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TO STUDY THE FEASIBILITY OF CSEB FOR LOW COST HOUSING

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Abstract

The pace of urbanization and development over the years has led to mass rural-urban migration, in turn, creating a shortage of the land available to house the permanent as well as the migrant population. As a result, real estate prices have escalated Thus, the demand for affordable housing has increased significantly. Over the years, multiple construction techniques and materials have been utilized towards achieving the goal of cost-effective construction. This study talks about the use of Compressed Stabilized Earth Block as a potential construction material with respect to affordable housing. It is an economic and environment-friendly substitute for conventional materials like brick and cement blocks. The study will cover different aspects related to the material which will determine its feasibility with respect to affordable housing.

Keywords: *Economic, low-Cost, cost-effective construction, affordable housing*

CSEB – Compressed Stabilized Earth Blocks

UN – United Nations

FF – Franc

SGD – Singapore Dollar

INTRODUCTION

India is a growing country, not only in terms of development but in terms of population as well. The present government is focused on sustained growth. This, in turn, makes the real state sector an area of key importance. The main factors driving this sector are rapid urbanization and growing occupier demand. Rural to urban migration is the key process affecting urbanization. The influx of population into the urban areas, for the purpose of employment, education, better living standards, etc., create a need for affordable housing.

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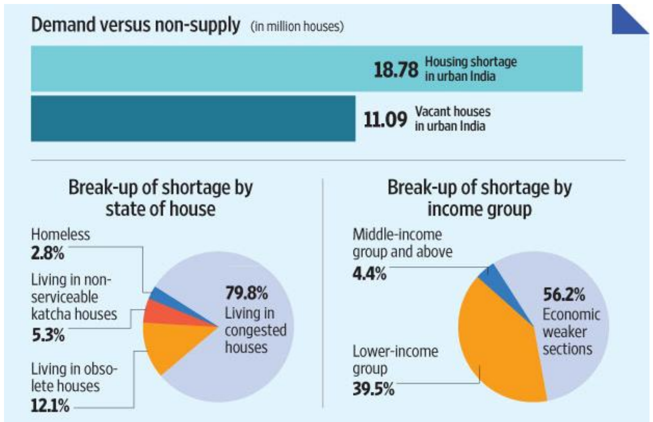

Fig. 1. Housing Supply and Shortage in India

Source: Fig 1. http://www.iipsenvis.nic.in/Database/Population_4074.aspx

The production of the good needs to keep up with the demand. This calls for rapid construction but in the case of low-cost housing, no compromise should be made in the economic value. With the progress made with time, a variety of materials and construction techniques have come to the aid of the problem. Compressed stabilized earth blocks are no exception.

Earthen construction has been a part of Indian architecture for a long period of time and is still being practiced in many parts of the country. However, a prenotion has been set regarding it being used only by the economically weaker section of the society, thus, limiting the use. The potential that innovation like CSEB carries is enormous but unaware of. Being one of the most environmentally friendly and economic material with a wide variety of construction variants to offer, puts CSEB in high on the scale of materials for low – cost housing. Through this study the question 'why CSEB is a feasible material for affordable housing?' will be explored.

METHODOLOGY

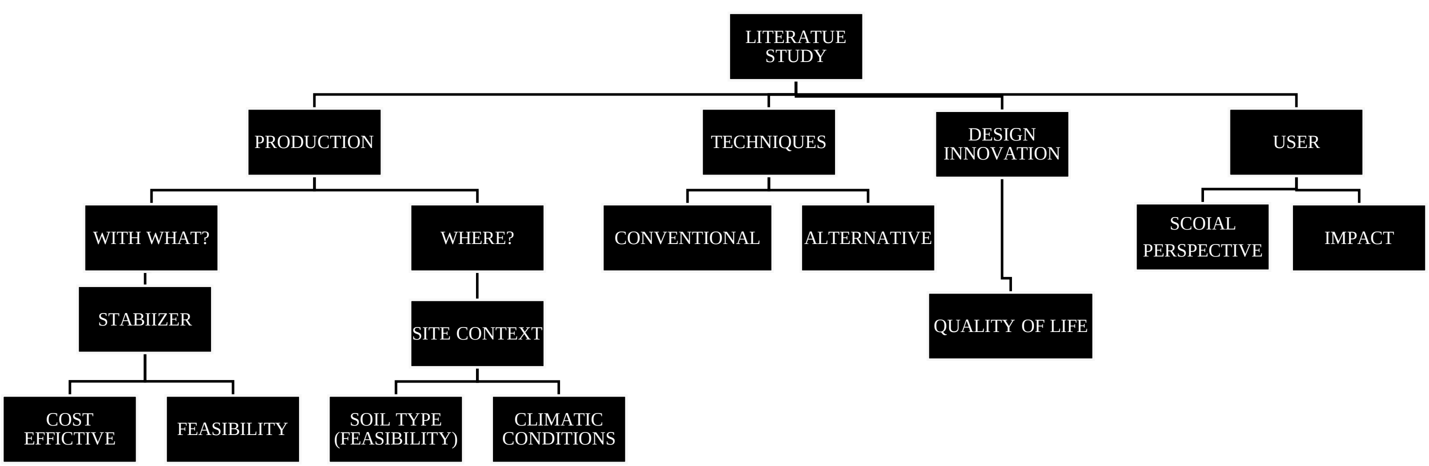

Fig. 2. Theoretical framework for Literature Study

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Table 1. Literature Study analyzed based on the framework and inferred.

