, floor and roofing with additional structural support, steel or RCC depending on the design. However, these may be used as single floor construction or stairs case slabs, kitchen/bathroom slabs etc. without support structure. Therefore, here the panels are being used with steel structure.

In this project, the total thickness of external walls is 90mm and internal walls is 75mm. The frame structure of the building is in steel (ISMB, ISMC) with prefabricated sandwich panel as infill. The roof slab is also made of prefabricated sandwich panel with concrete screed.

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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, 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/UTs, its Housing & Urban Development Departments, Housing Boards and other concerned departments are also promoting and using emerging technologies and materials for construction of mass housing in their States. As such PACS is proving to be 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 TAC members.

So far 19 meetings of TAC have been held and 84 PACs have been issued and out of these, 44 are emerging technologies/systems. The details of activities carried out recently under Performance Appraisal Certification Scheme (PACS) are highlighted below:

Approval of New PACs

PAC for the following seven systems/products have been approved in the 19th meeting of TAC held on June 7, 2023.

1. Concrete 3D Printing Technology (C3DP)
2. Ferron Panel as part of Ferrobuild Design System
3. Geopolymer Coarse Aggregate (GPCA)
4. Geopolymer Fly Ash Fine Aggregate (GFS)
5. Nano Concrete Aggregate (NACA)
6. Kinzok Aluminum Alloy Panels
7. uPVC Door & Window Systems

The brief about these technologies are given hereunder:

1. Concrete 3D Printing Technology (C3DP)

Concrete 3D printing is the technology in which concrete layers are laid one over the other using an automated robotic system. The system consists of a pump and extruder along with a print head. The entire printing process is streamlined with the help of software integrating the machine & material parameters.

Special features of the system include:

- Design Freedom – A wide range of designs can be constructed which are structurally stable.
- Construction Efficiency – Construction time can be reduced due to the inclusion of automation during construction. Also, the manpower requirement can be reduced significantly.
- Accuracy with Automation – The process of construction is performed using robotic systems, also bringing accuracy.

