

Use of cost-effective construction technologies in India to mitigate climate change

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Concentration of greenhouse gases play major role in raising the earth's temperature. Carbon dioxide, produced from burning of fossil fuels, is the principle greenhouse gas and efforts are being made at international level to reduce its emission through adoption of energy-efficient technologies. The UN Conference on Environment and Development, 1992 made a significant development in this field by initiating the discussion on sustainable development under the Agenda 21. Cost-effective construction technologies can bring down the embodied energy level associated with production of building materials by lowering use of energy-consuming materials. This embodied energy is a crucial factor for sustainable construction practices and effective reduction of the same would contribute in mitigating global warming. The cost-effective construction technologies would emerge as the most acceptable case of sustainable technologies in India both in terms of cost and environment.

Keywords: Cost-effective construction technologies, global warming, greenhouse gases, production of building materials.

Climate change and India's initiative

'WARMING of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level' – observed the Intergovernmental Panel on Climate Change in its recent publication¹. Greenhouse gases (GHGs) released due to human activities are the main cause of global warming and climate change, which is the most serious threat that human civilization has ever faced. Carbon dioxide produced from burning of fossil fuels, is the principle GHG.

The major part of India's emissions comes from fossil fuel-related CO₂ emissions. A World Bank report² has identified six countries, namely, USA, China, the European Union, Russian Federation, India and Japan as emitters of the largest quantity of CO₂ into the atmosphere. India generates about 1.35 bt of CO₂ which is nearly 5% of the total world emission.

India, a signatory to the Kyoto Protocol (see Note 1), has already undertaken various measures following the objectives of the United Nations Framework Convention on Climate Change (UNFCCC). These are almost in every sector like coal, oil, gas, power generation, transport, agriculture, industrial production and residential. While in

most of the above areas stress has been imparted on increasing energy efficiency and conservation, it is felt that reduction in consumption in various fields and rationalization of uses of energy-guzzling systems would also substantially contribute to our country's efforts in reducing GHGs and mitigating global warming.

Role of construction industry in climate change

The construction industry is one of the major sources of pollution. Construction-related activities account for quite a large portion of CO₂ emissions. Contribution of the building industry to global warming can no longer be ignored.

Modern buildings consume energy in a number of ways. Energy consumption in buildings occurs in five phases. The first phase corresponds to the manufacturing of building materials and components, which is termed as embodied energy. The second and third phases correspond to the energy used to transport materials from production plants to the building site and the energy used in the actual construction of the building, which is respectively referred to as grey energy and induced energy. Fourthly, energy is consumed at the operational phase, which corresponds to the running of the building when it is occupied. Finally, energy is consumed in the demolition process of buildings as well as in the recycling of their parts, when this is promoted³.

We have found that the cost-effective and alternate construction technologies, which apart from reducing cost of construction by reduction of quantity of building mate-

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rials through improved and innovative techniques or use of alternate low-energy consuming materials, can play a great role in reduction of CO₂ emission and thus help in the protection of the environment.

CO₂ emission during production of construction materials

Production of ordinary and readily available construction materials requires huge amounts of energy through burning of coal and oil, which in turn emit a large volume of GHGs. Reduction in this emission through alternate technologies/practices will be beneficial to the problem of global warming.

To deal with this situation, it is important to accurately quantify the CO₂ emissions per unit of such materials. In India, the main ingredients of durable and 'pucca' building construction are steel, cement, sand and brick.

Emission from crude steel production in sophisticated plants is about 2.75 t carbon/t crude steel⁴. We may take it as 3.00 t per t of processed steel. The actual figure should be more, but is not available readily.

Cement production is another high energy consuming process and it has been found that about 0.9 t of CO₂ is produced for 1 t of cement⁵.

Sand is a natural product obtained from river beds, which does not consume any energy, except during transport. The energy thus consumed has not been considered in this article.

