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Compressed Stabilized Earth Block as a Sustainable Building Material

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Abstract
In recent years Environment pollution is the most concerned issue. Awareness growing to save the environment. In Bangladesh, burnt clay brick is the most commonly used building material. Which produce a significant amount of greenhouse gasses and also it destroys a huge amount of agricultural land every year. Concerning the issue of scientist searching for sustainable and eco-friendly building material. Compressed Stabilized Earth Block (CSEB) give the opportunity of energy efficient, eco-friendly, agriculture friendly and sustainable development. It does not produce any harmful gasses during production. In this study, river dredged soil used to produce CSEB, so it also helps to save the agricultural land. CSEB have been prepared with the different composition of cement, sand and river dredged soil. The compressive strength of different blocks is measured to find the suitable composition to produce CSEB and also to compare among them to find out the optimum composition.
Keywords: Sustainability, Agriculture friendly, environment friendly, River dredged soil.

1. Introduction

Earth is one of the most ancient building material ever known. Once the modern building material and methods were discovered building with earth fell out of popularity(Patowary *et al.*, 2015). When the energy crisis is come to notice it again renewal its popularity. Considering environmental and ecological issue in the recent years scientists try to establish earth block again as a building material. Dried earth construction is common in some region of the world where the specific climate and economic condition dictate and where the earth construction is aesthetically accepted to all. CSEB has many advantages for the construction of durable, comfortable and low-cost housing.

Researchers have recognized that earth construction is sustainable with a fewer drain on infrastructure ((Minke, 2000); (Rael, 2009)). Construction with earth has advanced with a modern face of stabilized compressed earth blocks (CSEB) and rammed earth (RE) walls. The compressed earth block wall cost less than the burnt clay brick as well as it requires less maintenance than the traditional earthen wall.

Taylor and Luther, (2004) showed that the thermal properties of the earth have been improved by the large thermal capacity of the earth walls above that expected by consideration of R-values alone. (Morton, 2010) found in his study that sound reduction index of 46 db to 57 db; and that a 16 inch compressed earth block wall has a coefficient of acoustic attenuation (tested at 500 Hz) of 40 to 50 db. Earth also good for improving indoor air quality and lowers embodied energy (Minke, 2000).

Egenti, Khatib and Oloke, (2014) proposed a shelled compressed earth block which could be more economic and environment friendly.

The study used River Dredged soil to produce compressed stabilized earth block as it is available in abundance in Bangladesh.

2. Background

Accommodation is one of the basic needs of people. An ideal habit helps people to improve their work habits, comfort, and peace. About 17.2 billion bricks are made in Bangladesh every year for housing (World Bank, 2011). Greenhouse gas spread in the environment from the fixed chimney kiln (FCK) used in the brick kiln.

Around 240 tons of coal is used for making one million bricks (Khan, 2013). Each year only in Dhaka region about 23,300 tons of particulate matter, 1.8 million tons of carbon dioxide, 302,000 tons of carbon monoxide and also other substances emitted from brick kiln which is extremely harmful to human health (Skinder *et al.*, 2014). A huge amount of agricultural land is destroyed to make bricks per year. If the scenario continue like this then in near future we will going to face a serious food crisis.

High demand for clay bricks would result in price hike of clay bricks in near future and might be reached beyond the affordability of common people.

To keep the cost of building materials in a reasonable range, it is the time to opt in for alternative building materials like compressed stabilized earthen blocks/bricks, hollow or solid masonry blocks. Compressed Stabilized Earth Block (CSEB) made of dredged soil and cement expected to be a great alternative to burnt bricks to reduce the use of agricultural topsoil and carbon emission. It is also expected that CSEB will help to improve the quality of life of the population and play an effective role in environmentally friendly management thus support to achieve the Sustainable development goal (SDG).

3. Research methodology

The research started with the study of soil samples to identify appropriate river dredged soil for CSEB construction in the locality. The CSEB were produced with the suitable soil samples while varying the cement content from about 9 to 16 percent. The produced CSEB were then subjected to appropriate durability test with the aim of identifying the optimum cement content for different types of dredging soil. An assessment of the quantity of cement required to produce a durable CSEB, for different river soil, was made.

3.1 Soil Sample

In this study, the main raw material sand-silt-clay were collected from the following locations of the river.
a) Brahmaputra river at the point of Jamalpur.
b) Meghna river at the point of Gojaria.

Table 1: Properties of Soil Sample

Sl.	Properties of Soil	Brahmaputra Soil (BR)	Meghna River Soil (ME)
1.	Sp.gr	2.6	2.64
2.	Organic Content	< 1.0%	< 2%
3.	Sand	99%	99.5 %
4.	Silt	1%	0.5%
5.	Clay	0%	0%

3.2 Block Preparation

To produce Compressed Stabilized Earth Block CINVA RAM has been used.in this study. The original CINVA ram was engineered by Raul Ramirez of the Inter-American Housing Center (CINVA) in Bogota, Columbia, in 1952. The advantage of Cinva-Ram type presses is that they are light, well-made, low cost, and simple to manufacture and repair. Their main disadvantages are that they can wear out quickly, they only have a single molding module that can exert low pressures, and have a low output.

Figure 01: Molding Procedure to prepare CSEB

3.3 Molding

The soil mix was placed in designed CINVA RAM mold and compacted by a wooden bar in three equal consecutive layers. Finally, a lever was used to press the mixture in the designed mold. By the mechanical lever manually compacted soil was compacted again and its volume was reduced to 85% of the original volume. This procedure to prepare CSEB was repeated for every composition of the soil. The procedure of molding are shown in Figure 01.

