Effect of Portland Cement on the Development of Unfired Compressed Earth Bricks; Special Application as Construction Material in Poor Territory of Pakistan

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ABSTRACT: *Compressed Earth Bricks (CEBs) are the main constituents used in building materials like the pillar that holds the whole building. Scientists are struggling to produce stronger materials with the least cost and much more efficient strength. CEB products can very easily bear comparison with other materials such as the sand-cement block or the fired brick. Compressed Stabilized Earth Blocks (CSEBs) are environmentally friendly as these blocks are un-burnt and are economically cheap. These blocks require less labor with respect to fired bricks, so one can prepare them easily. To make CEB's water resistant and durable 8%, 10%, and 12% cement as a stabilizer is added to the dry soil. The compressive strength measured was much better and increased with an increase in cement content i.e. 17.71MPa for 8% cement additive, 18.334MPa for 10%, and 21.229MPa for 12% as compared to commercially fired clay bricks which are up to 13MPa. The compressive strength increases with an increase in cement proportion. By studying the XRD analysis it was observed that Calcium Aluminum Silicate Hydrate (CASH) peak intensity increases by adding cement to the dry soil. However, crystallinity size decreases. The elemental composition shows that quartz and calcite are the major constituents of these samples which gives them better compressive strength. Hence unfired compressed earth bricks are environmentally friendly and cost-effective by using a very minute amount of cement i.e. 8% and its compressive strength is high as compared to fired clay brick.*

KEYWORDS: *Compressed Earth Blocks (CEB, s); Compressive Strength; Construction Materials; Portland Cement.*

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INTRODUCTION

Building materials are the need of every generation and scientists are in a continuous struggle to produce low-cost materials with higher strength [1]. Human evolution has used soil as a building material over 9000 years ago [2]. Adobe bricks which are usually prepared by molding raw clay into an open timber frame and sun-baking has been used as a local and low-cost material since the ancient time [3]. Compressed Earth Blocks (CEBs) are one of the main constituents of these materials are made of fairly dry inorganic materials like subsoil, non-expansive clay, silica, and some amount of sand [4]. Compressed Earth Block (CEB) is one name given to earthen bricks compressed with hand-operated or motorized hydraulic machines [5]. CEB products can very easily bear comparison with other materials such as the sand-cement block or the fired brick [6, 7]. Due to scientific research and experimentation CEB technology has made great progress [8]. Soil reaches a high dry density during compaction when it is compacted at maximum moisture content and is used for measuring compressive strength in a dry state. The compacted soil loses its strength during saturation [9]. Using chemical and mechanical actions i.e. stabilization can remove these disadvantages [10]. Stabilizers like lime and cement are added to dry the soil to form stable hydrated compounds for the purpose to protect the adobe brick from deterioration and not to lose strength during saturation and abrasion due to rain impact [3, 9, 11]. Such blocks are called Compressed Stabilized Earth Blocks (CSEBs) or Stabilized Earth Blocks (SEBs). Different stabilizers can be used in different proportions for stabilizing CEB. Cement as a stabilizer is normally used from 4 to 10% and lime from 6 to 12% with the dry weight of the soil [12]. Compressed Stabilized Earth Blocks (CSEBs) are environmentally friendly. Soil-cement Compressed Stabilized Earth Block is an alternative to fired bricks [13]. As these blocks are un-burnt and during their preparation, no coal or burning materials are required and hence does not produce harmful gases like CO_2 which are emitted in the production of fired bricks. [14]. "CINVA RAM" press machine was used for the first time for compressing earth block into a high-density block during 1952 in Colombia [15].

Literature shows that stabilized Compressed Earth Blocks gain keen interest for research in the recent era and these CEBs are environmental friendly and economically cheap. Based on the environmental conditions and traditions people use different materials for habitats but the most prominently used building material is soil and one of the major reasons behind it is its availability [16].

Miguel F.C., et.al. [12] studied Compressed Earth Blocks (CEB). CEB consists of 80-90% of soil. Thus soil selection is very important in formulating CEB mixes. The soil composition in CEB consists of 0-30% of gravel; 25-70% of sand; 20-45% of silt and clay.