Sr. No.	TITLE	AUTHOR	SOURCE	PROBLEMS ADDRESSED	METHODOLOGY	FINDINGS
	STABILIZERS					
1	Durability study of stabilized earth concrete under both laboratory and climatic conditions exposure	A. Guettala	Construction and Building Materials	Deterioration of earth construction under climatic conditions.	An experimental study with respect to the different types of stabilizers. Eight walls using stabilized bricks are constructed and their performance is evaluated in climatic conditions. Then a comparative analysis is conducted.	There is a considerable amount of improvement in the durability with the addition of stabilizers. Cement and resin, cement, cement and lime, and lime are found to be the stabilizers that improve the durability of the brick. **However, resin is very expensive**.
2	Economical stabilization of clay for earth buildings construction in rainy and flood-prone areas	I. Alam	Construction and Building Materials	The economic use of stabilizers to overcome the problem of water retention.	An experimental study is done, which involves the production and testing of different samples.	According to the study, **4% cement and 1% straw by weight** when used in earth building construction, the resulted structure will show better results in rain and flood and will also be much economical, whereas, using **cement** alone in considerable content makes the brick **durable but uneconomical**.
3	Compressed Stabilized Earth Blocks by using Lime	Abhijeet D. Patil	Construction and Building Materials	The use of Lime as a stabilizing agent and its cost-effectiveness	An experimental study is done by making samples of CSEB with different percentage of lime content and laboratory test are performed to analyze the strength.	It is found that the optimum lime content is that which gives maximum strength at low cost which is taken as **10%**. This does not satisfy the **BIS recommendation but is the most economical option.**
4	Experimental analysis of Compressed Earth Block (CEB) with banana fibers resisting flexural and compression forces	Marwan Mostafa	Case Studies in Construction Materials	The use of Banana fibers as a stabilizing agent.	Experimental Study is done by making a CSE block sample with banana fibers as stabilizing agents and then subjected it to a compression test.	It is found that **the blocks with banana fiber reinforcement perform much better than the non-reinforced blocks in terms of compressive and flexural strength.**
5	Effect Of Varying Cement Proportions On Properties Of Compressed Stabilized Earth Blocks (CSEB) - A Sustainable Low-Cost Housing Material	Ayan Anil Garg	ICSCI 2014	The amount of cement stabilization required for CSEB.	Five soil types are tested and their contents are analyzed. The mixture for CSEB samples is made by mixing 4 different percentages of cement (5,7,9,10) with the selected soil sample. These blocks are subjected to the various test.	Sample with **9% cement stabilization** yield good engineering properties required for a masonry block. The water absorption value is 7.9% which is way below the limiting value, i.e., 20%.

ISSN: 2005-4238 IJAST

Sr. No.	TITLE	AUTHOR	SOURCE	PROBLEMS ADDRESSED	METHODOLOGY	FINDINGS
	SOIL TYPE					
6	A review of the use of lateritic soils in the construction/development of sustainable housing in Africa: A geological perspective	C.A. Oyelami	Journal of African Earth Sciences	The use of Laterite soil in the production of CSEB, its environmental impact, and benefits over burnt bricks.	Experimental study is done by understanding the properties of laterite soil, the addition of different stabilizers and comparing the mixtures.	It is found that Laterite soil is well suited for the production of CSEB and requires less quantity of stabilizer to produce a good quality block. Moreover, it is environmentally friendly.
	CONSTRUCTION AND DESIGN TECHNIQUES					
7	Masonry CSEB Building Models under Shaketable Testing-An Experimental Study	Lakshmi Keshav	International Journal of Civil and Environmental Engineering	Performance of CSEB constructed buildings when subjected to an earthquake.	The experimental study is done by constructing 4 cubical structures, 2 made out of CSEB and 2 made out of CSE hollow blocks. One structure of each type is reinforced with earthquake resistant features. Then the structures are subjected to earthquake-like conditions by placing them on shake-tables to observe their stability.	The study shows that the models built with **earthquake-resistant bands performed better** than the model without the bands. However, the use of the bands increases the overall construction **cost by 4% to 6%.**
8	Innovations, Applications, And Standards Of Compressed Stabilised Earth Blocks	Perera	University of Moratuwa	Problems faced by CSEB in the past constructions and it's social acceptance.	Literature study review on the past failures and why they happened, how the people perceived the use of CSEB, the standards that are developed for using CSEB and innovative construction and design techniques used.	The study gives an overview of the problems that the construction with CSEB faced in the past how they have been overcome. New techniques **like rat trap bond and shell construction have improved the status of construction.**
9	Conceptualization and pilot study of shelled compressed earth block for sustainable housing in Nigeria	C. Egenti	International Journal of Sustainable Built Environment	Limitations of the use of Earth construction caused because of surface erosion due to climatic conditions.	The methodology followed for making the samples was first, the selection of the type w.r.t locality, second, assessment of the cement quantity required w.r.t soil type and third, designing a mechanical kit for the making laboratory samples. These samples were subjected to a laboratory test.	The study concludes **that shelled CSE blocks have a higher compressive strength and lower water absorption.** Moreover, even when completely immersed in water**, the shell resists the expansion of the core and limits the absorption of water**. These findings are related to the block size of 150mm x 100mm x 70mm.

