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(Research Article)

Coir-fiber reinforced soil-cement block as walling material for rural houses

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Abstract

An investigation was undertaken to develop stabilized soil-cement blocks reinforced with coir fiber for use as a walling material in rural houses. The study evaluated the physical (density, water absorption) and mechanical (compressive and tensile strength) properties of the blocks. The soil sample consisted of 25% sand, 54% silt, and 21% clay, with a liquid limit of 32.8% and a plastic limit of 22%, and was classified as silt-loam. The maximum dry density and optimum moisture content were 1.61 g/cc and 20.83%, respectively, with a specific gravity of 2.60. Ordinary Portland Cement (OPC) was used for stabilization. Coir fibers, cut to 4 cm, were incorporated at 0, 0.2, 0.4, 0.6, and 0.8% by soil weight. To prevent water absorption, tar was applied to the fibers, which had a tenacity of 11 g/tex. A total of 40 blocks were prepared and cured for 28 days. Results showed that compressive and split-tensile strengths increased with fiber content, while density decreased. Compressive strength ranged from 360 psi (0% fiber) to 1136 psi (0.8% fiber), and split-tensile strength from 30.03 psi to 72.03 psi. Water absorption increased with fiber content, and unit cost also rose. The addition of 0.8% fiber significantly enhanced strength, suggesting that coir-fiber-stabilized soil-cement blocks could provide a durable alternative to traditional mud houses.

Keywords: Coir fiber; Soil-cement block; Rural housing; Compressive strength; Sustainable material

1. Introduction

Construction sector is one of the most resource-demanding sectors, with many of its practices are less sustainable. Recently, housing problem in our society, especially the society of low-income people is a serious primary problem. In the last few decades, housing conditions have been worsening due to the scarcity of resources, a rise in housing demand and the urgency to provide immediate practical solutions. Suitable shelter is one of the most important basic human needs. However, 25% of the world's population does not have any fixed home, and 50% of the urban population lives in slums. Indeed, 80% of urban areas in developing countries consist of slums and spontaneous settlements made of temporary materials [1].

Soil has been one of the primary components of construction since ancient times. Soil as a building material is available in most areas of the world. Using soil for wall construction has individual advantages. Soil is easily available locally, low cost, recyclable and environment friendly and it provides better thermal easement than other materials. Stabilized soil blocks can be prepared by compacting a moist mixture of soil and cement. If cement is the only binder used, they are also known as compressed earth blocks or soil-cement blocks. Stabilized mud blocks and stabilized compressed earth blocks (SCEB) are other names for soil cement bricks. Affordable construction supplies are required for the creation of affordable housing. Cement stabilized earth bricks in particular are a desirable building material due to their ease of production. Mud building is incredibly safe, economical, and energy-efficient and environment friendly [2]. These qualities are particularly relevant and important with the ever-growing need for increased awareness to reduce energy consumption worldwide [3]. Soils with 15% clay and 4% cement produce good quality durable soil-cement stabilized

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blocks [4]. Cement has long been used as a soil stabilizing material. Lambe and Moh, 1957 stated that Portland cement is one of the most successful stabilizers of soil [5]. OPC is the most usual stabilizer added to the soil. Pressed soil cement block is an alternative to burnt brick. Portland Cement Association, 1984 has narrated that, engineers and contractor have been using soil-cement to pave rods, streets, airports and its performance has been outstanding [6]. Soil-cement block was found to have a lower primary unit cost than other common building materials [7].

Fibrous material addition as a reinforcing material of SCEB is one of the promising outcomes of ongoing researches. Natural fibers are being used since ancient times in mud construction to improve the reduction of shrinkage cracking, tensile strength, durability and ductility in tension [8-10]. Because natural fibers are readily available and reasonably priced, they have been extensively utilized for many years as building materials in underdeveloped nations in cement composites and earth blocks [11]. Coconut fiber, scientific name: (*Cocos nucifera*) extracted from the outer shell of coconut acts as an excellent structural member along with being insect proof, resistant to fungi, unaffected by moisture and dampness, tough and durable. It is also called Coir-fiber. The using of coir-fiber as reinforcement in rammed earth construction will not only provide strength and durability to the structure but will also serve as a major step towards waste utilization. Coir-fibers contain cellulose, hemi-cellulose and lignin as major composition. The lignin content in coir-fiber is quite high, so the fiber becomes stiffer, tougher and more long-lasting when compared to other natural fibers. The coir-fiber is elastic enough to twist without breaking and use of fibers as admixtures in soil cement blocks showed a reduction in thermal conductivity. The tenacity and percentage of elongation for quality fibers, more than 15 cm long were 11.97 g/tex and 29.04% respectively [12]. An ideal length of coir-fiber used in SCEB is 3 – 5 cm [13].