Venu Madhava Rao et. al. [17] observed the bond strength of stabilized soil-sand masonry blocks by using cement-sand (1:4), cement-sand (1:6), cement-sand (1:10), Cement-Soil-Sand (1:1:6), and Cement-Lime-Sand (1:1:10). The increase in bond strength using Cement-Soil-Sand mortars was found to be 68% higher than similar cement: sand mix. Thus soil-cement mortars give better results compared to sand-cement mortars.

P.J. Walker [18] used 5 to 10% of the cement with a dry mix of soil for stabilizing Compressed Blocks. Modification of clay soil with sand provides a better result for stabilization with cement. Portland cement was added to the soil mixture in a proportion of 1:10, 1:15, and 1:20 (Cement-Soil by dry volume). The stabilization generally becomes less economical for the blocks containing greater than 10% cement content. The dry compressive strength and saturated compressive strength were reported as 3.5 to 7 MPa and 2 to 4 MPa respectively for 5-10% cement proportion which is economically suitable.

S.S. Namango [19] also worked on Compressed Earth Block (CEB) mechanical strength and reported dry compressive strength of 3.5 to 8 MPa. P. Walker [20, 21] said the physical characteristics of earth blocks can be greatly enhanced by mechanical compaction, often combined with the addition of cement, lime, or natural fibers. Minimum compressive strength requirements above 2.0 MPa are readily achieved using soils with 5–15% clay content, stabilized with 5–10% cement, and manually compacted at pressures of only 2 MPa. Hydraulic binders, such as cement and lime, improve block strength, erosion resistance, and dimensional stability [22]. Earth blocks are often characterized in terms of their compressive strength and resistance to rain-borne erosion.

To enhance the properties of CEB as a construction material mechanical strength and durability are the main characterizations to be increased economically [23]. Cement as a stabilizer in CEB provides the best stabilization and was analyzed in terms of their compressive strength, water absorption, resistance to water erosion, and thermal conductivity [24].

According to *Vilane* [25], and *Aubert et al.* [26], several studies have looked into ways to make unfired earth bricks more durable. The use of biological, synthetic, and mechanical stabilizers to enhance the wet and dry mechanical strength of blocks, as well as their water-resistant capabilities, dominates the study of un-burnt earth blocks [27]. Vilane [25], states that cow manure, rice husks, wheat straw, and sugarcane bagasse are all-natural stabilizers. According to *Aubert et al.* [26], by resisting contraction and deformation, these stabilizing techniques are used to strengthen the strength and help in reducing the cracking of un-burnt bricks during curing. For instance, *Aubert et al*. [26] observed that by adding 1.5 percent barley straw to earth blocks containing 28 to 40% clay content, the mechanical strength of the blocks was increased by 10%. Similarly, according to *Zak et al.* [28], chemical stabilization with cement, lime, and asphalt has been observed, and mechanical stabilization has been observed via compression according to *Maskell et al.* [29]. For instance, according to *Sharma et al.* [16], asphalt, and gypsum enhance water abrasion resistance of unfired bricks whereas; according to *Morel et al.* [30], integrating 4 to 10% cement enhances the mechanical properties of unfired earth bricks significantly when compared to those without cement. In another study, *Nagaraj et al.* [31] found that the wet compressive strength (7.2 MPa) of un-fired earth blocks stabilized with cement (6%) and lime (2%) was higher (4.9 MPa), compared to un-fired earth blocks stabilized with 8% cement only indicating the synergistic effects of stabilizers.