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Sr. No.	TITLE	AUTHOR	SOURCE	PROBLEMS ADDRESSED	METHODOLOGY	FINDINGS
10	A Low-cost Housing Solution: Earth Block Catenary Vaults	Mitchell Gohnert	Structures	The use of CSEB in low-cost housing limiting the design to the conventional styles of building.	Construction of a prototype house which was built without the use of any type of reinforcement. The ground floor walls are made and covered with a filler slab. Then the formwork for the catenary vaults is made, the blocks are laid and finished with waterproof cement slurry.	The entire cost of production of this house, inclusive of the labor cost in South Africa, comes up to **$15,000 whereas the average cost of a low-cost house in Africa is $35,000.**
11	Characteristics of Different Masonry Units Manufactured with Stabilized Earth	C Jayasinghe	International Symposium on Earthen Structures	Failures caused due to the unit and mortar joints.	The methodology followed, the construction of wall panels with CSEB, burnt clay bricks and cement-sand blocks for the destructive test, and analyzing the deformation w.r.t. masonry type and joinery type.	The standard size CSEB block can be used for load bearing structures with **English and Flemish bond** types. **CSEB of 235mm thickness can be used as an alternative** for to the bond type construction.
	SOCIAL PERSPECTIVE					
12	Attitudes towards earth building for Zambian housing provision	Karim Hadjri	Loughborough University Institutional Repository	Stakeholders' perception of Earth construction	Quantitative and Qualitative data collection methods for assessing the attitude of the end-users, the builders and the government towards Earth construction.	The majority of the people interviewed chose **not to stay in houses constructed with Earth.** Due to **lack of proper building codes**, the builders and contractors aren't aware of the proper usage techniques. The Zambian government has **neglected the use of local and vernacular construction material**.
13	Prospects and Challenges of Compressed Stabilized Laterite Bricks in Enhancing Sustainable Housing Development in Nigeria	Alagbe	Covenant University	Sustainable housing for low-income groups.	The study was carried out in 4 local government areas and conducting household surveys in these areas. A total of 600 household surveys were conducted covering different factors.	It is inferred that a large number of people are **aware of the material but they chose not to build their homes with it**. However, the majority of respondents are of the view that with **adequate knowledge regarding the physical properties of CSLB along with the promotion of the material will enhance its use**.

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Sr. No.	TITLE	AUTHOR	SOURCE	PROBLEMS ADDRESSED	METHODOLOGY	FINDINGS
14	Earth construction: Lessons from the past for future eco-efficient construction	F. Pacheco-Torgal	Construction and Building Materials	The problems that usage of exhaustible and no-ecofriendly materials cause to the environment. The construction industry is one of the largest and most active is a big contributor for the same.	The paper describes the typology and techniques used in the past and that are being used in the present with respect to earth construction. It focuses on the ecological aspects and environmental impact of Earth Construction. It also focuses on the social acceptance and user perspective on this type of construction.	Since earth construction **is related to low income**, this type of construction is usually found in developing countries. In developed countries, it is adopted by the aware portion of the society. The economy of this construction greatly depends on the type of binders used.

Table 2. Project overview and material availability of the case studies (only case studies relating to housing considered)

Sr. No.	CASE STUDY	LOCATION	PROJECT OVERVIEW	MATERIAL AVAILABILITY
	HOUSING			
1	(i) Low-cost housing Project: Help in Kind	Comore, Mayotte	Built by SIM as a low-cost housing policy to renew housing stock.	Local Laterite Soil Cement Imported (8% stabilization)
	(ii) Rented accommodations	Comore, Mayotte	Built to lay the foundation of Earthen construction in the island.	Local Laterite Soil Cement Imported (8% stabilization)
2	Hay al Massira project	Marrakesh, Morocco	The country is rich with traditional earth architecture. This project focused on the introduction of modern techniques and its integration with the rural economies.	Locally available soil used for construction.
3	(i) Low-cost housing project (T 3 - 2 storey building)	Kourou, Guyana	This project is linked with the will local urban land-use decision-makers of the town to try out new building industries other than the existing sand-cement industries. Since this type of architecture not traditional, it was more of an innovation. It also acted as a response to the sudden population growth in the city.	Locally available soil used for construction.
	(ii) T-4 1 storey building	Kourou, Guyana	This project is linked with the will local urban land-use decision-makers of the town to try out new building industries other than the existing sand-cement industries. Since this type of architecture not traditional, it was more of an innovation. It also acted as a response to the sudden population growth in the city.	Locally available soil used for construction.

