



CONSTRUCTIONS IN INDIA FOR SUSTAINABLE BUILT ENVIRONMENT BASED ON COMPRESSED STABILIZED EARTH BLOCKS (CSEB) CASE STUDIES

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ABSTRACT

The urbanization development in India over the last few decades has been fast, very unequal, and not sustainable. The UN projects that by 2050, it will be one of the top three nations in terms of urbanization. India's urban population is expected to grow from 481 million to 814 million by 2050 an added 333 million. There will be significant effects on energy consumption patterns and GHG emissions when India's urban population increases from 34.93% now to 57.7% in 2050. Conventional construction materials have a high embodied energy, and buildings account for most of the world's energy usage. The production of today's standard materials accounts for 20% of global CO₂ emissions and 25% of global energy usage. Rapid building is required to satisfy the need for housing, but if it is done wrongly, it will only meet the demand for housing temporarily and at the expense of livability, sustainability, pollution, resilience, and ultimately economic competitiveness.

The Compressed Stabilized Earth Blocks (CSEB) have the potential to revolutionize environmentally friendly construction in India. CSEBs provides the perspective of energy-efficient, cost-reduction, and environmentally-friendly building materials, overall contributing to sustainable development, at a time when there is a growing concern of awareness regarding environmental issue. Since CSEBs are unburned materials, no coal or other burning fuel is required in their manufacturing. The paper delves into the history of CSEB, passive architecture, and circular economy in Indian residences, incorporating many strategies into one plan, the potential to reduce a building's overall energy consumption while simultaneously improving its cost-effectiveness, usability, and social cohesion. The goal of this study is to demonstrate that stabilized earth walls may be utilized in low and medium-rise structures when paired with a frame constructed of today's standard materials, lowering total use while achieving density requirements.



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1. INTRODUCTION

India reflects the problems plaguing Asia as a whole, such as growing urbanization and inadequate planning for the effect of the environment on existing metropolitan regions. Although most structures are constructed of basic materials such as concrete, cement, brick, and steel, some urban practitioners and scholars are looking for more sustainable, locally appropriate alternatives. One such method is stabilized earthen construction, which combines old building traditions with cutting-edge technology. Since the 1970s and 1980s, the Auroville Earth Institute and the Indian Institute of Science's Centre for Sustainable Technologies have been researching earthen building methods and how they may be extended with the use of modern technology (Joseph, P. 2021). Building with earth has been practiced for thousands of years. Traditional adobe bricks were made by blending mud and straw and drying the resulting material in the sun, but this method created brittle and short-lived bricks. Later centuries perfected the procedure, enabling millions of bricks manufactured from burnt clay to be produced. Compressed stabilized earth bricks (CSEB) became popular in the mid-twentieth century. Wet and sandy soil components are stabilized with cement at a rate of 3 to 10% of the entire mix before being compacted into blocks using a manual or mechanized press (Thanushan K and Sathiparan N 2022). From its first trials in Colombia in the 1950s, the novel building material soon spread over the rest of South America, then to Africa in the 1960s and 1970s, and eventually to the United States and Australia in recent decades (1980s). It was first adopted in India in the late 1970s, and its use has progressively risen over the following decade.

I will be discussing two case studies one The Earth Institute's Vikas Community Auroville and Bangalore's Residential Neighbourhood Malhar to demonstrate how this alternative construction material can be scaled up to create ecologically friendly, highly habitable, and environmentally sensitive structures that adhere to circular economy principles.

2. CSEB APPLICATION EFFECTIVELY IN CONSTRUCTIONS

2.1 Vikas Community Auroville by the Earth Institute

Vikas Community in Auroville (Figure 1 and Figure 2) was built by the Earth Institute. The Auroville Earth Institute (AEI) is a non-profit organization committed to researching, developing, promoting, and spreading earth-based construction technologies since they are among the most cost-effective, low-carbon, and low-embodied energy options for sustainable development. Over the last 32 years, AEI has fostered and disseminated expertise in the construction of sustainable

habitats in 38 countries, making it one of the world's top centers for excellence in earthen architecture (Perello-Marín et al., 2018). This is the first project in Auroville to use stabilized earth in all phases of construction, from the foundations to the top. Individual flats, a few individual homes, and shared areas were constructed. In 2000, the Vikas neighbourhood was a leading contender for the World Habitat Award. It is still the greatest example of a completely accomplished comprehensive, synthetic development in Auroville (Mukherji et al., 2023).