EXPERIMENTAL SECTION

Materials and methods

Soil-cement blocks are prepared by using dry soil as a raw material along with a different proportion of cement content for the preparation of Stabilized Compressed Earth Blocks [32]. The raw material for the CEBs was collected from village Mattani of Peshawar, Pakistan having coordinates 33°47′40.38″N and 71°33′29.20″E. Increasing cement proportion and reducing clay content improves properties of the Compressed Earth Blocks in accordance with [33]. The material strength and durability can be increased by using cement content in the dry soil [34]. The following types of blocks were produced (a): Stabilized CEB with 8% of cement, (b): Stabilized CEB with 10% of cement, and (c): Stabilized CEB with 12% of cement, by mass with dry soil. 8%, 10%, and 12% cement content were mixed thoroughly with dry soil. The powder samples were molded in a mold and then compressed through a hydraulic press by applying a pressure of 10MPa to obtain 8%, 10%, and 12% cement-soil CEBs samples. The dry samples were then given room humid temperature for 28 days. At the start, the dry samples were too weak but gradually gain strength over the period. Different characterization tests were done to study its compressive strength, durability, stability, and water absorptions.

RESULTS AND DISCUSSIONS

XRD analysis

The X-ray diffraction patterns of pure soil and soil-cement CEBs with 8%, 10%, and 12% cement mixed soil are shown in Fig. 1. Quartz is identified as the major phase in the dry soil and soil mixed with cement 8%, 10%, and 12% samples. There also exist some calcite, Fe_2O_3 Albite, and Al_2O_3 phases as secondary phases.

Similarly, the interplanar spacing corresponding to the XRD peaks for stabilized CEBs 8%, 10%, and 12% cement content samples with dry soil matched with ICDD card# 46-1045 for Quartz having Hexagonal structure, ICDD card# 52-1449 for Iron Oxide having structure Orthorhombic, ICDD card# 73-1199 for Aluminum Oxide having structure Hexagonal, ICDD card# 1-89 for Calcium Aluminum Silicate Hydrate (CASH) having structure Monoclinic and ICDD card# 48-1882 for Calcium Aluminum Oxide having cubic structure.

The overall structure of the XRD graphs shows that there is no structural change in the XRD graph of the pure soil and that of the soil-cement CEBs with 8%, 10%, and 12% cement content. The peak intensity decreases by adding cement content to the dry pure soil so the crystallinity size decreases. The Calcium Aluminum Silicate Hydrate (CASH) peak intensity increases with cement intensity.

Morphological and surface studies of unfired bricks

The Secondary electron images of the unfired compressed pellets samples of 8%, 10%, and 12% cement

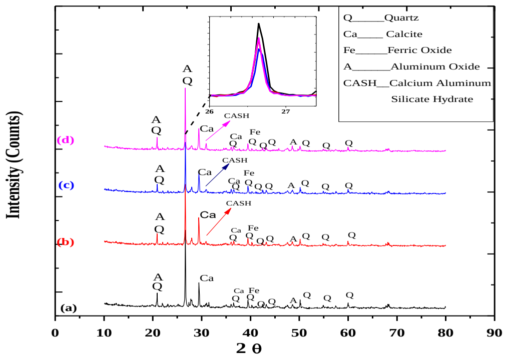

Fig. 1: The room temperature XRD of an unfired bricks (soil) with: (a) pure soil, (b) 8% cement mixed soil, (c) 10% cement mixed soil and (d) 12% cement mixed soil.