ISSN: 2005-4238 IJAST

Sr. No.	CASE STUDY	LOCATION	PROJECT OVERVIEW	MATERIAL AVAILABILITY
4	(i) Vikas Community	Auroville, Tamil Nadu, India	This community is built by Auroville Earth Institute. This project is made to show the use of Stabilized earth from the foundation to the roof.	Stabilized Rammed Earth for foundation (5% stabilization) with the excavated soil. CSEB (5% stabilization)
	(ii) Leagaum houses	Auroville, Tamil Nadu, India	The need of these houses arose when there was a shortage in housing in Auroville. They were planned to be movable houses. To be used as a temporary dwelling until the completion of major development.	Locally available soil used for construction. Waste from other construction used.
5	Realization Community	Tamil Nadu, India	The project came to be when a shortage of housing arose.	Locally available soil used for construction.
6	Low-Cost housing project	Khartoum and Darfur, Sudan	Post-Independence the country faced a major problem in providing housing for the displaced people, however, if the traditional building material, timbre, was to be used then it would lead to massive deforestation.	UN-habitat developed a program of woodless construction by using CSEB blocks made from locally available soil with 5%cement stabilization.

Table 3 Design innovations seen in the case studies (only case studies relating to housing considered)

Sr. No.	CASE STUDY	LOCATION	DESIGN INNOVATIONS
	HOUSING		
1	(i) Low-cost housing Project: Help in Kind	Comore, Mayotte	- 1 storey high. - Total ground coverage of each - 40m2. - 2 rooms + veranda - Dutch arches used as lintels for the opening.

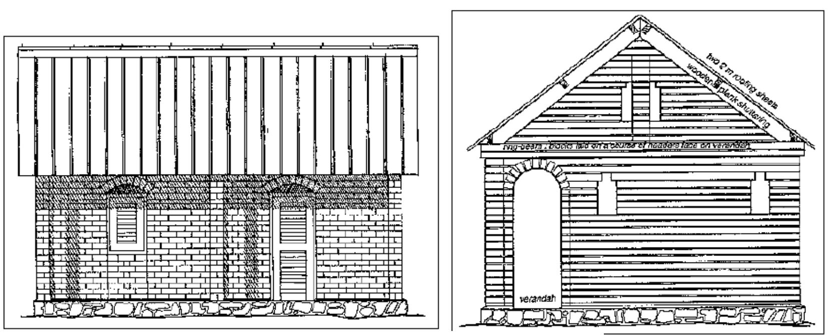


Fig. 3. Elevations of 'Help in Kind" model

Source: Fig. 3. Guillaud (1995), Compressed Earth Blocks, *Manual of design and construction vol. II*

ISSN: 2005-4238 IJAST

Sr. No.	CASE STUDY	LOCATION	DESIGN INNOVATIONS
	(ii) Rented accommodations	Comore, Mayotte	- 3 types T2 - 48 m2 T3 - 62 m2 T4 - 74 m2 - Dutch arches used as lintels for the opening. - Semi-circular arches used arches for kitchen and bathroom windows. - T3 - Extended 'Help in kind' 3 rooms with kitchen and bathroom. - Claustras used for aesthetics.

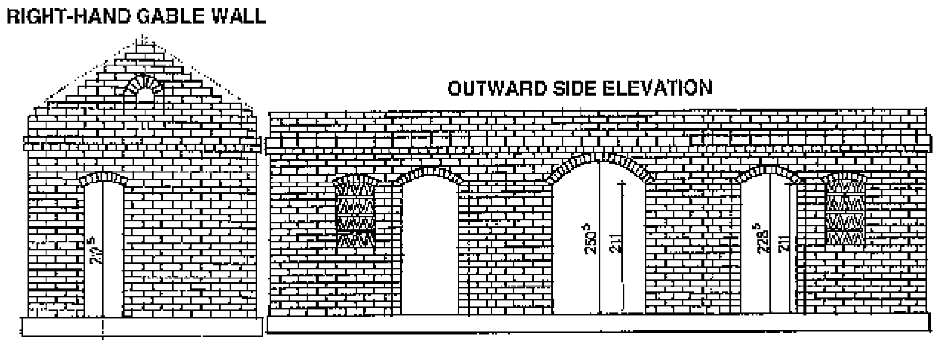


Fig. 4. Elevations of the T3 accommodation

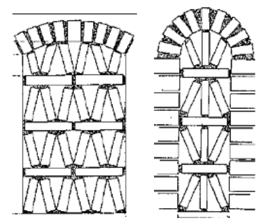


Fig. 5. Claustras

Source: Fig. 4. Guillaud (1995), Compressed Earth Blocks, *Manual of design and construction vol. II*
Fig. 5. Guillaud (1995), Compressed Earth Blocks, *Manual of design and construction vol. II*

2	Hay al Massira project	Marrakesh, Morocco	- 2 storey high houses with a plot area of 150 m2. - 2 bedrooms, kitchen, living room, bathroom. - Corbels projecting from partition walls used for shading.

Fig. 6. Elevations of Low cost house in Marrakesh

Source: Fig. 6. Guillaud (1995), Compressed Earth Blocks, *Manual of design and construction vol. II*

ISSN: 2005-4238 IJAST

Sr. No.	CASE STUDY	LOCATION	DESIGN INNOVATIONS
3	(i) Low-cost housing project (T 3 - 2 storey building)	Kourou, Guyana	- 2 storey high with a habitable area of 56 m2. - 2 bedrooms, kitchen, living room - The high gable wall and sloping roof (wide overhangs) give room for future expansion on either side. - The contrast created by the use of wood and CSEB - Dutch arches used for opening on the ground floor and semi-circular arches used in the first floor.