The Vikas community was built in stages starting in 1992 and completed in 1998; the fourth structure in the complex includes four levels: a basement and three storeys above ground. The community has a carpet area of 1448 m² and has 23 apartments as well as a communal kitchen for 50 people. To emphasize the common goal, the community kitchen was first erected. Then a first block of four apartments was constructed, followed by a second block of five apartments. The third building, which houses 13 units, has four stories: a basement floor and three floors above it. This structure was designed to be self-sufficient in terms of soil requirements.

The use of environmentally friendly materials (earth and ferrocement) and ecological water management (watershed harvesting and biological waste water treatment) constituted the backbone of its material execution. For compressed earth blocks, rammed earth, and other earth-based technologies, woodless building techniques with 5% cement stabilisation have been employed (Dash, Shanta Pragyan et al., 2020).



Figure 1. Vikas Community third building block



Figure 2. Vikas Community Exterior facade

Building Materials

The third structure's design required that it furnish all of the soil that it would ever need. Excavation of earth from 1.20 meters below ground level was necessary for the construction of the 819 m² carpeted, 4-story structure. The CSEB walls are 13.40 m tall, with 24 cm of stabilized rammed earth foundations. The living rooms' flooring and roofs were composed of extremely flat vaults and domes. These CSEB vaults and domes were built using the "Free-spanning" approach. All stabilizing efforts utilized cement at a weight proportion of 5 percent (Gohnert M et al., 2018)

The protection of the planet's natural resources has long been a priority. The quarries where the material was mined were always pre-accounted for. These precautions guaranteed that the excavations blended nicely with the surrounding landscape and buildings. The quarries might be used as a garden reservoir and for wastewater treatment in a common kitchen and ten apartments during the first and second stages of building (De Sousa E Castro 2020)

Passive Design

The construction was built in an opportune location and with energy efficiency in mind. Integration with the terrain, considering the actual surroundings as well as any trees or other features. Sun protection and natural ventilation was mainly focused. Different architectural characteristics let in more natural light while minimizing the amount of heat generated inside the structure, lowering the need for air conditioning. This is tailored to the local circumstances by considering, among other things, the prevailing wind patterns and the quantity of direct sunshine. A position that is ideal for a variety of tasks, including water collection, aquifer recharge, cooling public areas, and community water supply. During the monsoon season, water should be collected with the goal of preventing runoff as much as feasible. Windows and open spaces were intentionally positioned to enhance natural light exposure and allow unhindered views of the gorgeous scenery beyond.

Circular Economy

To catch the runoff water, there were landscaped percolation pits. All of the precipitation gathered at the facility is used to recharge aquifers. Wastewater is treated in an on-site aerobic-anaerobic digestion tank that is dosed with helpful bacteria on a regular basis. Lagooning is used to remediate biological waste water (Kumar & Goyal 2020). This water is collected, filtered, and then used in a drip irrigation system to hydrate plants and flush toilets.

Quality of Life

The style of the building was inspired by the Earth Institute's vision of establishing a society in which "every individual may experience a safe, healthy, and fulfilling existence in harmony with nature," which is key to Auroville's mission (Clarence-Smith & Monticelli, 2022). In keeping with this goal, the Auroville by the Earth Institute offers huge open spaces that provide natural cooling and green views, promoting comfort via the use of natural construction materials. The whole edifice was built by highly skilled craftsmen, many of whom grew up in traditional craft families but were exposed to industrialized processes that allowed them to compete in the current market.

2.2 Residential Neighborhood: Malhar, Bangalore

Good Earth was started in 1991 by nine persons who were passionate about sustainable building. The non-profit corporation has evolved into a consultancy business, construction company, and real estate development firm. For the last 18 years, Good Earth has worked closely with Jayakumar Sonam (Jayakumar & Associates), one of India's leading architects, to design and create buildings that are both environmentally friendly and designed with the local population in mind.

Over the past several years, Good Earth has created a number of earthen buildings, demonstrating their feasibility in low-rise, high-density urban contexts. The Good Earth Malhar is an eco-village residential community on 50 acres of land, located south-west of Bangalore and 18 kilometres from the city center, is a unique intervention that integrates six residential clusters around shared public areas (Cheshmehzangi et al., 2018). The Malhar was designed to house 500 households and is split into five villages of 75 to 90 families each. Each village covers 5 to 12 acres. This has allowed to construct a development that is on a human size and is simple to maintain (Figure 3).