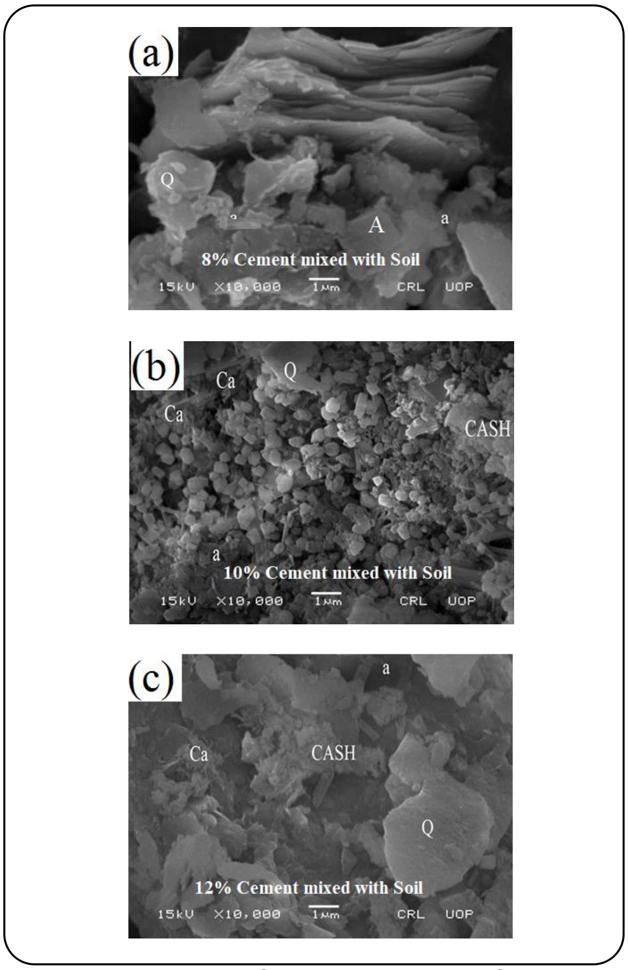

Fig. 2: The SEM Image of Cement Mixed Soil Unfired Brick a) with 8% Cement b) 10% Cement c) 12% Cement.

Similar some cubed-shaped grains labeled as C whose semi-quantitative elemental analysis shows that these grains are of Calcite. The semi-quantitative analysis of the mixed soil are shown in Figs. 2 (a), (b), and (c) respectively. The grain labeled as Q is of the Quartz phase. grains labeled as "a" are close to the Albite phase. The grains of Calcium Aluminum Silicate Hydrate phase is labeled as (CASH). The SEM results in Figs. 2 (a), (b), and (c), are in good agreement with the XRD results. The morphological study of all these images shows that they have rough surfaces and particle sizes are irregular.

FT-IR analysis

The CEBs samples were analyzed by Fourier Transform Infra-red spectroscopy as prepared. Figs. 3-5 shows the FT-IR spectrum of 8%, 10%, and 12% cement mixed soil CEBs samples. By studying FT-IR analysis, peaks for 8%, 10%, and 12% cement mixed soil pellets were observed. Peaks for 8% cement mixed soil were observed at 1415, 1002, 873, 776, and 713cm^{-1}, which are shown in Fig. 3. Similarly for 10% cement mixed soil peaks were observed at 2162, 1419, 1006, 873, 776, and 713 cm^{-1} and for 12% cement mixed soil at 3618, 2162, 1413, 1002, 873, 776, and 713 cm^{-1}, which are shown in Fig. 4, and Fig. 5 respectively. By studying all the peaks it is observed that most of the peaks are due to stretching modes [35, 36]. Peaks at 1002 cm^{-1} in 8% and 12% cement sample and at 1006 cm^{-1} in 10% cement sample are due to C−O [37]functional group and stretching modes. Peaks at 1413 cm^{-1}, 1415 cm^{-1}, 1419 cm^{-1} in 8%, 10%, and 12% cement samples are due to C═C functional group and stretching modes. Peaks at 2162 cm^{-1} in 8%, 10% and 12% cement sample are due to variable stretching mode and C≡C functional group. Peaks at 873cm^{-1} and 713 cm^{-1} are due to Si−O.

Compressive Strength Test

Universal Testing Machine (UTM) model "100-500 kN" (Testometric Inc. UK) was used for measuring the compressive strength of the soil-cement samples. Samples were placed between the load cells and force was applied until they break. The compressive strength of the blocks was determined at the age of 28 days. Two points were noted during the compression. The first point labeled as A is the one at which the first crack occurs in the specimens and the second point is labeled as B at which the specimens reached failure. The load value in each sample increased till failure occurs and then suddenly falls. All the samples are of dimension 3*2 inches having a cross-sectional area

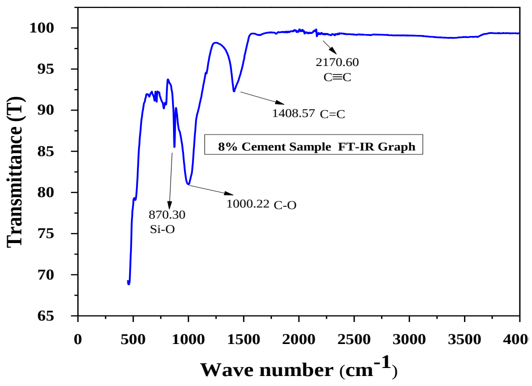

Fig. 3: The FT-IR Graph of an Unfired Brick with 8% Cement Mixed Soil showing Si−O, C−O, C═C and C≡C functional groups at 870.30, 1000.22, 1408.57 and 2170.60 respectively.

