Utilization of Earth Technologies for Socio-Economy Upliftment

Shalini Mishra
(Assistant Professor, Department of Civil Engineering, Gurgaon College of Engineering, Gurgaon (Haryana), India)

ABSTRACT

The two thrust areas in the housing sector are the promotion of building material units using local materials consistent with ecological balance, and the production of building materials with low energy inputs which substitute for energy intensive building materials. Considerable amount of energy is spent in the manufacturing processes and transportation of various building materials. Conservation of energy becomes important in the context of limiting of green house gases emission into the atmosphere and reducing costs of materials. Common burnt clay bricks are increasingly becoming costly due to excessive cost of fuel to burn them and not many suitable brick earths are found everywhere. Stabilized mud block could be an economic alternative to the traditional brick. The paper presents how environmentally-friendly building materials and construction technologies can be made more affordable to the urban poor while still meeting rigorous building standards. These techniques also help in mitigating climate change by avoiding carbon emissions during the production of building materials and construction as well as by saving thousands of trees & intended to help promote the use of earth construction in a wider region.

Keywords: *Burnt clay bricks, Cement stabilised earth blocks, Energy conservation*

1. INTRODUCTION

"The building and construction industry is considered a key player in sustainable development, with the potential to significantly impact society and the environment" (Shelter Initiative for Climate Change Mitigation). Meeting the need for adequate housing of the world's population requires sustained investment and continued innovation, particularly in appropriate technologies that lower the cost of construction and the cost to the environment. There is a need to promote awareness of appropriate construction technologies in civil society and the private sector. Appropriate technologies refer to materials, methods and/or practices which help protect the natural environment, take inspiration from the cultural values and practices in the area, make use of local resources, and contribute to local economic development. Selection of materials and technologies for the building construction should satisfy the felt needs of the user as well as the development needs of the society, without causing any adverse impact on environment. In recent years, awareness of environmental aspects has grown in the building and construction sector. Manufacturing processes of building materials contribute greenhouse gases like CO_2 to the atmosphere. There is a great concern and emphasis in reducing the greenhouse gases emission into the atmosphere in order to control adverse environmental impacts This paper discusses the use of Interlocking Stabilised Soil Blocks as an alternative to burned bricks. This technology makes use of soil for the making of blocks which is naturally or chemically stabilized and then compressed by manually operated or motor-driven machines. This paper deals only with the blocks made with the manually operated machine as it is the most affordable option, more easily transferable to different contexts, and easy to use and maintain.

2. EARLIER STUDIES

An experimental investigation was done by Dr. A.K. Choudhary, Shailendra Kumar, Dr. B.P. Verma at NIT, Jamshedpur as a part of a low cost housing project. The locally available soil in the Jharkhand region is a residual soil of lateritic origin and as such not so suitable for making good quality bricks. The lateritic soil after stabilizing with cement has been used for preparing pressure moulded building blocks of size 23 cm × 11 cm × 9 cm. The blocks were tested for their compressive strength, water absorption and block density and encouraging results have been obtained. It is concluded that the pressure moulded cement stabilized blocks could be used as an alternative to the burnt clay bricks in lightly loaded buildings (particularly in rural areas) [1].

Energy requirements for production and processing of different building materials and the CO2 emissions and the implications on environment have been studied by Buchanan and Honey [5], Suzki et al. [6], Oka et al. [7], and Debnath et al. [8] among others. These studies pertain to New Zealand, Japan and India. Energy consumption in the production of basic building materials (such as cement, steel, etc.) and different types of materials used for construction has been discussed. Energy spent in transportation of various building materials is presented. A comparison of energy in different types of masonry has been made. Energy in different types of alternative roofing systems has been discussed and compared with the energy of conventional reinforced concrete (RC) slab roof. Total embodied energy of a multi-storeyed building, a load bearing brickwork building and a soil–cement block building using alternative building materials has been compared. It has been shown that total embodied energy of load bearing masonry buildings can be reduced by 50% when energy efficient/alternative building materials are used [2].