In the present study was conducted to improve the engineering properties of soil by using cement as a stabilizer and coconut fiber as reinforcement in varying proportions. Stabilized soil-cement block with coir-fiber as a walling material is a new technique for low-income people. The strength of stabilized soil-cement block with coir-fiber to be used as walling material is higher than mud wall. The preparation of this stabilized blocks as a building material is very easy and requires low cost and are easily available. This study is to investigate the use of coir-fiber in the stabilization of soil-cement blocks for low-cost rural housing. Keeping the above discussion in view, the present study has been attempted with the following specific objectives:

- To develop stabilized soil-cement block with coir-fiber at varying percentages to be used as walling material for rural houses,
- To determine the physical properties (density, water absorption) and the mechanical properties (compressive strength and split-tensile strength) of stabilized soil-cement blocks, and
- To analyze the cost-effectiveness of the developed stabilized blocks

2. Materials and Method

2.1. Soil

Locally available soil from three places near Bangladesh Agricultural University, Mymensingh Campus, was used in this experiment. Top soils up to 1 ft (30 cm) were cleaned away to discard organic matter, then the soil samples were taken.

Table 1 Initial properties of soil

Sample from Local Mymensingh	Initial M.C (%)	Sand (%)	Silt (%)	Clay (%)	PL (%)	P. I.	pH	Textural classification
Boyra	16.1	17	60	23	19	11.2	6.09	Silt Loam
Curkhai	19.0	25	54	21	22	10.8	7.09	Silt Loam
Sutiakhali	16.8	23	54	23	13	15.8	6.23	Silt Loam

It is suggested that the soil having at 15% clay content is suitable for making stabilized blocks [14]. Suitability of soil for stabilized block manufacture can be based on whether the plastic limits of a soil lie between 20 and 24% and liquid limit 20 to 34% [15]. Lastly which soil sample can fulfill the requirement this is the suitable soil for this experiment. Among the soil sample, only the sample from Curkhai was within the acceptable PL range between 20% and 24% and LL range between 20% and 34% and 15% clay of suitability for stabilization. The physical properties of soils are shown as follows in table 1 and the Properties of soil used in block production is in the following table 2.

Table 2 Properties of soil used in block production

Properties	Test Results
Specific gravity	2.60
Sand (%)	25
Silt (%)	54
Clay (%)	21
Plastic limit (%)	22
Plasticity Index (P.I)	10.8
Optimum moisture content (%)	20.83
Maximum dry density (gm/cc)	1.61

2.2. Cement

OPC was used throughout this experiment. The properties of cement used in the experiment are given in Table 3.

Table 3 Properties of cement used in block production

Properties	Test Results
Normal Consistency (%)	31
Initial Setting Time (min.)	130
Final Setting Time (min.)	460
Compressive Strength at 3 days (MPa)	13.67
Compressive Strength at 7 days (MPa)	23.3
Fineness (cm^2/gm)	4370

2.3. Coir-fiber

Coir was obtained from the local market in Mymensingh Sadar showed in Fig. 1(a) and Tar coated coir-fiber after cut into pieces is illustrated in Fig. 1(b). The fibers were fresh and free from dust and pests. Fibers were cut into pieces of 3 – 5 cm in length. The physical properties of the coir-fiber used in the block preparation is in the following table 4.

Table 4 Properties of coir-fiber used in block production

Properties	Values
Color	Brown
Length (mm)	30 – 50
Average diameter (mm)	0.50
Bulk density (kg/m^3)	146
Specific gravity	0.86
Tenacity (g/tex)	11
Young's Modulus (kN/m^2)	4.0×10^6

Figure 1 (a) Raw coir-fiber, (b) Tar coated coir-fiber after cut into pieces

2.4. Water

Water sourced from public supplies via piping was utilized.

2.5. Selection and preparation of soil

Soil samples were collected from 3 places near BAU campus in Mymensingh to make stabilized block. Among the soil samples, sample from Curkhai, was within the acceptable PL range between 20 and 24% and LL range between 20 and 34% and 15% clay of suitability for stabilization [15]. Then soil was sieved and dried. The soil passing through #8 sieve was used for the test.