Brick is one of the principal construction materials and the brick production industry is large in most Asian countries. It is also an important industry from the point of view of reduction of GHG emissions as indicated from the very high coal consumption and the large scope that exists for increasing energy efficiencies of brick kilns. In a study by GEF in Bangladesh (where the method of brick is the same as in India), an emission of 38 t of CO₂ has been noted per lakh of brick production⁶.

Cost-effective construction technologies in India

Table 1 indicates that by careful selection of materials and technologies in order to reduce consumption, it is possible to significantly reduce emissions.

Let us browse through some of the available and usable technologies in India, which have proven to be successful after years of trial by scientists, engineers and architects from different parts of the country. There may be more

Table 1. CO₂ emission from building materials

Material	Unit	CO ₂ emission (kg)
Steel	1 t	3000
Cement	1 t	900
Brick	1000 nos	380

such technologies, since India is a country of diversity and rich cultural and architectural heritage. It may be noted that cost-effective construction technologies do not compromise with the safety and security of the buildings and mostly follow the prevailing building codes. The most popular ones have been discussed here.

Rat-trap bond wall, brick arches and filler slab

This housing construction is the result of a technology that has been developed by the architect Laurie Baker (see Note 2) and has been tested and proven during the past 40 years in India.

Rat-trap bond in wall construction: While laying bricks, the manner in which they overlap is called the bond. There are several types of bonds developed in different countries from time to time. They are called as stretcher bond (required to construct 125 mm thick partition walls), English bond (most widely used to construct walls of thickness 250 mm or more), Flemish bond (decorative bond, used to construct walls of thickness 250 mm or more, slightly difficult to lay) and rat-trap bond. The rat-trap bond is laid by placing the bricks on their sides having a cavity of 4" (100 mm), with alternate course of stretchers and headers (see Note 3). The headers and stretchers are staggered in subsequent layers to give more strength to the walls (Figure 1). The main advantage of this bond is the economy in use of bricks, giving a wall of one brick thickness with fewer bricks than a solid bond. Rat-trap bond was commonly used in England for building houses of fewer than three stories up to the turn of the 20th century and is still used in India as an economical bond.

The main features of rat-trap bond wall are:

- Strength is equal to the standard 10" (250 mm) brick wall, but consumes 20% less bricks.
- The overall saving on cost of materials used for construction compared to the traditional 10" wall is about 26%.



Figure 1. Rat-trap bond wall (source: FOSET, Kolkata).

- The air medium created between the brick layers helps in maintaining a good thermal comfort inside the building. This phenomenon is particularly helpful for the tropical climate of South Asian and other countries.
- As construction is done by aligning the bricks from both sides with the plain surface facing outwards, plastering is not necessary except in a few places. The finished surface is appealing to the eye.
- Buildings up to two stories can easily be constructed with this technique (Figure 2). Baker has pioneered this type of construction and had built such houses more than 40 years ago, without showing any signs of distress till now.
- In RCC framed structures, the filler walls can be made of rat-trap bond.

Brick arches: The traditional RCC lintels which are costly, can be replaced by brick arches for small spans and save construction cost up to 30–40% over the traditional method of construction (Figure 3 a). By adopting arches of different shapes blended with brick corbelling (see Note 4; Figure 3 b), a good architecturally pleasing appearance can be given to the external wall surfaces of the brick masonry.

Filler slab in roof: This is a normal RCC slab where the bottom half (tension) concrete portions are replaced by filler materials such as bricks, tiles, cellular concrete blocks, etc. These filler materials are so placed as not to compromise the structural strength, result in replacing unwanted and non-functional tension concrete, thus resulting in economy. These are safe, sound and provide aesthetically pleasing pattern ceilings and also need no plaster (Figure 4 a).

The main features of the filler slab are:

- Consumes less concrete and steel due to reduced weight of slab by the introduction of a less heavy, low-cost filler material like two layers of burnt clay tiles. Slab thickness minimum 112.5 mm (Figure 4 b).
- Enhances thermal comfort inside the building due to heat-resistant qualities of filler materials and the gap between two burnt clay tiles.
- Makes saving on cost of this slab compared to the traditional slab by about 23%.
- Reduces use of concrete and saves cement and steel by about 40%.