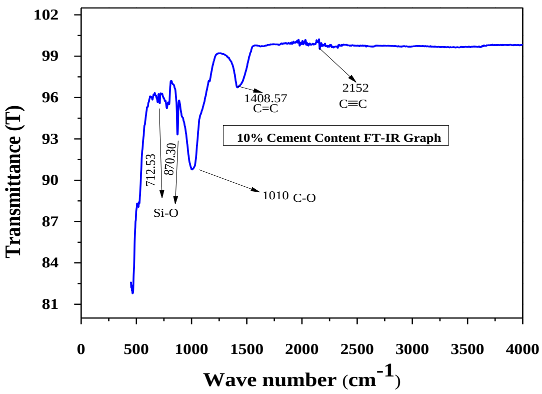

Fig. 4: The FT-IR Graph of an Unfired Brick with 10% Cement Mixed Soil showing Si−O, C−O, C═C, and C≡C functional groups at 712.53, 870.30, 1010, 1408.57 and 2152 peaks respectively.

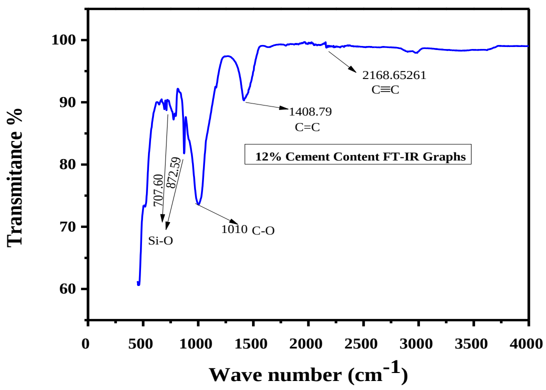

Fig. 5: The FT-IR Graph of an Unfired Brick with 12% Cement Mixed Soil showing Si−O, C−O, C═C, and C≡C functional groups at 707.60, 872.59, 1010, 1408.79 and 2168.65261 cm^{-1} peak respectively.

of 3870.96mm^2. The first crack for the 8% cement content CEB occurs at 57.366 kN but it can bear further load up to 68.5841 kN. At 68.5841 kN load the sample completely distorted and bears no more load (Fig. 6) thus having a compressive strength of 17.71MPa. Similarly, for the 10% sample, the first crack occurs at 60.754 kN and can bear more loads till 70.973 kN load, and has a compressive strength of 18.334MPa. The sample bears no more load onward this (Fig. 7). The graph of 12% cement content CEB shows that the first crack occurs at 81.193 kN load and can afford further load till 82.177 kN load and thus having a compressive strength of 21.229MPa but above this point, it can bear no more load (Fig. 8). So by increasing the cement content from 8% to 12% the compressive strength increases. The compressive strength of CEBs is much greater than that of fired clay bricks which are up to 13MPa [38]. The compressive strength increases with an increase in cement proportion but it is recommended for the industrialist to keep it in the range of 8-12%, as in the mentioned range CEBs are of low cost, durable, and of high compressive strength.

CONCLUSIONS

In this study, the phase, microstructure, and mechanical properties of cement-added unheated clay bricks were investigated. Quartz and calcite are the major phases present in the unfired brick samples while aluminum oxide and iron are also present in a little amount. XRD of the dry soil and soil-cement mixture with 8%, 10%, and 12% cement content shows that the peak intensity of CASH increases respectively with an increase in cement proportion. Soil-cement blocks with cement content of 8% show larger size pores compared to soil-cement blocks with a 10% and 12% cement-based which results in an increase in the compressive strength of the soil-cement bricks from 68.5841 k-N to 82.177 k-N as the cement content increased from 0 to 12%. The morphological study of the soil-cement bricks with 8%, 10%, and 12% cement content shows that they have rough surfaces and particle sizes are irregular. However, the crystallinity size decreases by increasing cement content while the amorphous size increases. So it is recommended for the users to use compressed stabilized earth block as its compressive strength and durability are far better than fired clay bricks and are also included in the green synthesis.