3.4 Curing

To achieve maximum strength, compressed stabilized earth blocks need to cure for 28 days. In this study, CSEB was cured by immersed in water. What is important is that the moisture of the soil mix is retained within the body of the block for a few days. If the block is left exposed to hot dry weather conditions, the surface material will lose its moisture and the clay particles tend to shrink. This will cause surface cracks on the block faces.

4. Result and Discussion

In this phase of research mainly compressive strength test for an individual block was performed for different composition. Compressive strength was measured for each set of blocks. Water absorption of the CSEB blocks also measured.

4.1. Compressive strength

Brahmaputra and Meghna river dredged soil were used to produce CSEB with different cement content varying from 9 to 16 percent. A set of three specimens of each block type and composition were tested for compressive strength. The Compressive strength of different block is shown in table 2 and table 3. CSEB attained greater strength at higher cement stabilization. The difference in compressive strength for a lower quantity of cement was low. While the change is significant for a higher percentage of cement.

The Compressed Stabilized Earth Blocks (CSEB) was taken for strength determination at 3 days, 7 days and 28 days. The compressive strength of the blocks made by using Brahmaputra river dredged soil are comparatively better than the blocks made from Meghna River dredged soil. It could be the presence of some organic content on Meghna river dredged soil.

The compressive strength of CSEB can be increased by the addition of course sand. Again it could be made by using river dredged soil and cement. If only river dredged soil and cement used then the price will be lower and when adding course sand the price will increase.

Hopefully, all composition of soil gives satisfactory result comparing the codes and standard available for Compressed Stabilized Earth Blocks (CSEB).

Table 2. Properties of CSEB blocks prepared by using dredged soil from Brahmaputra river bed at Jamalpur region.

Cement : dredged soil : Sylhet sand	Percentage of cement	Compressive strength in psi			Water absorption %
		3 day	7 day	28 day	
1:5:0	16	390	450	900	8.5 %
1:4:1	16	480	680	1280	8.3%
1:3:2	16	701	890	1701	8.0%
1:6:0	14	420	450	780	8.9%
1:5:1	14	450	510	801	8.5%
1:4:2	14	540	670	850	8.5%
1:7:0	12	390	550	705	10%
1:6:1	12	540	678	745	9.5%
1:5:2	12	570	692	820	9.3%
1:8:0	12	300	450	570	12.9%
1:7:1	12	320	500	590	12.5%
1:6:2	12	410	540	610	12.2%
1:9:0	9	250	310	450	14.0%
1:8:1	9	250	320	520	13.5%
1:7:2	9	270	350	550	13.3%

Water absorption

Water absorption was conducted by immerging blocks into the water. Water absorption was calculated for different percentage of cement and for different soil sample. This water absorption test was intended to find out the behavior of CSEB with water. The test shows that for different percentage of cement water absorption fluctuated but with the change of sand ratio with river dredged soil, water absorption did not differ much.

Table 3. Properties of CSEB blocks prepared by using dredged soil from Meghna river bed at Gajaria region and using Sylhet sand.

Cement : dredged soil : Sylhet sand	Percentage of cement	Compressive strength in psi			Water absorption %
		3 day	7 day	28 day	
1:5:0	16	460	550	750	9.0 %
1:4:1	16	505	456	605	8.9%
1:3:2	16	401	705	1050	8.5%
1:6:0	14	448	560	700	8.9%
1:5:1	14	470	601	670	8.6%
1:4:2	14	405	501	605	8.3%
1:7:0	12	348	450	620	9.9%
1:6:1	12	330	415	450	9.5%
1:5:2	12	356	460	520	9.5%
1:8:0	12	300	410	520	11.8%
1:7:1	12	320	450	520	11.8%
1:6:2	12	380	5200	650	11.3%
1:9:0	9	230	350	420	13.5%
1:8:1	9	250	340	450	13.3%
1:7:2	9	250	350	520	12.9%

Application of Compressed Stabilized Earth Block (CSEB)

Using the CSEB several structure has been constructed in HBRI campus to observe the performance of the block. The study found that blocks that are prepared with small amount of stabilizer are sensitive to heavy rainfall. Some portion of the block were washed away with the rain. While twelve percentage of cement is adequate to withstand heavy rainfall.

Figure02: Housing and Building Research Institute guard room using Compressed Stabilized Earth Block (CSEB)

Figure03: Pilot plant shed structure for Compressed Stabilized Earth Block (CSEB) production at HBRI campus

Conclusion

The paper considers river dredged soil for Compressed Stabilized Earth Block (CSEB) instead of clay. The study found that river dredged soil could be a sustainable alternative to making CSEB. Due to the presence of sand in river dredged soil, there should be some changes in the making process of CSEB. Instead of pressure, the study was made CSEB with a combination of tamping or vibration and pressure. Required cement amount for making a durable Compressed Stabilized Earth Block (CSEB) was identified. An impressive compressive strength of up to 2240 psi was found for Compressed Stabilized Earth Block (CSEB) made of Brahmaputra river dredged soil but the cement content is much higher for this properties. Twelve percent of cement was found adequate for masonry wall construction. Some wall was also constructed with a lower percentage of cement but some portion of the blocks were washed away by rain. Twelve percent cement stabilization can be used for outer wall construction and a lower percentage of cement can be used for inner wall construction. A shelled Compressed Earth block concept could be a good opportunity for more economical product. Which was proposed by (Egenti, Khatib and Oloke, 2014) in their research Article.

CSEB does not produce harmful gases during production as they do not require coal or burning material. So, CSEB is a eco-friendly building material (Patowary *et al.*, 2015).

Compressed Stabilized Earth Block (CSEB) could be a great alternative to a mud house in the rural part of Bangladesh.

Use of River dredged soil for making CSEB give hope for saving agricultural land as well as it will solve the river navigation problem.

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