A Report on Low Cost Housing using Stabilised Mud Blocks submitted by Dr. L. Dinachandra Singh & Shri. Ch. Sarat Singh at Manipur Science & Technology Council, Imphal was discussed about the low socio-economy condition of Manipur state and hence, it is essential for the people of Manipur to explore an alternative technology for low cost housing in a consequence of styles of modernisation. Direct use of soil (without burning) for wall construction in various forms in inexpensive though it has certain disadvantages. Hence, there is a need for some advanced technologies for wall construction using soil/mud at a village Leimaram, Bishnupur district, Manipur. Leimaram, the project village is situated in Bishnupur district of Manipur and 25km from the state capital, Imphal. The soil found in the area is silt clay loam and it is suited for making of mud/soil blocks. Topographically, the area is at an undulated higher slope and it is free from flood/water logging. The Compressed earth block (CEB) technology offers a cost effective, environmentally sound masonry system. A stabilised earth/mud block has wide application in construction for walling, roofing, arched openings, corbels etc. The blocks are manufactured by compacting raw earth mixed with stabilised such as cement or lime under a pressure of 20-40 kg/cm2 using a manual or mechanised soil press. TARA-Balram Compressed earth blocks machine manufactured by Technology and Action for Rural Advancement (TARA) New Delhi has been utilised for making stabilised soil blocks of the project. The project workers and local youths have been trained about the operation of the machine and mud blocks making techniques. In India the technology for stabilised earth block is being promoted by HUDCO's network of Building Centres to build public sector housing and institutional projects [3].

3. SCOPE OF THE PRESENT STUDY

Earth is the oldest material used by man. People have used their native ingenuity to develop forms for the utilisation of earth ranging from the extremely simple to highly complex. They have used the material in response to varying resources, social needs and site conditions. With the individual revolution, people had access to machines, easily available fossil fuels and a range of newly developed materials. New technologies became popular and earth construction skills were lost or regulated to the vernacular builder. Impetus was given to earth architecture in the post world war II era due to economic and energy saving concerns. However, as western nations worked their way to prosperity, the use of earth was eclipsed by a desire for modernity. Earth has always been the most widely used material for building in India and is a part of its culture. Traditionally, mud construction varies enormously with topography, climatic condition and needs of different regions. The common methods used for earth construction are cob, wattle and daub, rammed earth, and adobe. Approximately 55% of all India homes still use raw earth for walls. Earth is now though of as a poor man's material because of disadvantages such as high maintenance and low durability. Its major limitations are:

- water penetration
- erosion of walls at level by splashing of water from ground surfaces
- attack by termites and pests
- high maintenance requirements

The compressed earth block overcomes these limitations by an increase in block density through compaction using a mechanic press. The water content in soil is low for compaction as compared to the puddle clay required for mud bricks and ensures much greater dimensional stability.

A block :

- has high density which varies between 1.8 and 2.1 gm/c.c., this gives more load bearing capacity and improved water resistance.
- is low cost
- is easy to manufacture locally by small group of people
- is low in energy consumption because no fuel is burnt for block making or transportation
- can use soil available at site
- has smooth surfaces

With these advantages a compressed earth block can be used for construction of houses. Greater design care and stabilisation enable the construction of more ambitious structures that need less maintenance and are longer lasting.

3.1 Objectives stated in this paper

(i) To upgrade the rural traditional Kutcha houses.

(ii) To introduce cost-effective and durability houses – an alternative of burnt bricks.

(iii) To demonstrate and popularise the technology of stabilised mud blocks using locally available soils/muds.

(iv) To uplift the poor people with standard houses of the technology

(v) To impart the technology to rural artisans for socio-economy upliftment.

3.2 Embodied Energy of building materials & technology-

Energy in buildings can be categorised into two types:

(1) energy for the maintenance/servicing of a building during its useful life, and

(2) energy capital that goes into production of a building (embodied energy) using various building materials.

Study of both the types of energy consumption is required for complete understanding of building energy needs. Embodied energy of buildings can vary over wide limits depending upon the choice of building materials and building techniques. RC frames, RC slabs, burnt clay brick masonry, concrete block masonry, tile roofs represent common conventional systems forming the main structure of buildings in India. Similar building systems can be found in many other developed and developing countries. Alternative building technologies such as stabilised mud blocks (SMB's), prefabricated roofing systems, masonry vaults, filler slab roofs, lime-pozzolana (LP) cements, etc. can be used for minimising the embodied energy of buildings. Examples of buildings using alternative building technologies can be found in India and elsewhere [9–15].

Embodied energy can be split into:

(1) energy consumed in the production of basic building materials,

(2) energy needed for transportation of the building materials, and

(3) energy required for assembling the various materials to form the building.