Compressed earth block

Compressed earth blocks (CEBs) are earthen bricks compressed with hand-operated or motorized hydraulic machines. Stabilizers such as cement, gypsum, lime, bitumen, etc. are used during production or on the surface of the bricks. In many areas of the world, proper materials are

available for making CEBs, and thus this type of block may be a better choice than any other building material. One of the factors that affect the use of CEBs is the mental barrier of using simple earth rather than burnt clay bricks. Non-availability of skilled manpower and technical guidance to produce large quantities of CEB with proper quality is also a determinant force.

Advantages of CEB include:

- Uniform building component sizes, which result in faster construction.
- Use of locally available materials and reduction of transportation (CEBs are mostly produced locally by transporting the equipment and machine at the work site).
- Modular elements like sheet-metal roofing, and pre-cast concrete door/window frames can be easily integrated into a CEB structure.
- The use of locally available materials and manpower helps in improving local economy rather than spending for procuring building materials from a distant place (Figure 5 a).
- The earth used is generally subsoil and thus the top agricultural soil remains intact.
- The reduction of transportation requirement can also make CEB more environment-friendly than other materials.
- CO₂ emission is practically nil in the production of CEBs.
- If the wet compressive strength is more than 20 kg per sq. cm, then a RCC roof can be laid and a second storey can be built (Figure 5 b). If the blocks have more than 8% cement stabilization, then a three-storey, load-bearing structure can be built. But, in such cases, expert advice is suggested⁷.
- Good quality blocks having lesser water absorption can safely be used in areas with high rainfall.



Figure 2. Two-storied building with rat-trap bond wall (source: FOSET).



Figure 3. (a) Brick arch and (b) Brick corbelling (source: FOSET).

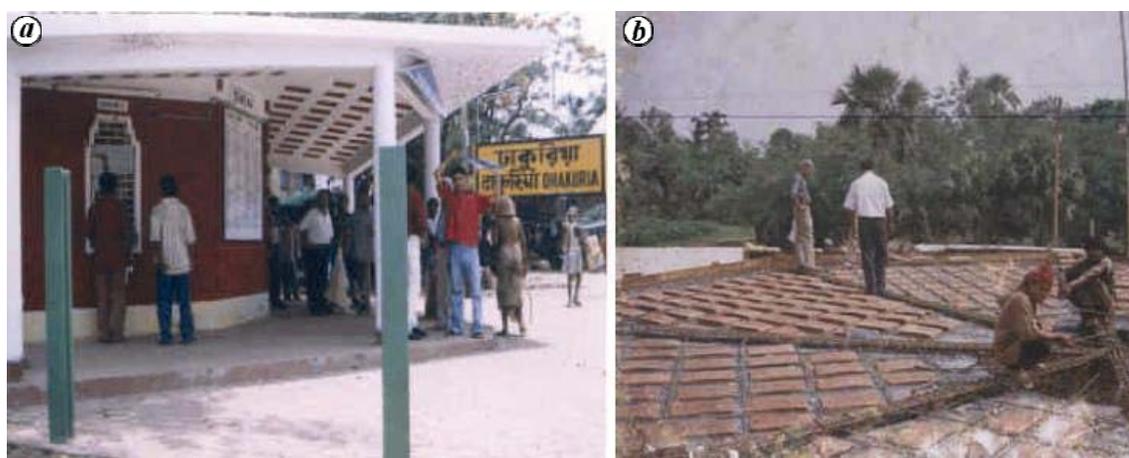


Figure 4. (a) Filler slab roof and (b) Filler slab under construction (source: FOSET).