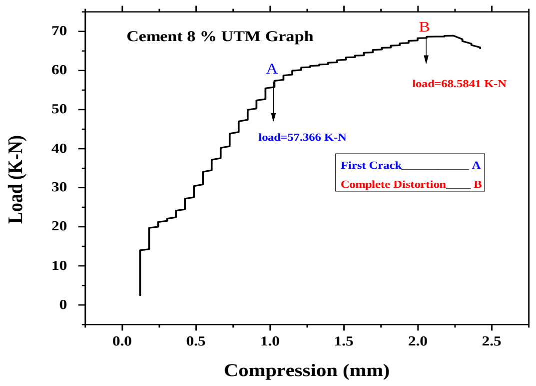

Fig. 6: Compressive Strength measurement of Stabilized CEB with 8% of Cement content showing first crack at 57.366 kN and complete deformation at 68.5841 kN.

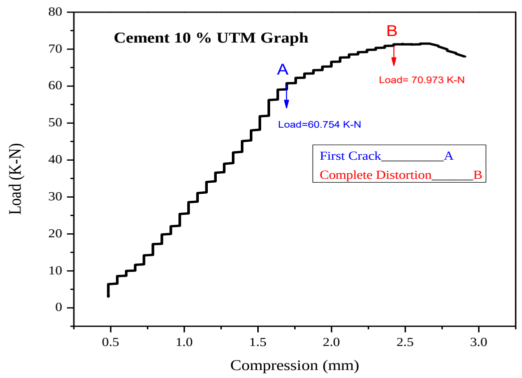

Fig. 7: Compressive Strength measurement of Stabilized CEB with 10% of Cement content showing first crack at 60.754 kN and complete deformation at 70.973 kN.

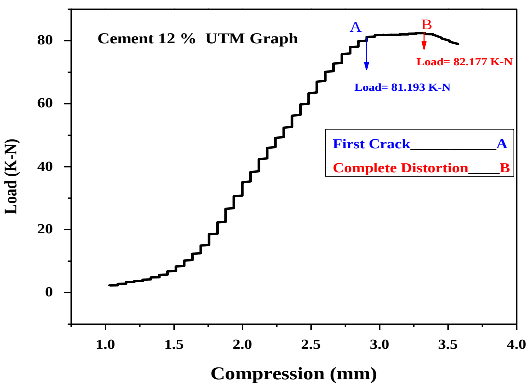

Fig. 8: Compressive Strength measurement of Stabilized CEB with 12% of Cement content showing first crack at 81.193 kN and complete deformation at 82.177 kN.

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REFERENCES

[1] Waziri B.S., Lawan Z.A., Properties of Compressed Stabilized Earth Blocks (CSEB) for Low-Cost Housing Construction: A Preliminary Investigation, *International Journal of Sustainable Construction Engineering and Technology*, **4(2)**: 39-46 (2013).

[2] Kumar N., Barbato M., Compressed and Stabilized Earth Blocks in Louisiana.

[3] Leonel R.F., Folgueras M.V., Dalla Valentina L.V.O., Prim S.R., Prates G.A., Caraschi J.C., Characterization of Soil-Cement Bricks with Incorporation of Used Foundry Sand, *Cerâmica*, **63(367)**: 329-335 (2017).

[4] Aziz T., Mehmood S., Haq F., Ullah R., Khan F. U., Ullah B., Muhammad R., Mudassir I., Asmat U., Synthesis and Modification of Silica-Based Epoxy Nanocomposites with Different Sol–Gel Process Enhanced Thermal and Mechanical Properties, *Journal of Applied Polymer Science*, **138(40)**: 51191 (2021).