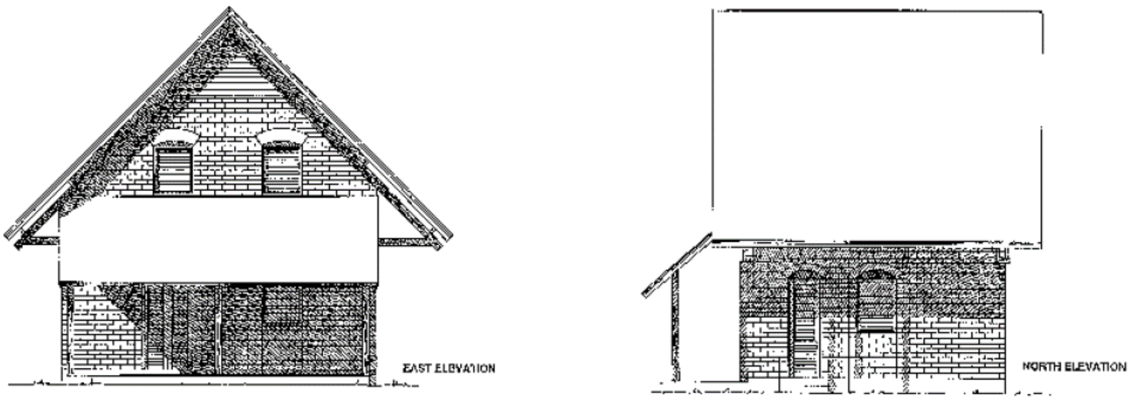


Fig. 7. Elevations of the T3 accommodation

Source: Fig. 7. Guillaud (1995), Compressed Earth Blocks, *Manual of design and construction vol. II*

Sr. No.	CASE STUDY	LOCATION	DESIGN INNOVATIONS
	(ii) T-4 1 storey building	Kourou, Guyana	- 1 story high with a habitable area of 70 m2. - 3 bedrooms, kitchen, living room - Thin exterior walls (stretcher bond), thus, buttress used where openings are present. - The high gable wall and sloping roof (wide overhangs) give room for future expansion on either side.

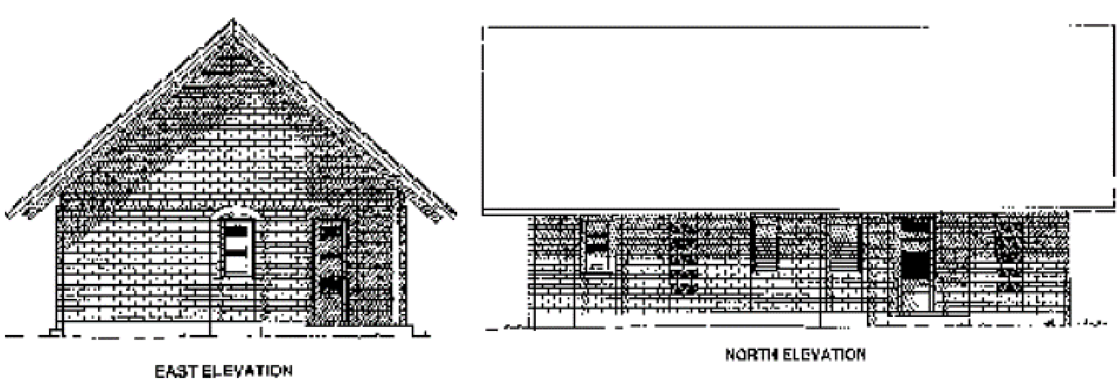


Fig. 8. Elevations of the T4 accommodation

Source: Fig. 8. Guillaud (1995), Compressed Earth Blocks, *Manual of design and construction vol. II*

ISSN: 2005-4238 IJAST

Sr. No.	CASE STUDY	LOCATION	DESIGN INNOVATIONS
4	(i) Vikas Community	Auroville, Tamil Nadu, India	- 1st block with 4 apartments, 2nd block with 5 apartments. - 3rd block with 13 apartments, 4 storey high (3 storey + basement 1.2m below ground). 1BHK & 2BHK - The building is designed to be self-sufficient. - To protect the basement from water the surrounding landscape was designed to create a shallow pit to drain the water in percolation pit.

13 apartments on 4 floors 'ater tank tower with staircase

Fig. 9. Views of the Third Building

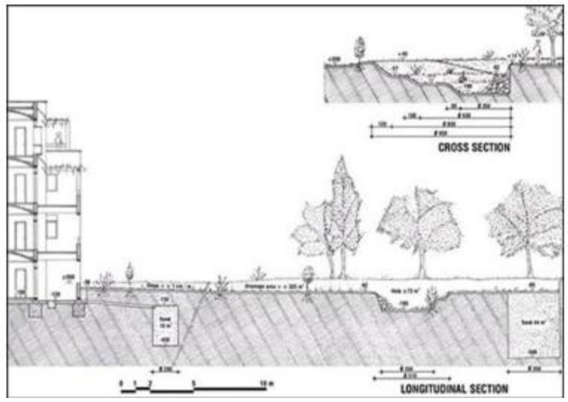


Fig. 10. Percolation System of the third Building

Source: Fig. 9. http://www.earth-auroville.com
Fig. 10. http://www.earth-auroville.com

	(ii) Leagaum houses	Auroville, Tamil Nadu, India	- Integration of CSEB with other earth construction techniques. - Initial prototypes without foundation (movable).