It help in selecting energy efficient building technologies and building systems based on embodied energy thereby reducing cost of materials as well as CO_2 emission into atmosphere.

- Soil–cement block is the most energy efficient among the alternative materials for walling, consuming only one-fourth of the energy of burnt clay brick. Concrete blocks and steam cured blocks also consume much less energy during manufacturing process, when compared to burnt clay brick.
- Building materials are transported over distances in excess of 100 km in many urban centres in India. Diesel energy spent for transportation could be about 5–10% of energy spent during manufacturing process for burnt clay bricks. Energy spent in transporting high-energy materials like steel and cement is negligible when compared to the energy spent in the manufacture of these materials.
- LP mortars have lowest energy content when compared with other mortars like cement mortar, cement–pozzolana mortar, etc.
- Energy content of burnt clay brick masonry is 2141 MJ/m3. Soil–cement block masonry is most energy efficient at one-third the energy of burnt clay brick masonry. Concrete block masonry has about 40–45% of energy content of burnt clay brick masonry.
- Use of SMB filler blocks in solid RC roof/floor slabs leads to 20% reduction in energy content. Masonry vault roofs are more energy efficient than solid RC slab. Tile roofs have least energy content when compared with other roofing systems.
- Use of energy efficient alternative building technologies can result in considerable reduction in the embodied energy of the buildings. Load bearing soil–cement block masonry and SMB filler slab has resulted in 62% reduction in embodied energy when compared to RC framed structure building and 45% reduction when compared with burnt clay brick masonry and RC solid slab building [2].

3.3 Predominant Earth Construction Techniques :

Compressed Earth Blocks (CEB) are construction blocks made from a mixture of soil and a stabilizing agent compressed by different types of manual or motor-driven press machines. The Interlocking Stabilised Soil Blocks (ISSB) are a variation on this.

Adobe blocks are similar to CEB's and sometimes tagged as the precursor of CEBs. Adobe blocks are usually made of a compacted mixture of clay and straw, however are less uniform in size and shape than CEB's.

Cob construction does not involve blocks or bricks. Instead a mix of clay, sand and straw is made, then molded and compressed into flowing forms to make walls and roofs.

Rammed earth construction entails the making of a mold into which the soil, inclusive of a weatherproofing agent, is compacted and left to dry. Subsequently, the mold is released and the earthen form remains.

Earth sheltering refers to the use of earth on the structure of a building; it includes Earth berming, in-hill construction, and underground construction.

Wattle and Daub consists of a wooden or bamboo frame laid vertically and horizontally reinforced on which earthen daub is packed.

4. DEVELOPMENT OF ISSB TECHNOLOGY

The idea of making blocks by compacting earth or mixing it with stabilizing supplements is an old concept dating back thousands of years. Previously, and still customary in certain parts of the world, wooden molds are used for making sun-

dried or burned earth blocks. A key step in the evolution of this technology was the creation of the CINVA-RAM press in the 1950s by the Chilean engineer Raul Ramirez for the Inter-American Housing Center in Bogota, Colombia (CINVA). Since then, the methods of producing earth blocks has progressed resulting in diverse types of motor-driven and manual presses, and mobile and industrial scale production units. Even though the CINVA-Ram and other machines of this sort provided a more cost effective and environmentally-friendly solution for block-making, some disadvantages remained. There was still a need for masonry skills to lay the blocks, as well as significant amounts of cement for mortar.
The Human Settlements Division of the Asian Institute of Technology (HSD-AIT) along with the Thailand Institute of Scientific and Technological Research (TISTR) combined efforts for the creation of the first interlocking soil blocks by modifying the CINVARAM machine in the early 1980s. This new wall construction technique reduced the use of cement drastically, hence reducing final building cost considerably, and enhanced the structural stability of the wall. Extensive research in appropriate technologies continues in response to the increasing need for affordable and environmentally friendly shelter options. Technological advances include new types of interlocks, alternative stabilizing supplements that can be added to the soil and further improvements to the press machine. These technological developments allow for ISSB technology to become more competitive due to increased productivity, a more user and environmentally friendly profile, and an enhanced cost effectiveness. In the early 1990s, Dr. Moses Musaazi, from Makerere University in Uganda, developed a type of double interlocking system and curved blocks for the construction of water tanks [4].