Figure 3. Malhar terraces Exterior Façade

Each Malhar Pattern and Malhar Resonance is like a townhouse (Figure 4, 5 and 6). The Malhar Terraces neighborhood has economical high-rise apartment complexes, while the Malhar Mosaic neighborhood features low-cost two-story structures. The second is the focus of study because it suggests a new strategy for conceptualizing middle-class housing in India that is both inexpensive and comfortable for its residents. There are about 2,000 people living there, and the land area is 4,046 square meters. The proportion of public space to total land area is far larger than in BAU instances of inexpensive housing clusters, at 46% (Kirby 2020). This research focuses on the 100 Apartments building to show that stabilized earth walls are feasible in low to medium-rise structures when combined with a frame produced using today's standard materials, thereby reducing their total consumption while still satisfying density criteria.



Figure 4. Malhar terraces Open terraces



Figure 5. Malhar terraces Landscape



Figure 6. Malhar terraces Pedestrian walkways

Building Materials

Two 5-story buildings were joined into one at Malhar Terraces, necessitating a concrete base and an RCC framework. The CSEB used in the construction of the walls is manufactured on-site using soil taken from the basement's excavation. Cavity skin walls are constructed using hollow terracotta bricks to increase thermal insulation and reduce the need for maintenance.

Passive Design

Malhar Terraces' delicate design was definitely inspired by terrace gardens located on mountain slopes. All apartments have direct access to natural light, and terrace gardens cool the interiors of the buildings. Corridors, bay windows, verandas, and alternate floors all help to improve the building's ventilation. An atrium act as an open-air, air-conditioned community space. Evaporative cooling is provided through a water feature in the Atrium.

Circular Economy

All of the flats get their water supply from a central underground sump tank that receives rainwater from the rooftops, filters it, and then distributes it to the units. Dedicated recharge wells are used to replenish ground water supplies with extra rainfall. Using a decentralized waste water treatment system (DEWATS), Wastewater is purified before being recycled for indoor and outdoor uses.

Quality of life

The Malhar neighborhood is a wonderful example of people-centered design due to its various features that contribute to the residents' high quality of life. Plenty of parks and gardens for the public to enjoy; jogging tracks, Revitalized local ecosystems, Human scale and aesthetically diverse architecture with a wide range of building materials, colours, and designs. All of the amenities at Malhar Terraces were thoughtfully designed to make each and every one of the residents feel right at home (Figure 7 and Figure 8). All occupants have access to the same communal spaces, and there are more than 20 different floor plans.



Figure 7. Malhar patterns Exterior Façade and landscape



Figure 8. Malhar patterns landscape

3. IMPACT IN LIFECYCLE

A local context tailored construction method that incorporates local context customized passive design, building materials, and circular economy concepts yields considerable environmental, quality of life, and economic advantages over the course of a building's whole lifecycle. The monitoring of indicators and the estimation of improvements in comparison to BAU scenarios are not done nearly often enough by projects. Despite this, there is a good deal of empirical research, both quantitative and qualitative, that demonstrates the advantages.

3.1 Environmental Benefits

This is reflected in a variety of indicators, including embodied energy, associated CO₂ emissions, lifetime of a structure, sustainable use of natural resources, and circular economy. In the current investigation, operational energy optimization was purposefully omitted so that the underappreciated subject of embodied energy may get the undivided attention it deserves.

The embodied energy and corresponding CO₂ emissions – The embodied energy and corresponding CO₂ emissions of a structure must be considered at every stage of the building's lifetime, from the procurement of raw materials and their processing through their delivery to the construction site and finally to its eventual destruction and disposal. Simply said, switching to CSEB from today's standard construction materials saves energy over the whole life cycle, which corresponds to less carbon dioxide gas released into the atmosphere. Table 1, compiled from various publications and data, compares these several phases.

Sustainable use of natural resources and circular economy- The demand placed on water supplies may be greatly reduced if the water cycle within a given region is made to circulate in that area. Twenty-one of India's largest cities are forecast to exhaust their groundwater

supplies by 2025, making India one of the world's most water-stressed nations. The ability to adopt such a strategy is essential at this point. In the same vein, India produces 62 million tons of solid waste yearly, of which approximately 30 million tons are simply discarded and just 10 million tons are handled. As a result, it's critical that solid waste should be minimised by reducing and recycling wherever possible. It is clear from the aforementioned case studies that the construction industry may play a pivotal role by implementing similar initiatives.