Use of cost-effective technologies in India – Reduction in GHG emission and cost of construction

As already mentioned, there are other improved alternate technologies available like bamboo panels, bamboo-reinforced concrete, masonry stub foundation, etc. All of them can contribute significantly, if not more, in reducing in the cost of construction and CO₂ emission. For academic purpose, this article restricts discussion to rat-trap bond wall, brick arches and filler slabs only, for which data on material consumption and reduction from conventional techniques are readily available.

By adopting the techniques mentioned above, a reduction of 20% can be achieved in the cost of construction

without compromising on the safety, durability and aesthetic aspect of the buildings (Figure 6). In 2006, the cost of structural work for a building with ordinary masonry wall and slab in India was to the tune of Rs 3000 per sq. m. It may vary by 15–25% depending upon the location and availability of materials. A 20% saving in cost means reduction by Rs 600 per sq. m and for a 50 sq. m residential house, the saving will be to the tune of Rs 30,000.

The figures given in Table 2, when related to the Table 1 show reduction in CO₂ emission for a 50 sq. m building.

The above reduction of 2.4 t in CO₂ may qualify for carbon trading (see Note 5) also and according to the current rate of trading may fetch a minimum of Rs 1800 also. (Experts feel that though subject to wide fluctuations, the going rate of one Carbon Emission Reduction (CER) unit



Figure 5. (a) Production of CEB and (b) Two storied building made with CEB (source: Auroville Earth Institute, Puducherry).

Table 2. Reduction in CO₂ emission for a 50 sq. m building

Building material required by conventional method	Reduction by using cost-effective construction technology (rat-trap bond wall, brick arch and filler slab)	Reduction in carbon dioxide emission (kg)
Brick – 20,000 nos	20%, i.e. 4000 nos	1440
Cement – 60 bags or 3.0 t	20%, i.e. 0.6 t	540
Steel – 500 kg or 0.5 t	25%, i.e. 0.125 t	375
Total reduction in carbon dioxide emission		2355 (say 2.4 t)



Figure 6. Office building with rat-trap bond wall, filler slab (source: FOSET).

in the European market is around 12–13 Euros. One Euro is now equivalent to Rs 57.43.) In case of houses made of compressed mud block, reduction in CO₂ emission would be to the tune of 8000 kg or 8 t per 50 sq. m of the house.

The Indian housing scenario and scope of reduction of CO₂ emission

Increase in population, rise in disposable income, and aggressive marketing by financial institutions to provide

housing loan on easier terms are pushing up the demand for durable permanent houses in both urban and rural areas of India. Construction of permanent market complexes, malls and other recreational amenities in big cities has also undergone phenomenal growth in recent times. In accordance with India’s National Housing and Habitat Policy 1998, which focuses on housing for all as a priority area, with particular stress on the needs of the economically weaker sections and low income group categories, the Two Million Housing Programme was launched during 1998–99. This is a loan-based scheme, which envisages facilitating construction of 20 lakh (2 million) additional units every year (7 lakh or 0.7 million dwelling units in urban areas; 13 lakh or 1.3 million dwelling units in rural areas).

If we consider that each house will be of a bare minimum area of 20 sq. m according to the standards of different government schemes, the total area of construction per year will be 40 million sq. m. If cost-effective construction technologies like rat-trap bond and filler slab are adopted, India alone can contribute to a reduction of 16.80 mt of CO₂ per year and at the same time can save Rs 24,000 million (20% cost reduction over 40 million sq. m of construction @ Rs 3000 per sq. m), which will go to the state exchequer as the schemes are funded by the Government. The reduction in CO₂ emission in monetary terms is equivalent to a CER of nearly Rs 1200 million.

Conclusion

Now it is the task of scientists, engineers and policy makers of our country to popularize the technology, so that India can significantly contribute to reduction in CO₂ emission from its huge and rapidly growing construction sector. Most Government Bodies and Municipalities in India are reluctant to accept this technology and give permission to people to build their house with cost effective technology (CET).