EMERGING CONSTRUCTION SYSTEMS CERTIFIED UNDER PACS

PRECAST CONCRETE CONSTRUCTION SYSTEM – 3D PRECAST VOLUMETRIC		
1	Volumetric (3D) Concrete Printing Technology (VCPT)	1059-S/2022
2	Concrete 3D Printing Technology (C3DP)	1067-S/2023
PRECAST CONCRETE CONSTRUCTION SYSTEM – PRECAST COMPONENTS ASSEMBLED AT SITE		
3	SRPL Building System (Waffle-Crete)	1021-S/2015
4	Walltec Hollowcore Concrete Panel	1022-P/2015
5	Precast Large Concrete Panel System	1027-S/2016
6	Industrialized 3-S system using RCC precast with or without shear walls, columns, beams, Cellular Light Weight Concrete Slabs/Semi-Precast Solid Slab	-
7	Robomatic Hollowcore Concrete Wall Panels	1040-S/ 2018
8	K-Wall Panels	1043-S/2019
9	Urbanaac Precast Construction Technology	1046-S/2019
10	Integrated Hybrid Solution - One	1048-S/2020
11	Kon_Crete Reinforced Autoclaved Aerated Concrete Panels	1056-P/2021
LIGHT GAUGE STEEL STRUCTURAL SYSTEM & PRE-ENGINEERED STEEL STRUCTURAL SYSTEM		
12	Factory Made Fast Track Modular Building System	1011-S/2013
13	Speed Floor System	1013-S/2014
14	Light Gauge Steel Framed Structure (LGSF)	1014-S/2014
15	Light Gauge Steel Framed Structure with Infill Concrete Panel Technology	1028-S/2016
16	Continuous Sandwich (PUF) Panels With Steel Structure	1038-S/2018
17	PUF Sandwich Panel with Pre Engineered Building Structure	1060-S/2022
18	Ferron Panel as part of Ferrobuild Design System	1066-S/2023
PREFABRICATED SANDWICH PANEL SYSTEM		
19	Advanced Building System – Emmedue	1010-S/2014
20	QuickBuild 3D Panels	1019-S/2015
21	Reinforced EPS Core Panel System	1020-S/2015
22	Rapid Panels	1026-S/2016
23	Prefabricated Fibre Reinforced Sandwich Panels	1030-S/2017
24	Concrewall Panel System	1031-S/2017
25	Rising EPS (Beads) Cement Panels	1032-S/2017
26	PIR Dry Wall Pre-Fab Panel System	1039-S/2018
27	Baupanel system	1041-S/2018
28	Flyash EPS (Beads) Cement Sandwich Panels	1042-S/2018
29	V-Infill Wall (Light Weight EPS Wall)	1045-S/2019
30	Nano Living System Technology	1047-S/2019
31	Factory Assembled Insulated Sandwich Panels using Mineral Wool	1057-P/2021
32	Factory Assembled Insulated Sandwich Panels using PUF	1058-P/2021
33	Everest Rapicon Panel / Solid Wall Panel	1061-S/2022
MONOLITHIC CONCRETE CONSTRUCTION		
34	Monolithic Concrete Construction System	1006-A/2011
35	Modular Tunnel Form	1018-S/2015
STAY IN PLACE FORMWORK SYSTEM		
36	Glass Fibre Reinforced Gypsum Panel System	1008-S/2011
37	Sismo Building Technology	1025-S/2016
38	Insulating Concrete Forms	1029-S/2017
39	Lost-in-place formwork system- Plasmolite Wall Panels	1033-S/2018
40	Lost-in-place formwork system- Plaswall Panel system	1034-S/2018
41	Structural Stay-in-place formwork system	1035-S/2018
42	Monolithic Insulated Concrete System	1036-S/2018
43	Stay-In-Place PVC Wall Forms	1044-S/2019
44	Permanent Wall Form (PVC)	1050-S/2020

Concrete 3D Printing Technology (C3DP)

- Labour safety – The safety of the workers can be enhanced by the use of this technology.
- No Requirement of Formwork- The printing operation of the vertical elements does not require formwork.

2. Ferron Panel as part of Ferrobuild Design System

Ferron panel is cladding solution for light gauge steel frames. It consists of two layers of steel mesh of galvanized mild steel, 250 MPa yield strength (minimum) with minimum cover to mesh as 2.5 mm. The two layers of weld mesh, minimum 1 mm diameter, at required intervals on either side are encased in mortar of M35 Grade. The thickness of panel comprising of steel weld mesh and mortar composite is 18 mm or above (as per the requirement). This makes Ferron panel a light weight and sleek wall unit, easy to be fitted.

Since, ferrocement is the base material, the ferron panels have relatively high strength in direct tension, flexural tension, compression and shear. Ferron panels are screwed and/or glued to the light gauge steel frames mobilizing composite action and forming novel structural system for walls, beams and slabs. This structural system is also referred to as 'Ferrobuild Design System' or Light gauge steel and ferron composite structure. Transport and handling of structural components is easy as weight of individual component is less than 25 kg.

Ferron Panel as part of Ferrobuild Design System

The Ferron Panels based Ferrobuild design system has following features;

- Stronger walls having higher flexural strength compared to brick masonry walls
- For typical G+3 residential building, there is reduction in steel consumption, cement consumption, CO_2 emission, water consumption & dead weight in comparison to conventional RCC construction
- Smaller & economical foundation size due to reduced self-weight of the building
- Higher speed, quality & better seismic performance compared to RCC Construction
- Composite action between steel and ferron panels enhance the capacity of bare LGS sections
- Higher thermal insulation of the wall. The same can be further improved with insulation material in cavities.
- In case of the failure in buildings, the debris will never be formed enabling easy evacuation. Hence, suitable for strategic buildings like fire stations, hospitals etc.
- For defence, ready to use bunkers can be made and transported easily. The walls have high strength under impact loads hence are suitable. The strength of the walls can be further enhanced as per the

requirement.