Soil stabilization – It refers to the application of additional supplements or forces to the soil in order to make it more waterproof and stronger. The quality of the block depends on the properties and mix of soil types, the amount of force applied for compaction, and the addition of chemical or natural products to further stabilize and strengthen the blocks.
The interlocks – It increase the structural stability of the wall and reduce the amount of cement needed as mortar. The different types of interlocks have different structural purposes and architectural uses.

4.1 ISSB MACHINE

In East Africa, the manual Interlocking Stabilised Soil Block machine is manufactured in Kenya. ISSB blocks are used for the construction of buildings, latrines, wells, septic tanks, and water tanks. The main function of the machine is soil compression. Block quality is not so much defined by the machine but by the quality of the raw materials introduced into the mould, the method used for mixing them and the moisture content of the mix.
There are many factors to be considered when choosing the most appropriate machine. Among these considerations are:
» Affordability of end product
» Type and scale of building structures
» Availability of construction skills
» Availability of maintenance possibilities
» Reliability and cost of electricity
The manual machine is the most affordable option for block making an also the most convenient in rural settings due to the fact that it is manually operated and easy to use [4].

Technical specifications of the manual ISSB machine used in East Africa:
» Typical compression force: 80-100N
» Weight: 140kg
» 2-4 workers in an 8hr work day can produce 400-600 blocks
» Low maintenance: requires to be lubricated with engine oil.
» 130 stabilised blocks can be produced from a 50kg bag of cement.

4.2 ISSB Blocks

Depending on the machine, different type of ISSB blocks can be produced:
Straight Double Interlocking Block: The most commonly used block for wall creation.
Curved Double Interlocking Block: Used for making water tanks and sanitation facilities.
Wide Format interlocking Block: Allows for stronger, thicker walls, especially useful when making high walls.
Straight Single Interlocking Block: Contains a larger face, hence less blocks are needed to cover wall area. This was the predecessor to the straight double interlocking block.
Grooved Double Interlocking Block: The grooves of this block facilitate plastering, however, this machine is no longer produced.

5. COMPARATIVE ANALYSIS [4]

Properties	Interlocking Stabilised Soil Block	Sun-dried Mud Block	Burned Clay Brick	Stabilised Soil Block	Concrete Masonry Unit
Block Apperance					
Dimension (L x W x H) (cm)	26.5 x 14 x 10 cm	25 x 15 x 7 cm to 40 x 20 x 15	20 x 10 x 10 cm	29 x 14 x 11.5 cm	40 x 20 x 20 cm
Weight (kg)	8-10 kg	5-18 kg	4-5 kg	8-10 kg	12-14 kg
Texture	Smooth and flat	rough and powdery	rough and powdery	smooth and flat	coarse and flat
Blocks needed to make up a sq.m.	35	10 to 30	30	21	10
Wet Compressive Strength (mps)	1-4	0-5	0.5-6	1-4	0.7-5
Thermal Insulation (W/m C)	0.8-1.4	0.4-0.8	0.7-1.3	0.8-1.4	1-1.7
Density (kg/m^3)	1700-2200	1200-1700	1400-2400	1700-2200	1700-2200
Per Block (UgS)	350	50	150	400	3000
Per Sq Meter	35000	10000	55000	45000	75000

6. ADVANTAGES OF ISSB

Health

The curved ISSBs are ideal for meeting water and sanitation needs.

The curved ISSB can make water tanks, lining for pit latrines, and septic tanks. The final cylindrical shape of the structure and the block interlocking mechanism resists well against water pressure.

Environmental

ISSB technology provides an alternative to the commonly used fired brick, which currently is the cause of grave environmental degradation due to deforestation, and destruction of wetlands.

Economical

ISSB technology is an affordable way of construction. The bricks are weatherproof hence, there is no need to plaster the building exterior. Also, due to its interlocking mechanism, little cement is needed between block joints and wall construction goes up quickly allowing for labor savings. The machine itself weighs 140kg, making it in cases, easy to transport and work with onsite construction.

Easy To Use

The ISSB machine is easy to use and to maintain. After long use, repairs can be made locally through scrap material and welding. Due to the interlocking mechanism of the blocks, wall construction is much easier and quicker.

Aesthetic

ISSB technology is growing in popularity due to its aesthetic qualities, and has been successfully embraced by many communities trained on it.