Legaum prototype with wooden shingles and interlocking CSEB | Legaum prototype modified with coconut leaves | Second Legaum prototype with wattle & daub, and wooden floor

Fig. 11. Views of the initial prototypes of Leagaum houses

Source: Fig. 11. http://www.earth-auroville.com

ISSN: 2005-4238 IJAST

Table 4 Construction techniques seen in the case studies (case studies relating to housing as well as other public buildings are considered)

Sr. No.	CASE STUDY	LOCATION	CONSTRUCTION TECHNIQUES
	HOUSING		
1	(i) Low-cost housing Project: Help in Kind	Comore, Mayotte	- Cyclopean masonry foundation and footing. - The walls consolidated with projecting buttress and ring beam. - Stretcher bond used for the wall.

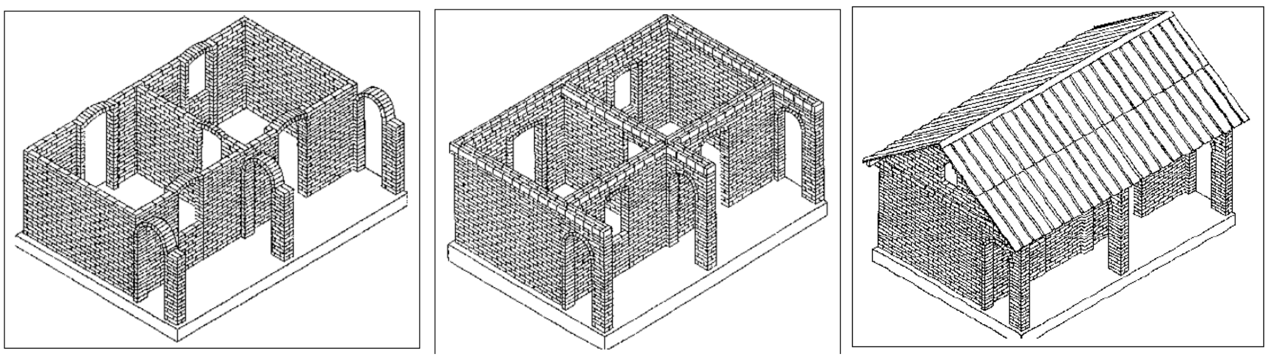


Fig. 15. Phases of Construction of 'Help in Kind'

Source: Fig. 15. Guillaud (1995), Compressed Earth Blocks, *Manual of design and construction vol. II*

	(ii) Rented accommodations	Comore, Mayotte	- Cyclopean masonry foundation and footing. - The walls consolidated with projecting buttress and ring beam. - Header bond used for the wall. - Anchoring of wooden roof on masonry.

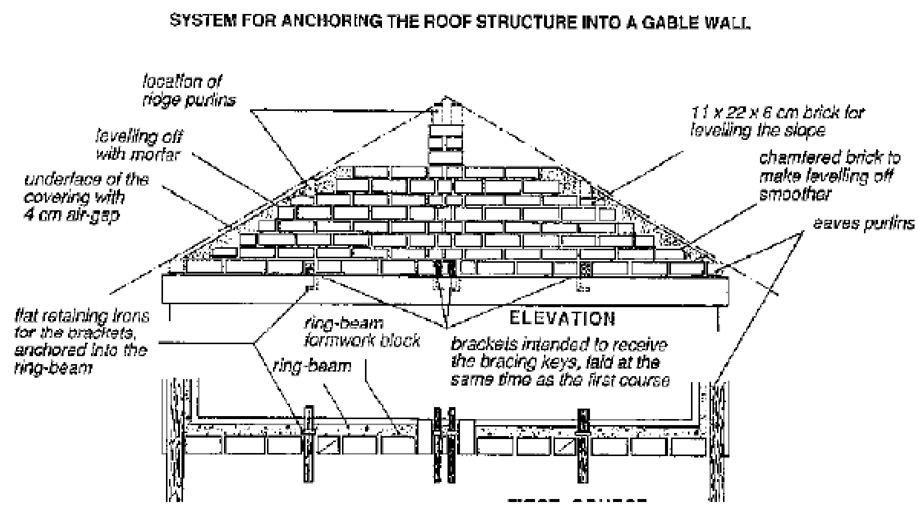
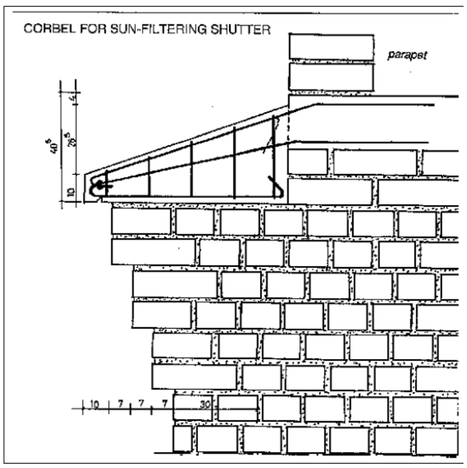