- The Ferron panels are maintenance free & its replacement is easy.

3. Geopolymer Coarse Aggregate (GPCA)

The Geopolymer Coarse Aggregate (GPCA) has been developed by NTPC by primarily utilizing Fly Ash, an Industrial by-product, from coal based Thermal Power Plants (TPPs). The initial production & lab scale research work on these aggregates were conducted at NTPC Ramagundam. Apart from fly ash from ESP 2nd field onwards from coal based TPPs, the other main ingredients for making GPCA include Sodium Hydroxide (NaOH) flakes, sodium silicate (Na2Sio3) liquid and water. The designed proportions of all the raw materials are thoroughly mixed & transferred to roller compressed machine to produce aggregates.

After the trial production, a pilot project of 20MT/Day capacity has been installed at NTPC Sipat to manufacture GPCA for its various applications as alternate to natural stone aggregate.

Geopolymer Coarse Aggregate (GPCA)

Special features of the system include:

- Geopolymer coarse aggregates are artificial aggregates made from industrial waste as fly ash.
- The aggregate is light in weight and meet the specifications to be used in concrete works.
- Being light in weight material handling is easy compared to natural stone aggregate.
- Self-weight of RCC structures will reduce with the usage of GPCA, resulting in the reduction in cost of construction.
- No need of any stone quarrying required for the production of GPCA, conserving the already scarce natural resource.
- Manufacturing of GPCA does not require water for curing.

4. Artificial Geopolymer Fly Ash Fine Aggregate (GFS)

NTPC with VNIT, Nagpur has developed Artificial Geopolymer Fly Ash Fine Aggregate (GFS). For the production of geopolymer fly ash sand (GFS), initially the laboratory scale production was carried out by mixing fly ash in the alkaline activator solution consisting of sodium hydroxide and sodium silicate. After the successful trial production of the GFS at laboratory scale, a pilot plant was setup at VNIT Nagpur from the funding provided by NTPC for the production of GFS at larger scale.

Artificial Geopolymer Fly Ash Fine Aggregate (GFS)

Geopolymer fly ash sand is manufactured by addition of different molar concentration of sodium hydroxide and sodium silicate activator solution to the fly ash particles. The raw materials mixed thoroughly and granulated through a granulator to a desired size as per IS 383: 2016. The fly ash sand granules are then heated at a suitable temperature to provide curing and achieve the desired characteristics.

NTPC is presently in the process of installation of a commercial plant of 10 Ton/Hour (50,000 Ton/Annum) for converting Flyash to sand at Sipat premises for its various applications as replacement of river sand in construction works.

Special features of the system include:

- Geopolymer Fine Flyash Aggregate (GFS) are artificial aggregates made from industrial waste like fly ash.
- The GFS is light in weight and meets the specifications to be used in concrete works.
- The GFS based concrete gains strength with passage of time. The durability characteristics of the concrete in terms of Rapid Chloride penetration, chloride migration & carbonation resistance are much better with use of GFS as replacement of river sand in concrete.
- With the production & use of GFS, already scarce natural resource (river sand) can be conserved.

Nano Concrete Aggregate (NACA)

5. Nano Concrete Aggregate (NACA)

NTPC has started the production of Nano Concrete Aggregate (NACA) using the technology patented by Technologists Dr. N Bhanumathidas and Sh. N Kalidas, wherein the NAC Aggregates are manufactured by crushing NAC stone (Boulders). The technology was chosen through a Nation-wide open competition named "NTPC Ash contest" in February 2019.

The basic process for manufacturing NACA based coarse aggregate involves production of homogenous self-compacting paste by mixing fine fly ash, cement, water and admixture which is used to cast Nano Concrete (NAC) boulders. After curing and gaining designed strength, the boulders are crushed in crusher to get aggregates of desired size.