2.6. Preparation of coir-fiber

Raw coir-fiber was collected from the local market near Mymensingh. The fibers were extracted from the coir manually. Then it was cleaned and free from dust and pests. Fibers were cut at length 3-5 cm showed in Fig.1(b), the fiber was applied with various percentages (0, 0.2, 0.4, 0.6 and 0.8%) with respect to weight of soil. All the pieces of fibers covered by tar as fibers could not absorb water showed in Fig.1(b). Fiber is organic in nature so if fiber absorbed water, it can be decomposed and the tar was applied to solve this problem.

2.7. Production of stabilized soil-cement block

After selecting and preparing the soil by drying and sieving, the portion passing through the #8 sieve was used to make stabilized blocks. Coir-fiber was also prepared. The soil used in this study had a plastic limit ranging from 20% to 24% and a liquid limit between 20% and 34%. Based on Dad's findings (1986), an optimal cement content of 4% was selected as the stabilizing agent, calculated by the total weight of the mixture [15]. Five blocks were made without fiber, while 20 blocks were made with varying fiber content (0.2, 0.4, 0.6, and 0.8%). The soil-cement mixture and fiber were mixed, water was added, and the mixture was compacted in a block frame using a hammer. A total of 25 blocks were made for density, water absorption, and compressive strength tests. Additionally, 15 cylindrical blocks were created for split-tensile strength measurement with different fiber percentages (0, 0.2%, 0.4, 0.6, and 0.8%). After production, the blocks were cured for 28 days by covering them with gunny bags and sprinkling water.

2.8. Test Procedures

2.8.1. Density

The density was measured by using the following expression:

$$\text{Density (lb/ft}^3) = \frac{\text{Weight in lb}}{\text{Volume in ft}^3} \qquad \text{……………………(1)}$$

2.8.2. Water Absorption

The initial weight of dry block (w_1) was taken. Then they were immerged in water for 24 hours. After 24 hours the final weight of block (w_2) was taken. The amount of water absorbed by the block $=W_2-W_1$. The water absorption of blocks was calculated in percent (%) by using following formula:

$$\text{Water absorption of block (\%)} = \frac{W_2 - W_1}{W_1} \times 100 \qquad \ldots\ldots\ldots\ldots\ldots(2)$$

2.8.3. Compressive Strength

The compressive strength was calculated by using the following formula:

Compressive strength,

$$S = P/A \qquad \ldots\ldots\ldots\ldots\ldots(3)$$

where,

S = Compressive strength (lb/in^2)
P = Load for which the block was failed (lbs)
A = Cross sectional area (inch^2)

2.8.4. Split-tensile strength

The tensile strength was measured by using the following formula [16]:

$$\text{Split-Tensile strength (lb/in}^2\text{)} = \frac{2P}{\pi DL} \qquad \ldots\ldots\ldots\ldots\ldots(4)$$

where,

P = Compressive load on the cylinder (lb)
L = Length of the cylinder (in)
D = Diameter of the cylinder (in)

2.8.5. Tenacity test

In this experiment the strength of fiber was measured. A bunch of fibers were put in Stelometer and worked with pendulum lever principle. The breaking load was found and the weight of the fiber was taken. The tenacity of fiber was measured using the following formula [17]

$$\text{Tenacity} = \frac{\text{Breaking load (N)}}{\text{Linear Density (tex)}} \qquad \ldots\ldots\ldots\ldots\ldots(5)$$

2.8.6. Units of Tenacity

SI Unit: N/tex (Newton per tex), Commonly Used Unit: g/tex (gram-force per tex)

Since 1 N = 101.97 g_f, tenacity is often expressed in g/tex.

The experimental setup for tenacity test of coir-fiber [Fig 2(a), (b)], the experimental test setup of compressive strength and split-tensile strength is illustrated in [Fig. 2(c),(d)].