Fig. 16. Views of Realization Community

Source: Fig. 16. Guillaud (1995), Compressed Earth Blocks, *Manual of design and construction vol. II*

ISSN: 2005-4238 IJAST

Sr. No.	CASE STUDY	LOCATION	CONSTRUCTION TECHNIQUES
2	Hay al Massira project	Marrakesh, Morocco	- Earth block vaulting flooring supported by reinforced concrete girders. - Spanning of openings using reinforced concrete lintels. - Earth block depressed arches. - RCC corbels used for sun-filtering.



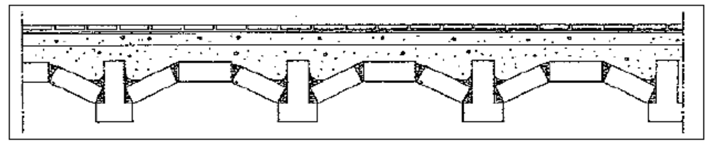


Fig. 17. Construction techniques showing

(a) Vaulting using RCC girders and CSEB
(b) Corbel for dun-filtering shutter

Source: Fig. 17. Guillaud (1995), Compressed Earth Blocks, *Manual of design and construction vol. II*

3	(i) Low-cost housing project (T 3 - 2 storey building)	Kourou, Guyana	- Double-slope roof with a high gable wall. - Ring Beam used after the first level and at the level of gable. - The local redwood used to make door, windows, and frames. - Header bond used for walls.

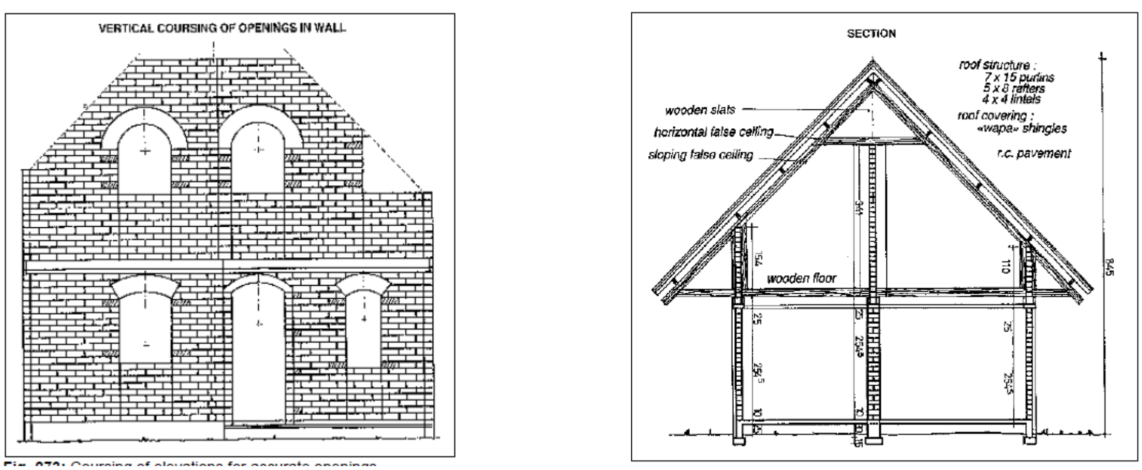


Fig. 18. Elevation and Section of T3 building

Source: Fig. 18. Guillaud (1995), Compressed Earth Blocks, *Manual of design and construction vol. II*

ISSN: 2005-4238 IJAST

Sr. No.	CASE STUDY	LOCATION	CONSTRUCTION TECHNIQUES
	(ii) T-4 1 storey building	Kourou, Guyana	- Double-slope roof with a high gable wall. - Ring Beam used after the first level and at the level of gable. - The local redwood used to make door, windows, and frames. - Stretcher used for walls.

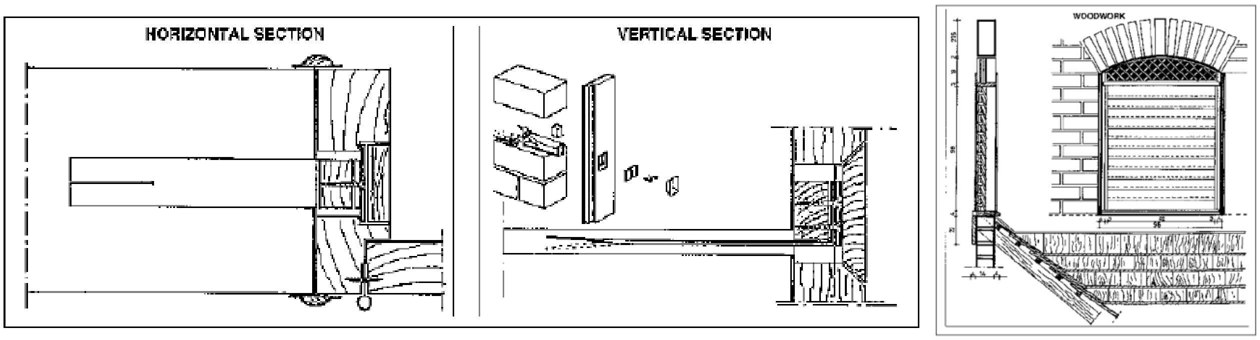


Fig. 19. Joinery details of wooden frames and masonry

Source: Fig. 19. Guillaud (1995), Compressed Earth Blocks, *Manual of design and construction vol. II*