NACA has a specific gravity of 1.85 and a bulk density of 1.0 t/cum compared to Natural Stone Aggregate (NSA) of 2.6 specific gravity and Bulk density of 1.4 t/ cum. As a result NACA based concrete is about 20% lighter then NSA concrete. NACA can be used in various concrete based applications as an alternate to NSA. The use of this aggregate can help in sustainable development of construction industry through use of Industrial by-product with proportionate conservation of natural stone aggregate resources.

Special features of the system include:

- As the product (NACA) attains strength through hydration chemistry, no thermal energy is involved in the production.
- Product is obtained from the crushing of the flyash cement based boulder. Hence, it is green product due to use of flyash, which is a by-product/ waste from coal based TPPs.
- Product is cast as stone and then broken in crushers. The broken multiple phases of aggregates are useful for better bonding.
- The product gains strength with passage of time.
- Specific gravity of the product is in the range of 1.8 to 1.9 gm/cc. Being light in weight in comparison to NSA, it can be easily stored anywhere, and comfortably handled at site.

6. Kinzok Aluminum Alloy Panels

The Panels are factory fabricated single skin aluminum alloy panels for use as external /internal cladding & ceiling applications in various types of building structures. The panels are available in thickness of 0.8 mm to 1.4 mm, to achieve required level of structural stability.

The structure built with the panels can incorporate MEP services along with various other architectural elements such as cove. These panels act as Rain screen facade which through natural air ventilation system brings some advantage in terms of thermal efficiency in the buildings. Being aluminum based, the panels have good strength to weight ratio.

Special features of the system include:

- Aluminium is one of the most recyclable materials. The recycling of aluminium reduces significant amount of energy & proportionate greenhouse gas emission as compared to processing of virgin raw material.
- Aluminium cladding does not need frequent maintenance resulting in cost saving & ecological advantages.
- It protects the base structure from direct exposure of harsh climate, thus improving its longevity.
- These panels act as Rain screen facade which through natural

Kinzok Aluminum Alloy Panels

air ventilation system brings some advantage in terms of thermal efficiency in the buildings.

7. uPVC Door & Window System

uPVC Doors & Windows are fabricated by the Agency from the unplasticized Poly vinylchloride (uPVC) extruded hollow multi chamber profile sections. The uPVC comprises of Poly vinylchloride, Calcium carbonate, Titanium dioxide, stabliser (Ca-Zn) and Impact modifier. The agency is authorized partner of Deceuninck, one of the world's largest manufacturers of uPVC profile sections, having origin in Belgium & a branch office in Chennai, India, and presently sourcing uPVC extruded profiles from the Deceuninck production facility at Turkey. These sections of uPVC extruded profiles are available in small and big series, and meet various sizes of door & window systems as per customer requirements.

Special features of the system include:

- Ease of Installation and Usage: the uPVC doors & windows fabricated & finished in a factory/ controlled condition, enables it achieve alignment accuracy & help in ease of installation and smooth operation during its usage.
- Appearance and Aesthetics: there is large product range including customized solutions, which comes with good appearance and aesthetics.
- Resistance to Water and Moisture: product provides good resistance to water and moisture penetration.
- Thermal & Sound Insulation: the product exhibits good thermal & sound insulation.
- Provision of grills: The provision for grills can be made as per the requirements.

uPVC Door & Window System

PACs for Renewal

PACs for the following systems/ products have been renewed;

1. M/s Mutha Industries Ltd., Mumbai (Bamboo wood products)
2. M/s Beardsell Ltd., Chennai (Quik Build Panels)
3. M/s ESES Bio Wealth Pvt. Ltd, Morigaon (Assam) (Strand Woven Bamboo Wood Flooring, Wall Panels & Door/Window Frames)
4. M/s Outinord Formworks Pvt. Ltd., Pune (Modular Tunnelform System)
5. M/s Larsen & Toubro Limited, Chennai (Volumetric (3D) Concrete Printing Technology (VCPT)
6. M/s Coffor Construction Technology Pvt. Ltd., Vadodara (Structural Stay-in-Place Formwork System)
7. EPACK Polymers Pvt. Ltd., Greater Noida (PUF Sandwich Panels with Pre Engineered Building structure)

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. Masonary Reinforcement
2. Plastic Embeded Light Weight Brick
3. Interlocking Block
4. Non-Corrosive Stainless Steel Rebar

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 reports of samples of the products/ systems etc. before preparation of Performance Appraisal Certificates (PACs).