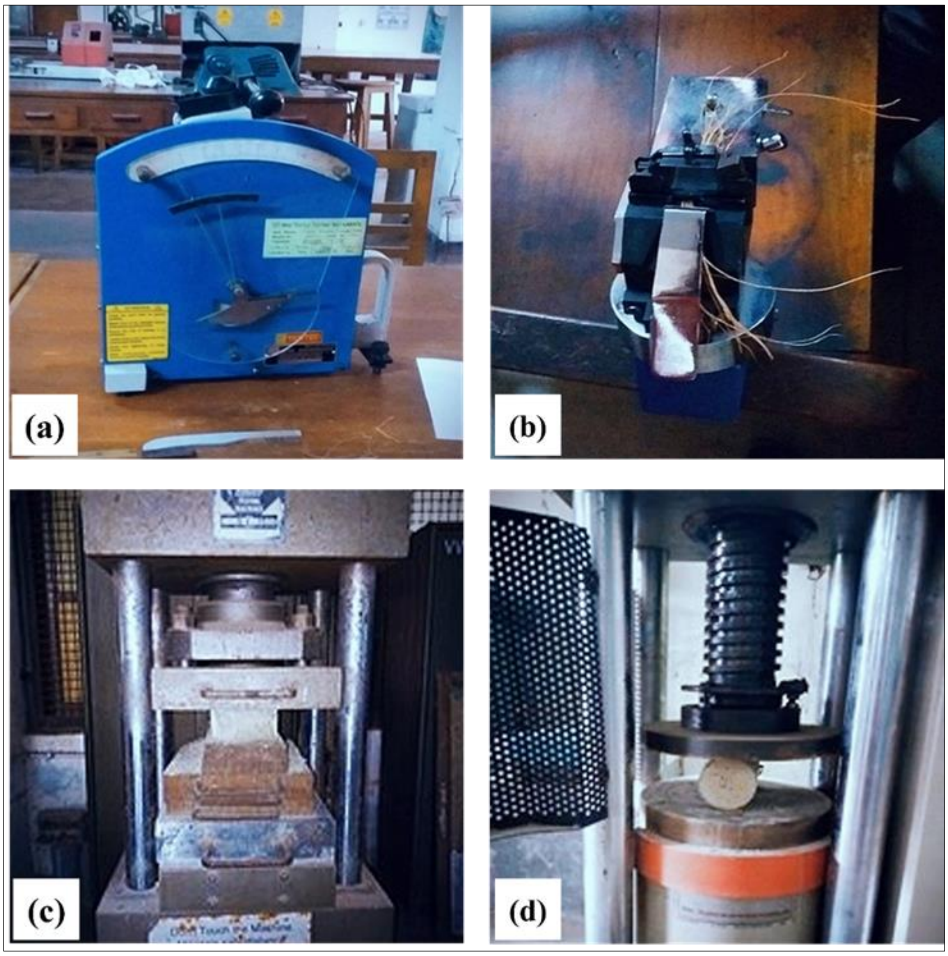

Figure 2 (a) Stelometer for strength test, (b) Experimental setup for tenacity test of coir-fiber, (c) Soil-cement block under compressive load, (d) Soil-cement cylinder under tensile load

3. Results and discussion

3.1. Density of stabilized soil

Comparison of density for various percentage of coir-fiber is given in the Fig. 3(a). It is clearly shown that the density of blocks for 0% fiber content is the highest amount all. The density of stabilized soil-cement blocks are gradually decreases with the increase of coir-fiber percentage with 28 days curing age.

3.2. Water Absorption of stabilized soil

Comparison of water absorption for various percentage of coir-fiber is given in the Fig. 3(b). The water absorption of stabilized soil-cement blocks are gradually increases with the increase of coir-fiber percentage with 28 days curing age. Water absorption of stabilized soil-cement blocks reached maximum value at 0.8% of fiber content.

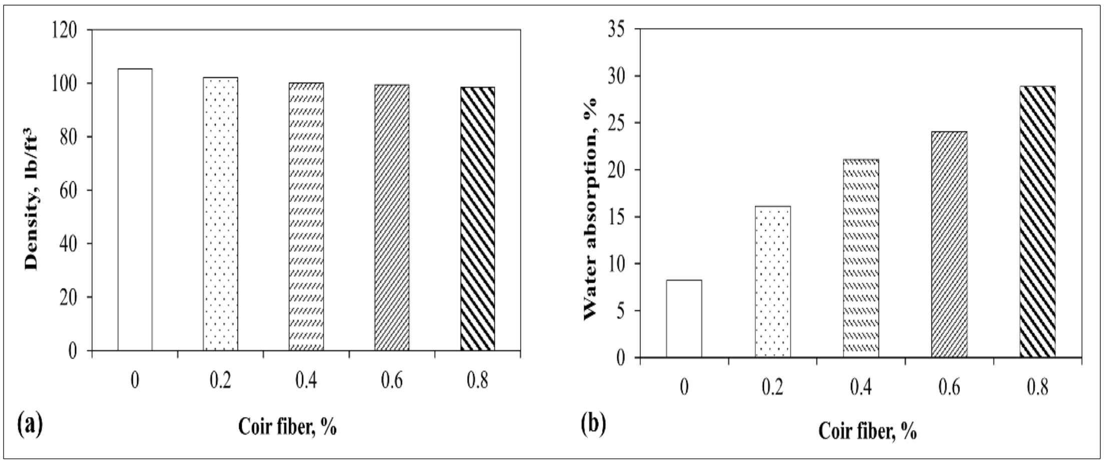

Figure 3 (a) Density of blocks at different percentage of coir-fiber, (b) Water absorption of blocks at different percentage of coir-fiber