Structural

ISSB technology has proven to be strong and durable when compared with traditional method of construction. It is suitable for multistory building, has a good compressive strength and in many examples has been used for the retaining wall of buildings.

Educational

As a new technology, this construction method can increase local skills and become an income-generating opportunity for various populations. It is easy to learn and can stimulate educational dialogue regarding environmental issues due to its nature.

7. CONCLUSIONS

The advantages of ISSB technology are many and even when compared to other technologies; it is affordable, environmentally sound, user friendly, performs well, versatile in use, among others. However, like with any other construction technology, care must be taken to ensure quality. The quality of ISSB's depends on good and locally available soil selection, a stabilizer to compliment the type of soil, and good practices during production and implementation. Therefore, for selecting an energy efficient building technology leading to considerable reduction in embodied energy of the building as a whole.

Interlocking Stabilised Soil Block (ISSB) technology has been gaining recognition, particularly in East Africa. This material and method of construction has the advantages of low cost and minimal environmental impact, while providing comparable quality to conventional fired brick construction. With a growing number of organisations using the technology there is a need to improve communication and knowledge-sharing, to quantify and verify the benefits, and to develop efficient approaches for its promotion and adoption.

8. REFERENCES

[1] Ashok Raajiv. V.S, Prof.G. Augustine maniraj pandian, *Experimental Investigation On The Effects Of Using Soil As A Replacement Of Sand In Concrete,* International Conference on Engineering Trends and Science & Humanities (ICETSH-2015), ISSN:2348 –8352, Volume-2, Issue -2, February 2015, Page 66.

[2] Good Earth Trust. (2009). *Interlocking Stabilised Soil Blocks, Project Database. Appropriate earth technologies in Uganda.*

[3] Dr. L. Dinachandra Singh, Shri Ch. Sarat Singh, *Report On Low Cost Housing Using Stabilised Mud Blocks, Manipur Science & Technology Council Central Jail Road, Imphal,* May 14-31, 2007.

[4] Dr A K Choudhary, Shailendra Kumar, Dr B P Verma, *Pressure Moulded Building Blocks with Lateritic Soils, IE (I) Journal,* Vol 85, November 2004.

[5] B.V. Venkatarama Reddy, K.S. Jagadish, *Embodied energy of common and alternative building materials and technologies, Energy and Buildings 35* (2003) 129–137.

[6] P. Walker, B. V. Venkatarama Reddy, A. Mesbah, J.-C. Morel, The case for compressed Earth block construction, in: Proceedings of 6th International Seminar on Structural Masonry for Developing Countries, Allied Publishers Ltd., Bangalore, India, October 2000, pp. 27–35.

[7] A. Debnath, S.V. Singh, Y.P. Singh, *Comparative assessment of energy requirements for different types of residential buildings in India, Energy and Buildings 23* (1995) 141–146.

[8] M. Suzuki, T. Oka, K. Okada, *The estimation of energy consumption and CO2 emission due to housing construction in Japan, Energy and Buildings 22* (1995) 165–169.

[9] P. Walker, Strength, durability and shrinkage characteristics of cement stabilised soil blocks, Cement and Concrete Composites 17 (4) (1995) 301–310.

[10] A. H. Buchanan, B. G. Honey, *Energy and carbon dioxide implications of building construction, Energy and Buildings 20* (1994) 205–217.

[11] H. Houben, H. Guillaud, Earth Construction: A Comprehensive Guide, IT Publications, London, UK, 1994.

[12] T. Oka, M. Suzuki, T. Konnya, *The estimation of energy consumption and amount of pollutants due to the construction of buildings, Energy and Buildings 19* (1993) 303–311.

[13] B.V. Venkatarama Reddy, Studies on static soil compaction and compacted soil–cement blocks for walls, Ph.D. thesis, Department of Civil Engineering, Indian Institute of Science, Bangalore, India, 1991.

[14] K.S. Jagadish, *The progress of stabilised soil construction in India, in: Proceedings of National Seminar on Application of stabilised mud blocks in Housing and Building, Bangalore, India,* November 1988, pp. 17–43.

[15] M.G. Lunt, Stabilised soil blocks for building construction, Overseas Building Notes no. 184, February 1980.

[16] R. Fitzmaurice, Manual on Stabilised Soil Construction for Housing, United Nations, New York, USA, 1958.