3.2 Economic benefits

It is possible to classify the costs of CSEB and the adoption of circular economy techniques into two broad categories: initial capital expenditures and ongoing operational costs. For this study, a comparison study of the two has not been found; nonetheless, literature references from various sources and interviews have yielded the following insights.

Capital cost - The entire capital cost of a wall erected using CSEB is comparable to that of a wall made with burnt bricks. Possible price spikes of 5 to 7 percent higher (Unni, A., & Anjali, G. 2022). The higher skill level required to manufacture CSEB is one element leading to this variation. It is necessary to make well-considered choices for each building component in order to keep capital expenses reasonable.

Lifecycle cost- Lifecycle costs are predicted to be much lower than those of business-as-usual buildings. For instance, the cost of a CSEB may be half of what a similarly-quality burnt brick would be. Consequently, the advantages of CSEB in terms of durability, strength, and building quality are overshadowed by its initial price. Water supply from rainwater collection and on-site wastewater recycling and reuse are examples of circular economy solutions that are extremely competitive in terms of lifetime cost since they need no financial input beyond the initial investment.

3.3 Benefits Related to Quality of Life

This is difficult to put a price on, but the qualitative advantages are on par with those to the environment and the economy. Human-scale structures, green spaces, improved shading and ventilation in public areas, a shared feeling of purpose in conserving natural resources, and a stronger sense of community are all byproducts of a locally-tailored, sustainable building process. Most Indian cities fall far short of the World Health Organization's recommendation that each urban resident have access to at least 9 square meters of green space, and this is especially true in low-income neighborhoods (Singh KK, 2018). The Malhar Terraces serves as an important example of an affordably liveable community (Table 1).

Table 1. Comparison Of Conventional and CSEB Building Materials

SL NO.	STEP	CONVENTIONAL MATERIALS	CSEB
1	Manufacturing	According to the International Energy Agency, the production of traditional construction materials accounts for 25% of world CO ₂ emissions and 20% of global energy consumption.	Tools, both manual and motorized, from the homestead to the semi-industrial scale may be used to create CSEB with a negligible amount of energy.
2	Transportation	Transport distances for conventional commodities might be in the hundreds of kilometers.	CSEB constructed from the subsoil hence no transportation required. If CSEB becomes widespread in areas where subsoil quality is adequate, it has the potential to significantly reduce CO ₂ emissions. CSEB = 51.5 Kg/m ³ Country Fired Brick (CFB) = 642.9 Kg/m ³
3	Maintenance	Concrete and glass walls may be aesthetically pleasing when first constructed, but they age far more quickly than more traditional building materials like stone or CSEB. The upkeep of modern skyscrapers made of concrete and glass is quite expensive.	Houses built with CSEB can resist severe weather with little upkeep, including rain, snow and frost.
4	Lifespan	A curtain wall made of reinforced concrete and glass has a lifespan of around 60 years, compared to 120 years for a wall made of conventional building materials like masonry and wood. Although embodied energy saving methods like hollow cement walls are effective in reducing energy consumption, they pale in contrast to CSEB in terms of durability.	Compared to its counterparts, CSEB have a competitively long lifetime. For instance, the Malhar Terraces structures have an expected 75-100 years of life duration.
5	Reuse/Disposal	Recycling of conventional construction and demolition waste is still in its infancy in India, despite the fact that the nation generates 15 million tons of this kind of garbage every year. To address the problem, more effective procedures and rules must be implemented.	Few instances of CSEB reuse have been investigated as of this writing. There is nonetheless a good possibility of doing so using two methods: 1. Deconstruct and repurpose CSEB. This needs a certain mortar, such as lime. 2. Crush blocks to create new ones. We can try to repurposing these items on-site or in close proximity to the site.

4. IMPLEMENTATION AND ENABLERS

Several enabling aspects are shared by the two case studies and may be grouped into three broad categories: dedicated professionals, enthusiastic participants, and an encouraging environment.

4.1 Professionals who are dedicated to their work

A group of architects who are experts in green building practices have taken the lead in stabilizing ground for building. These essential characteristics are shared by all of them:

Expertise: These professionals are well-versed not just in the standard building materials used today, but also in the vernacular materials and possibilities afforded by advances in technology and techniques. Their expertise has been refined through decades of use, and they are now in a position to see sustainable opportunities where others would pursue business as usual.