[5] Nelson W., Compressed earth blocks. The Art of Natural Building, 138-142 (2002).

[6] Deboucha S., Hashim R., A Review on Bricks and Stabilized Compressed Earth Blocks, *Scientific Research and Essays*, **6(3)**: 499-506 (2011).

[7] Mansour M.B., Jelidi A., Cherif A.S., Jabrallah S.B., Optimizing Thermal and Mechanical Performance of Compressed Earth Blocks (CEB), *Construction and Building Materials*, **104**: 44-51 (2016).

[8] Rigassi V., "Compressed Earth Blocks: Manual of Production", Deutsches Zentrum fur Entwicklungstechnologien-GATE, (1995).

[9] Garg A.A., Yalawar A., Kamath A., Vinay J., "Effect of Varying Cement Proportions on Properties of Compressed Stabilized Earth Blocks (CSEB)-A Sustainable Low-Cost Housing Material", *International Conference on Sustainable Civil Infrastructure: India Section*, October, Hyderabad, India (2014).

[10] Krishnaiah S., Suryanarayana R., "Effect of Clay on Soil Cement Blocks", *The 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG)*, October, Índia (2008).

[11] Alam I., Naseer A., Shah A., Economical Stabilization of Clay for Earth Buildings Construction in Rainy and Flood Prone Areas, *Construction and Building Materials*, **77**: 154-159 (2015).

[12][da Silva M.F.C.G., "Compressed Earth Blocks with and Without Cementitious Materials", Lisboa: Universidade de Lisboa, (2015).

[13] Reddy B.V., Pressed Soil-Cement Block: An Alternative Building Material for Masonry, *Sustain. Constr*, **1**: 425-433 (1994).

[14] Patowary B.N., Nath N., Hussain I., Kakoti H.J., Study of Compressed Stabilised Earth Block, *Int. J. Sci. Res. Publ*, **5(6)**: 4-7 (2015).

[15] Reddy B.V., Gupta A., Characteristics of Soil-Cement Blocks Using Highly Sandy Soils, *Materials and structures*, **38(6)**: 651-658 (2005).

[16] Sharma V., Vinayak H.K., Marwaha B.M., Enhancing Sustainability of Rural Adobe Houses of Hills by Addition of Vernacular Fiber Reinforcement, *International Journal of Sustainable Built Environment*, **4(2)**: 348-358 (2015).

[17] Rao K.V.M., Reddy B.V., Jagadish K., Flexural Bond Strength of Masonry Using Various Blocks and Mortars, *Materials and Structures*, **29(2)**: 119-124 (1996).

[18] Walker P., Strength, Durability and Shrinkage Characteristics of Cement Stabilised Soil Blocks, *Cement and Concrete Composites*, **17(4)**: 301-310 (1995).

[19] Namango S.S., "Development of Cost-Effective Earthen Building Material for Housing Wall Construction: Investigations into the Properties of Compressed Earth Blocks Stabilized with Sisal Vegetable Fibres, Cassava Powder and Cement Compositions. Cassava Powder and Cement Compositions", Doctoral Dissertation, Brandenburg Technical University, Cottbus, Germany (2006).

[20] Walker P., Bond Characteristics of Earth Block Masonry, *Journal of Materials in Civil Engineering*, **11(3)**: 249-256 (1999).

[21] Walker P.J., Strength and Erosion Characteristics of Earth Blocks ad Earth Block Masonry, *Journal of Materials in Civil Engineering*, **16(5)**: 497-506 (2004).

[22] Zheng J., Aziz T., Fan H., Haq F., Khan F.U., Ullah R., Bakhtar U., Khattak N.S., Wei J., Synergistic Impact of Cellulose Nanocrystals with Multiple Resins on Thermal and Mechanical Behavior, *Zeitschrift Für Physikalische Chemie*, **235(10)**: 1247-1262 (2021).

[23] Aziz T., Fan H., Khan F.U., Ullah R., Haq F., Iqbal M., Ullah A., Synthesis of Carboxymethyl Starch-bio-Based Epoxy Resin and their Impact on Mechanical Properties, *Zeitschrift für Physikalische Chemie*, **234(11-12)**: 1759-1769 (2020).