4	(i) Vikas Community	Auroville, Tamil Nadu, India	- Composite CSEB ring-beams, lintels and column. - Roof - CSEB vaulting with waterproofing & ferrocement channel. - Windows with sunshades and pronounced overhangs. - Improved ventilation with the increased velocity of wind through pier walls. - A solar chimney that creates a natural stack effect draft inside the apartments through the temperature differential inside the chimney. - Windmill run - borewells. - Photovoltaic panels for electricity. - Rain-water harvesting for zero water-runoff.

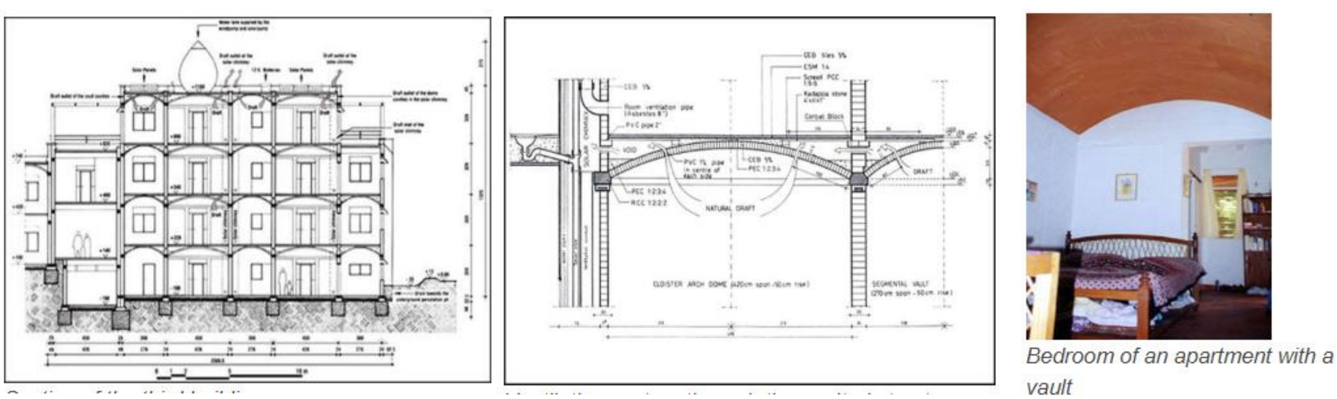


Fig. 20. Joinery details of wooden frames and masonry

Source: Fig. 20. http://www.earth-auroville.com

ISSN: 2005-4238 IJAST

FORMULATION OF DESIGN GUIDLEINES

- Stabilization of 4% cement and 1% straw by weight should be used in CSEB if the building is 1-2 stories high as it is the most economic stabilization component composition.
- If the building needs to be more than 2 stories high, then a stabilization of 8 – 9 % of cement should be used in the blocks.
- Laterite soil is well suited for the production of CSEB, requires less quantity of stabilizer to produce a good quality block and thus, should be used for the production if locally available.
- The blocks should be produced on site with the help of the CSEB block press. If the area for storage is not adequate on site, then they should be transported to the site from the production area within the radius of 2 km.
- Shelled CSEB blocks should be used in areas which areas which are prone to heavy rains and floods.
- Stretcher or header bonds should be used for wall construction if the building is only one storey high. External buttresses can be provided if the span of the wall is large.
- Header bonds can also be used in 2 storey buildings.
- English and Flemish bonds should be used for construction of building higher than 2 stories.
- Vaulting earth block techniques should be used when using CSEB for flooring/roofing. If the span is more than 8 - 9 m, then composite CSEB or RCC girders should be used for additional support.
- CSEB construction in earthquake prone areas should be done with either:
  1. With the use of RCC earthquake resistant bands at the plinth beam and lintel level.
  2. With the use of hollow interlocking CSEBs.
- Passive construction techniques should be incorporated when building with CSEB.
  1. CSEB itself acts as hydro-cooling agent.
  3. Vaulting helps in providing thermal insulation.
  4. Planned vaulting in relatively high storey building can help in creating stack effect.
- CSEB construction helps in the reduction of labor cost. Self-employment policies which help in providing employment to the owner of the house with by constructing their own house should be implemented.

CONCLUSION

CSEB can be used for construction in areas which experience heavy rains as well as areas which are earthquake prone. It can also be used in hot regions making it a versatile material at the same time not compromising the cost – effectiveness. Many techniques can be employed for the construction of low-cost housing with the use of CSEB and have proved to be effective in their own means. By using different stabilizing agents and composition, the block required for a particular purpose can be achieved. Social

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acceptance of CSEB comes with consistent use and has always been well received. All these properties make CSEB feasible for being used in the construction of low - cost housing.

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