The following steps may be taken to ensure proper and extensive use of CET in the light of sustainable development and protection of the environment:

- Sensitization of people: Extensive awareness campaigns and demonstrations among general public and also among engineers and architects to make them familiar with these technologies. The market force of cost reduction will definitely play a major role in acceptance of CET if Governments/Municipal Bodies acknowledge these technologies and direct their concerned departments to adopt them. Promotion of cost-effective technologies through institutes like the HUDCO-sponsored building centres may also be thought of.
- Manpower development: Shortage of skilled manpower can play a crucial role in implementing any sort of new technologies in the construction sector. To promote cost-effective technologies, skill upgradation programmes have to be organized for masons. These technologies should also be a part of the syllabus for students of civil engineering and architecture at undergraduate and diploma level.
- Material development: The Central and State Governments should encourage the setting up of centres at regional, rural and district levels for production of cost-effective building materials at the local level. The building centres set up by HUDCO for this purpose should be further strengthened. Appropriate field-level research and land-to-lab methodology should be adopted by leading R&D institutes and universities to derive substitutes to common energy-intensive materials and technologies. Reuse of harmless industrial waste should also be given priority.
- Technical guidance: Proper guidance to general public through design, estimation and supervision has to be provided by setting up housing guidance centres, in line with the concept mooted by the HUDCO building centres.

We have solutions in hand to reduce global warming. We should act now through use of clean and innovative eco-friendly technologies, and evolve policies to encourage

their adoption by the statutory bodies to stop global warming. Along with other key sectors, this relatively ignored construction technology sector can also play a major role in reduction of CO₂ emission and mitigate global warming. With sincere efforts of all stakeholders, the goal can be achieved.

Notes

1. The Kyoto Protocol to the United Nations Framework Convention on Climate Change is an amendment to the international treaty on climate change, assigning mandatory emission limitations for the reduction of GHG emissions to the signatory nations. The objective is the 'stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'.
2. Laurie Baker (1917–2007): An award-winning English architect, renowned for his initiatives in low-cost housing. He came to India in 1945 as a missionary and since then lived and worked in India for 52 years. He obtained Indian citizenship in 1989 and resided in Thiruvananthapuram. In 1990, the Government of India awarded him with the *Padma Shri*, in recognition of his meritorious service in the field of architecture.
3. Stretcher: Brick (or other masonry blocks) laid horizontally in the wall with the long, narrow side of the brick exposed. Header: The smallest end of the brick is horizontal, aligned with the surface of the wall and exposed to weather.
4. Corbelling: A layer (or course) of bricks or any other type of masonry units that protrude out from the layer (or course) below.
5. Carbon trading: (i) Under Kyoto Protocol, developed countries agreed that if their industries cannot reduce carbon emissions in their own countries, they will pay others like India (a signatory to the Protocol) to do it for them and help them meet their promised reduction quotas in the interest of worldwide reduction of GHGs. (ii) The 'currency' for this trade is called Carbon Emission Reduction (CER). One unit of CER is one tonne equivalent of carbon dioxide emission. (iii) UNFCCC registers the project, allowing the company to offer CERs produced by the project to a prospective buyer.

1. *Climate Change 2007: The Physical Science Basis – Summary for Policymakers*, IPCC, 2007, p. 5.
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3. Buildings and Climate Change – Status, Challenges and Opportunities, United Nations Environment Programme, Chapter 2.1, p. 7.
4. Corporate Sustainability Report 2003–04, TATA Steel; www.tatasteel.com/sustainability_05/environmental/ev_09.htm
5. <http://www.bee-india.nic.in/sidelinks/EC%20Award/eca05/03Cement>
6. UNDP Project Document, Government of Bangladesh, Improving kiln efficiency in the brick making industry, 2006, p. 50.
7. www.chaarana.org/ecofriendlyhouses.html

ACKNOWLEDGEMENTS. I thank late Prof. Lawrie Baker; COSTFORD, Kerala; Dr M. R. Yogananda, Alternative Construction Technologies, Bangalore; Auroville Earth Institute; HUDCO; UNESCO, and FOSET.

Received 17 June 2007; revised accepted 5 December 2007