[24] Aziz T., Fan H., Zhang X., Khan F. U., Synergistic Impact of Cellulose Nanocrystals and Calcium Sulfate Fillers on Adhesion Behavior of Epoxy Resin, *Materials Research Express*, **6(11)**: 1150 (2019).

[25] Vilane B., Assessment of Stabilisation of Adobes by Confined Compression Tests, *Biosystems Engineering*, **106(4)**: 551-558 (2010).

[26] Laborel-Preneron A., Jean-Emmanuel A., Camille M., Christelle T., Alexendra B., Plant Aggregates and Fibers in Earth Construction Materials: A Review, *Construction and Building Materials*, **111**: 719-734 (2016).

[27] Ahmadi R., Kalateh K., Alizadeh R., Khoshtarkib Z., Amani V., Tetrakis (6-methyl-2, 2'-bipyridine)-12N, N'; 22N, N'; 32N, N'; 42N, N'-tetra--nitrato-1: 22O: O'; 2: 33O: O', O"; 2: 33O, O': O"; 3: 42O: O'-tetranitrato-14O, O'; 42O, O'-tetralead (II), *Acta Crystallographica Section E: Structure Reports Online*, **65(10)**: 1169-1170 (2009).

[28] Zak P., Ashour T., Korjenic S., Sinan K., Wei W., The Influence of Natural Reinforcement Fibers, Gypsum and Cement on Compressive Strength of Earth Bricks Materials, *Construction and Building Materials*, **106**: 179-188 (2016).

[29] Maskell D., Heath A., Walker P., Laboratory Scale Testing of Extruded Earth Masonry Units, *Materials & Design*, **45**: 359-364 (2013).

[30] Morel J.C., Pkla A., Walker P., Compressive Strength Testing of Compressed Earth Blocks, *Construction and Building Materials*, **21(2)**: 303-309 (2007).

[31] Nagaraj H.B., Sravan M.V., Arun T.G., Jagadish K.S., Role of Lime with Cement in Long-Term Strength of Compressed Stabilized Earth Blocks, *International Journal of Sustainable Built Environment*, **3(1)**: 54-61 (2014).

[32] Reddy B.V., Gupta A., Influence of Sand Grading on the Characteristics of Mortars and Soil–Cement Block Masonry, *Construction and Building Materials*, **22(8)**: 1614-1623 (2008).

[33] Walker P., Stace T., Properties of Some Cement Stabilised Compressed Earth Blocks and Mortars, *Materials and Structures*, **30(9)**: 545-551 (1997).

[34] Acchar W., Marques S.K., Soil-Cement Bricks, in Ecological Soil-Cement Bricks from Waste Materials, *`Springer,* 5-13 (2016).

[35] Kalateh K., Ahmadi R., Amani V., (4, 4′-Dimethyl-2, 2′-bipyridine-κ2N, N′)(dimethyl sulfoxide-κO) diiodidocadmium (II), *Acta Crystallographica Section E: Structure Reports Online*, **66(5)**: 512-512 (2010).

[36] Ahmadi R., Amani V., Khavasi H.R., Dichlorido (4, 7-diphenyl-1, 10-phenanthroline-κ2N, N′) gold (III) tetrachloridoaurate (III), *Acta Crystallographica Section E: Structure Reports Online*, **64(9)**: 1156-1157 (2008).

[37] Amani V., Ahmadi R., Naseh M., Ebadi A., Synthesis, Spectroscopic Characterization, Crystal Structure and Thermal Analyses of Two Zinc (II) Complexes with Methanolysis of 2-Pyridinecarbonitrile as a Chelating Ligand, *Journal of the Iranian Chemical Society*, **14(3)**: 635-642 (2017).

[38] Bompa D., Elghazouli A., Compressive behaviour of Fired-Clay Brick and Lime Mortar Masonry Components in Dry and Wet Conditions, *Materials and Structures*, **53**: 1-21 (2020).