3.3. Compressive strength of stabilized soil-cement blocks

Comparison of compressive strength for various percentage of coir-fiber is given in the figure 4(a). The compressive strength of stabilized soil-cement blocks gradually increases with the increase of coir-fiber percentage with 28 days of curing period. The compressive strength of stabilized blocks for 0.8% fiber content was reached at the maximum values.

3.4. Tensile strength of stabilized soil-cement blocks

The figure 4(b), shows a comparison of tensile strength for different percentages of coir-fiber. After 28 days of curing, the tensile strength of stabilized soil-cement blocks increases steadily as the amount of coir-fiber increases. The stabilized blocks with the highest tensile strength have 0.8% fiber content.

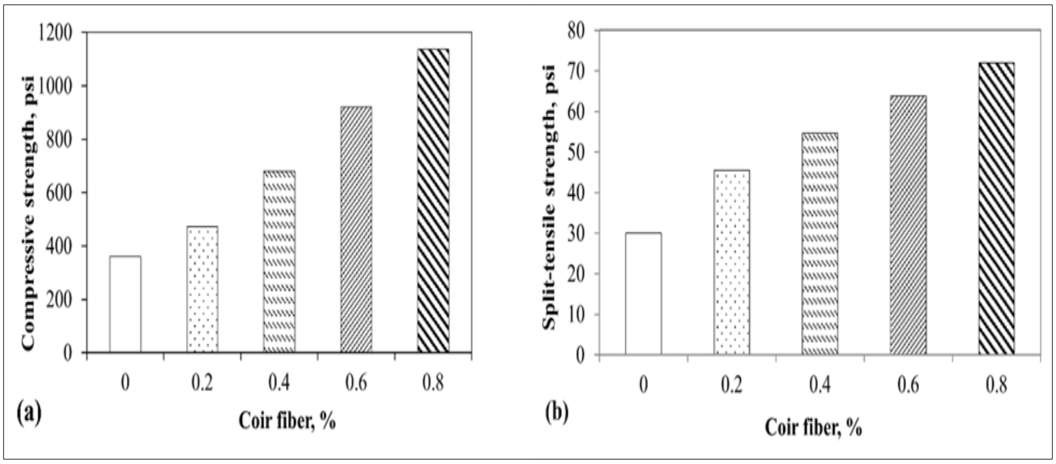

Figure 4 (a) Compressive strength of different stabilized soil-cement blocks with coir-fiber at varying percentages, (b) Split-tensile strength of different stabilized soil-cement blocks with coir-fiber at varying percentages

3.5. Unit cost of stabilized blocks with fiber

The estimated unit cost of five types of stabilized blocks was plotted against the fiber content of each. From Fig. 5, it is observed that unit cost of the block increases as the fiber content increases.

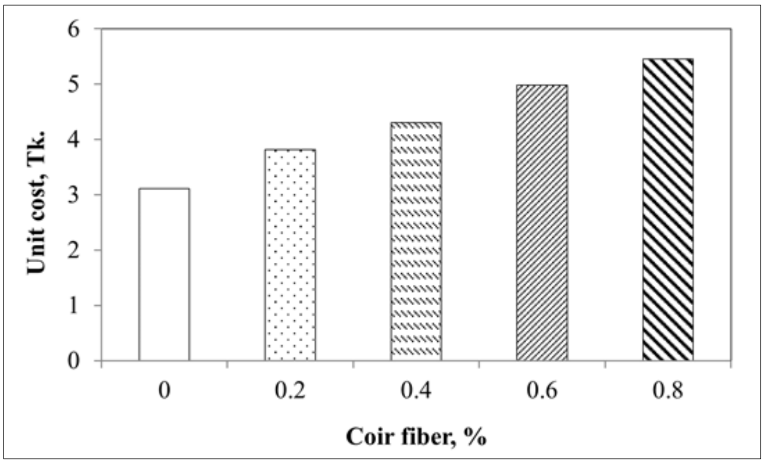

Figure 5 Unit cost for different stabilized soil-cement blocks at varying percentages of coir-fiber