Personal commitment/ Sense of a mission: This understanding is motivated by a strong feeling of personal purpose. It is very unusual for these specialists, who see themselves as gatekeepers of sustainable urban development, to reject initiatives that do not align with their vision.

Context Specific: No project is a duplication of another project, but the local context is meticulously examined, evaluated, and used. This encompasses social and cultural background in addition to characteristics such as geography, topography, hydrology, and climatology. This method allows specialists to identify local context-specific passive design characteristics, suitable building materials, and construction procedures using local talents.

Optimal mix of designs and materials: The prevalent strategy is to pick the most suitable design and materials that concurrently fulfill the criteria of sustainability, affordability, construction time and liveability. In this technique, both conventional and vernacular or novel materials come together in an appropriate blend that

works well in each individual local setting. For example, concrete foundations may be decided for in a 4-5 stories structure while stone foundations may be utilized for a 2-storey building, the total usage of concrete being limited as much as appropriate in both circumstances (De Angelis A et al., 2020). Such an approach is far more facilitating in terms of its potential upscaling than a purist approach aiming to exploit non-conventional materials solely.

Ability to share knowledge with the beneficiary/client: Thus, the expert may successfully share information with the recipient, taking into account aspects of significance to the latter such as the cost and timeline of the building, which ultimately wins them over.

4.2 Building owner's support to sustainability

The eventual homeowner's approval is crucial to the success of any construction project. To a greater or lesser extent, both the short-term owners (such as real estate developers) and the long-term owners (the end users) in the chosen situations show a personal sensitivity to sustainability. A great example is the Vikas Community in Auroville, whose mission is to improve environmentally friendly urban planning by developing "models to establish sustainable lifestyles in huge numbers. "The instance of Good Earth is especially intriguing because it shows how an architectural firm, Jayakumar & Associates, and a real estate business, Good Earth, were able to build a seamless method of working together over time. The two organizations collaborate throughout the whole process, from initial concept to final inspection. They also create and refine building methods together and conduct thorough reviews of the project at each level. Understanding the client's or beneficiary's goals and wants, as well as winning their confidence and buy-in for long-term strategies, is impossible without first building a strong relationship with them. This method is incorporated so that studio-generated concepts may be put into action immediately. This helps get over the problem of traditional real estate developers seeing sustainable architecture as excessively hazardous and time consuming, which is a prevalent impediment. Buildings and neighborhoods that are sustainable, locally adapted, and people oriented at a fair cost are in great demand, as seen by the Malhar neighbourhood. Stakeholder participation in the form of insightful debates, informative seminars, and consistent interactive procedures throughout the project further helps supply and demand to come into harmony.

4.3 Enabling supporting ecosystem in place

Stabilized earthen building is still a specialized method that calls for experience and training. Although they would not be too difficult to acquire, training takes time, which might make the building process longer than

usual. Throughout the years, many of India's most revered earth-based practitioners have built up a supportive community in order to solve this issue. Good Earth draw on a larger pool of highly talented masons and craftspeople from all throughout India. The ecosystem has been built up through time via the efforts of many people who have been able to connect with one another, train, and gain knowledge and appreciation of the local craftsmen's abilities. Architects can keep the capital cost and duration of the building process under control for the customer if they have a steady stream of work for the ecosystem in which they operate.

5. SCALABILITY AND LESSONS LEARNED

As a result of the fact that the enabling factors that were discussed earlier are confined to a very specific community, the promising alternative construction style is a stand-alone approach rather than a mainstreamed and widely recognised approach. As a result, it has very little impact on the urban fabric as a whole. Since it has been shown that the concept is technically feasible, the next step is to consider how to advance the project and make it possible to scale it up.

In this regard, it is necessary to examine three primary areas of focus: the dissemination of information and skills; the mainstreaming of tried and proved sustainable ways into laws and regulations; and research on new breakthroughs.

5.1 Disseminate proven knowledge and skills

The expertise that made the chosen case studies possible is twofold: an appreciation for the crucial necessity of constructing sustainably, and a mastery of the technical know-how required to achieve that importance. Such insight is productive, but it is now restricted to an elite few. The feasibility of indigenous materials and the possibility of upscaling with industrialized techniques is not widely disseminated information, according to a number of India's top architectural institutes. So, few architects feel confidence working with stabilized earthen buildings.