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Session on Vulnerability Atlas of India

A Technical Session on Vulnerability Atlas of India, was organised for NICEE weeklong residential program for Architects at IIT, Kanpur on July 28, 2023. BMTPC has created a dedicated website https://vai.bmtpc.org for easy access and downloading the hazard maps w.r.t. earthquakes, wind/cyclones, flood, landslides, thunderstorm & damage risk tables for the country & states upto district levels. BMTPC, MoHUA and SPA New Delhi has launched e-Course on Vulnerability Atlas of India on https://ecourse.bmtpc.org. 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.

NIDM – BMTPC Webinar Series

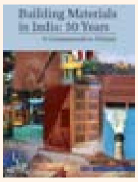
A Webinar series was organized by the National Institute of Disaster Management, Ministry of Home Affairs, Govt. of India in collaboration with BMTPC covering the myriad topics in the area of disaster mitigation and management. A few of them are:

How Rooftop Lightweight Construction Works?	May 19, 2023
How Lightning Arrester works?	May 26, 2023
How Rejuvenation of Water Bodies by Natural Extract Works?	June 2, 2023
Earthquake induced Liquefaction Mitigation Measures	June 9, 2023
How Bridge Monitoring & Inspection Works?	June 16, 2023
How Post-Disaster Communication Network works?	July 7, 2023
Technology Transition through Light House Projects under PMAY(U)	July 21, 2023
How HAM Radio based Post Disaster Communication works?	July 28, 2023

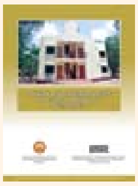
Tech Titan of India 2023 Award

Commemorating the 6th Punya Tithi of Bharat Ratna Atal Bihari Vajpayee ji on 16th August 2023, BMTPC is felicitated in a gala digital ceremony with **Tech Titan of India 2023** in the **Construction Tech category**. The award was given by Rethink India Institute for our work specially towards building capacities through NAVARITIH (an online Certificate Course on Innovative Construction Technologies) and as knowledge repository. The organisers selected BMTPC though impact survey assessment conducted independently.

Priced Publications of BMTPC



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



MANUAL ON WATERPROOFING OF GFRG BUILDINGS
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SCHEDULE OF ITEMS & RATE ANALYSIS FOR GFRG CONSTRUTION
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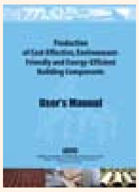
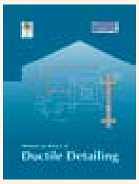


USER'S MANUAL on Production of Cost-Effective, Environment-Friendly and Energy-Efficient Building Components -
116 Pages, Rs. 250 + 50 postage



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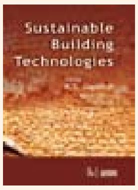

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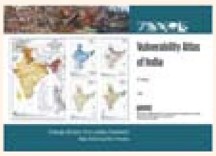

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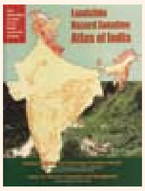

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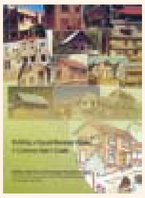

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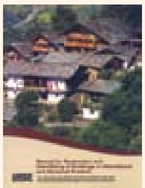

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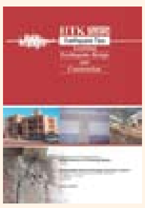

EARTHQUAKE TIPS – LEARNING EARTHQUAKE DESIGN & CONSTRUCTION (Third Edition)
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2 October 2023

World Habitat Day

Resilient urban economies

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

Vision

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

Mission

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

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