4. Conclusion

This study concludes that adding coir-fiber to stabilized soil-cement blocks improves both compressive and split-tensile strengths. The strength improvements observed as fiber content increases. The compressive strength of stabilized soil-cement blocks for 0, 0.2, 0.4, 0.6 and 0.8% fiber contents are 360, 473, 680, 920 and 1136 psi respectively, and the tensile strength of the blocks for 0, 0.2, 0.4, 0.6 and 0.8% fiber contents are 30.03, 45.5, 54.65, 63.83 and 72.03 psi, respectively. The compressive strength and split-tensile strength both reached their maximum values at the fiber content of 0.8%. The compressive strength reached its highest at 1136 psi with 0.8% of fiber content. Similarly, tensile strength increased to 72.03 psi at 0.8% of fiber content. Both strengths are improving after 28 days of curing. The density of stabilized soil-cement blocks with coir-fiber gradually decreases, and water absorption of the blocks gradually increases with the increase of coir-fiber percentage after 28 days of curing period. The unit cost of the blocks also increases with the increase in fiber content.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no known conflicts of interest related to this research. There are no financial, personal, or professional relationships that could influence the findings or interpretation of the study.

References

[1] Asmamaw, T., 2007: study of compressed cement stabilized soil block as an alternating wall making material. The Schools of Graduate Studies of Addis Ababa University. ResearchGate.

[2] Rigassi, V., 1995: “Compressed Earth Blocks: Manual of Production”. Vol. 1, CRA Terre-EAG. Vilefontaine Cedex, France

[3] Adam, E.A. and Agib, A.R.A. (2001) Compressed Stabilised Earth Block Manufacture in Sudan. Printed by Graphoprint for the United Nations Educational, Scientific and Cultural Organization, UNESCO, Paris, 11.

[4] Dad M., M., 1985: The Use of Cement Stabilized Soil for Low-cost Housing in Developing Countries. Ph.D. Thesis. University of Newcastle Upon Tyne, England, U.K.

[5] Lambe T., W., and Moh, Z., 1957: Improvement of strength of Soil-Cement with Additives. Highway Research Board, Bul. 183.pp. 38-87

[6] Portland Cement Association 1984: Soil-Cement for Facing Slope and Lining Channel, Reservoirs and Lagoons, Soil-Cement. 5420 old orchard Road, Skokie, Illinois 60077-4321, U.S.A.

[7] Fitzmaurice, R., F., 1958: Manual on Stabilized Soil Construction for Housing U.N. Technical Assistance Programme, New York.

[8] Oliver, M., Gharbi, Z., E., L., 1995: “Sisal Fiber reinforced soil block masonry”, Proceedings of 4th International Masonry Conference, British Masonry Society, London, pp. 55-58.

[9] Morel J., C., Ghavami K., and Mesbah, A., 2000: “Theoretical and experimental analysis of composite soil blocks reinforced with sisal fibers subjected to shear”, Masonry International, Vol. 13 No. 2, pp. 54-62.

[10] Binici H, Aksogan O, Bakbak D, Kaplan H, and Isik, B., 2009: “Sound insulation of fibre reinforced mud brick walls”, Construction and Building Materials, Vol. 23 No. 2, pp. 1035-1041.

[11] Aziz M., A., Paramasivam P., and Lee, S., L., 1984: Chapter On "Concrete with Natural Fibers" In the Book Entitled New Reinforced Concretes, Edited by R.N. Swamy, Int. Textbook Co., Glasgow, pp.106-140.

[12] Satyanarayana, K., G., Kulkarni, A., G., and Rohatgi, P., K., 1981: Structures and Properties of Coir-fiber, Proc. Indian Acad. Sci. Vol. 4, pt. 4, December 1981, pp. 419-436.

[13] Subramani, T., and Udayakumar, D., 2016: Experimental Study on Stabilization of Clay Soil Using Coir-fiber, IJAIEM, Volume 5, Issue 5, May 2016

[14] Webb D. J. T., 1983: Stabilized Soil Construction in Kenya Proc. of UNESCO Conf. Held in Paris.

[15] Dad MM 1986: Prediction of the Suitability of Soil for Making Cement Stabilized Block as a Building Material. Seminar on Habitat day 1986.Held at H.B.R.I campus in Dhaka on October 6, Bangladesh.

[16] Neville A. M., 1995, “Properties of Concrete”, 4thEdition, Longman Group Ltd., Essex, pp. 844,1995.

[17] ISO 2062:2009: Textiles — Yarns from Packages — Determination of Single-End Breaking Force and Elongation