Similarly, the talents of artisans are seldom given enough recognition and support. Selected artisans create economic prospects for themselves by using industrialized technologies to increase production volume without compromising on quality. Overall, low demand causes low supply, which in turn severely hampers the rate at which new entrants may penetrate the market. In conclusion, the vast majority of property owners and developers are skeptical about non-traditional methods. By dramatically increasing their level of understanding, we can better prepare the supply and demand sides for the coming change. As a result, the public, educational, and development sectors might work together to increase the rate at which the market for stabilized earthen buildings forms.

5.2 Adopt design and building regulations to the sustainability imperative

The use of earthen buildings is neither encouraged nor discouraged by India's National Building Code since it is neither expressly prohibited nor specifically considered (Rajagopalan, R. 2020). As a result, many Indian architects who work with natural materials rely on the standards of other nations. Such a strategy is effective in isolated situations, but it is necessary to have legislative backing in order to scale up and mainstream earthen buildings and other sustainable methods of urban development.

The importance of rules is best shown by the issue of operational energy efficiency in buildings. At this point in time, operational energy efficiency is mandated by national construction codes across the board, even in many emerging Asian economies. By tracing the sequential events that led to this breakthrough, we may draw analogies and provide suggestions for improving the building industry's embodied energy efficiency.

It is necessary to keep track of the amount of energy used in building from the start, a process known as embodied energy (Dixit, 2019). The time for this exercise has passed. Neither case study we're looking at has even attempted to estimate savings, much alone come close.

Establishing embodied energy standards and formulating laws and regulations would be impossible without regular monitoring, which will lead to a much better quantification of advantages associated to alternative methods of construction.

The operational energy efficiency and renewable energy sectors provide a model for how policies and regulations might be crafted to achieve the same results (market formation through the progressive introduction of minimum requirements or incentive-driven cross-subsidized rates). If we look at solar power as an example, the development of the solar energy industry was hastened by feed-in-tariffs and/or rules requiring utilities to purchase a minimum quantity of electricity from renewable energy sources.

It is imperative that the world community recognize that the building industry must undergo fundamental transformation in order to meet the goals of the Paris Agreement.

5.3 Facilitate R&D on alternative options and collect evidence building data

Even though materials made from earth are among the lowest in embodied energy and have been subjected to

the most extensive testing, there is still room for improvement in terms of how quickly and how high they can be built. Equally as much research is needed on less explored sustainable materials and their potential upscaling through new technologies, on how to more systematically reuse waste in construction, and on urban development models that better support sustainable construction. All of these areas of study are equally important. For instance, a model of urban growth with a high population density but a modest building height would not only help make earth-based buildings possible, but it would also provide a variety of other beneficial co-benefits. It is possible to protect a structure of up to four stories against earthquake damage with just a little amount of steel and concrete, which will in turn lower the building's embodied energy. Additionally, a structure like this one maximises operating energy and the possibility for solar rooftops, promotes affordability and shared public areas, and provides the comfort of a human-scale urban fabric. In other words, the mainstreaming of sustainable construction materials has to be accompanied by a strategic reflection on the types of urban fabric that are now the most aligned with the expectations of residents and with the sustainability imperatives that are facing the world today.

4. CONCLUSION

For centuries, many Indian communities have used locally available materials to build environmentally friendly green dwellings. It has changed throughout the years because of deep-rooted traditions and influenced by use and climatic trends. According to American Express Trendex survey, Indians are the most inclined to purchase sustainable products, with 87 percent saying they do so often and 97 percent stating they are interested in spending money on products that have a constructive effect on local firms and communities (Monaco S, 2021). Over 98% of Indian respondents said they would be willing to spend their money to help build low-carbon communities throughout the world, according to this. Therefore, there is much to be done to create Indian cities in a way that is environmentally responsible. Subsoil extracted during CSEB foundation excavation may sometimes be used as a raw material (Nahar, 2018). This might have a significant impact on the construction process due to the abundance of resources accessible on the development site. As soon as possible, sustainable construction methods should include wood-based structures, modular building techniques tailored to local conditions, and three-dimensional construction methods. Efforts must be made by corporations, non-profit organisations, and the international development community, as well as urban practitioners, to address this issue head-on.

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