World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(Research Article)

Check for updates

Investigation on the use of natural soil stabilizers for compressed earth bricks

Junaid Asghar [1, *], Muhammad Yasir Sami [2], Riaz Ur Rahman [2] and Muhammad Umair [2]

[1] *Msc Student, Department of civil Engineering, UET Peshawar, Pakistan.*
[2] *BSc Student, Department of civil Engineering, UET Peshawar, Pakistan.*

World Journal of Advanced Engineering Technology and Sciences, 2024, 13(02), 435–439

Publication history: Received on 15 October 2024; revised on 30 November 2024; accepted on 02 December 2024

Article DOI: https://doi.org/10.30574/wjaets.2024.13.2.0586

Abstract

This study focuses on investigating the natural soil stablizers for Compressed Stabilized Earthen Bricks (CSEB) with cement, lime, and bentonite clay. The research aims to evaluate the impact of bentonite clay on the strength of CSEB and traditional clay bricks, analyze the effect of bentonite clay. The research methodology involves collecting soil samples and preparing them by mixing with bentonite clay in different proportions. The samples were then compacted using a specialized machine to create CSEB. The diagonal test results demonstrated that the CSEB exhibits good resistance to diagonal cracking. The results emphasize the suitability of CSEB for various construction applications, especially in regions prone to natural disasters and where traditional building materials are scarce or expensive.

Keywords: Compressed Stabilized Earthen Bricks (CSEB); Bentonite Clay; Clay Bricks; Flexural Strength; Compressive Strength

1. Introduction

Earth construction is most common and widespread all over the world, both in developed and under developing countries. Pakistan is a developing country with a 200 million population living in 23 million buildings till 2013, continuously increasing, and the existing building topology can be depicted in Figure 1.2 [1]. More than 62% of the built environment of Pakistan consists of brick masonry. It can be observed that the number of buildings has a direct relation with the locally available raw materials for masonry units. Soil is considered one of the most important and widely used material and can be evident from the history of civilization of human [2]. Moreover, according to literature more than half of the world population are living in earth structures own to their upsides [3]–[5]. The popularity of these structures are owing to the fact that their construction can be carried out economically using local available raw materials [6]. One promising form of earthen building material is Compressed Earthen Brick (CEB). When specific stabilizing agents, such as cement, lime, or jute, are incorporated in specific proportions during the formation of compressed earth bricks (CEB), the resulting product is referred to as Compressed Stabilized Earthen Brick (CSEB) [24], [25].

The production of traditional clay bricks involves the use of fertile soil, leading to large amounts of CO_2 emissions and greenhouse gases. Additionally, these bricks have weak compression strength and high-water absorption rates. To address the need for environmentally friendly, sustainable, and economical construction materials, new combinations of materials for brick production must be explored. Bentonite clay is a promising material due to its availability, affordability, and low labor intensity. While previous research has explored the use of cement and lime in Compressed Stabilized Earth Bricks (CSEB), there is a lack of literature on the combination of cement, lime, and bentonite clay. Therefore, it is necessary to investigate the mechanical and physical properties of CSEB using these materials. The objective of this study is to determine the optimal combination of bentonite clay, lime, and cement to enhance the strength and durability of compressed earth bricks. By identifying the most effective combination of these materials,

* Corresponding author: Junaid Asghar

the compressed earth bricks will be able to withstand harsh weather conditions and natural disasters such as heavy rainfall.

2. Methodology

The soil sample was placed in the casting yard of the Civil Engineering Department as part of the preparation process for CSEB. In order to create the CSEB mixture, the necessary amounts of bentonite clay, cement, lime, sand, and water were added to the ingredients. Initially, all the materials were mixed in their dry form. Following that, water was added to the mixture and the materials were thoroughly mixed in their wet condition. Once the wet materials were ready, they were placed into the mold of the compaction machine to create the CSEB (9” x 4.5” x 3”) in a similar manner. The table 1 representing the mix composition for preparation of CSEB is given below:

Table 1 Mixing Preparation for Preparation of CSEB

Mix Composition (percent by weight)							
Mix Designation	Clay	Sand	Bentonite clay	Cement	Lime	Water [Plastic Limit]	Water [OMC]
CSEB-0%	89	1	0	5	5	19.5	15
CSEB-5%	84	1	5	5	5	24	18
CSEB-10%	79	1	10	5	5	27	21
CSEB-15%	74	1	15	5	5	29	23
CSEB-20%	69	1	20	5	5	32	25

2.1. Diagonal Tensile Test of Masonry Wallets

The mechanical shear parameters, including indirect tensile strength, shear strength, shear strain, and modulus of rigidity, are determined through the diagonal compression test conducted on compressed earthen bricks. In this test, the walls are subjected to a constant and uniform compressive load, while cyclic diagonal loading is applied to evaluate the performance of the masonry. To confine the specimens diagonally, loading shoes are attached at each end (Figure 1).

Figure 1 Final Samples for Testing

3. Results and Discussion

The findings of the diagonal tests offer important insights into how compressed earth bricks (CEBs) respond to diagonal shear force.

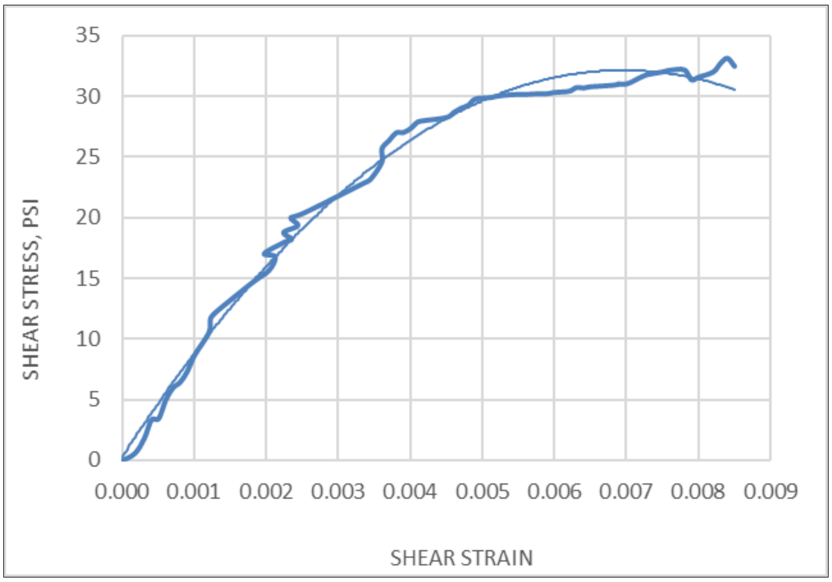

Figure 2 Diagonal test shear stress vs. shear strain curve

The diagonal shear strain obtained from the test reflects the CSEB ability to resist diagonal cracking. It can be seen from figure 2 that the strains are sufficiently close to the ultimate values. The highlighted red area under the curve represents the Young’s modulus of rigidity/resilience. The maximum shear strength 32.45 psi, indicating the material's resistance to shear deformation. A higher diagonal shear strain indicates greater deformation before failure, suggesting improved resistance to crack propagation along the diagonal planes of the brick.

Indirect Tensile (Shear) Stress Tn is 0.0833 Mpa. Indirect tensile strength is a measure of a material's resistance to fracture under tensile (pulling apart) forces. It's determined by applying a load (P) to a specimen and measuring the resulting tensile stress. The coefficient of friction (μ) is 0.3. It represents the slope of the line, and it characterizes the frictional behavior of the material. From the above data, the coefficient of friction (μ) can be computed by calculating the stress-strain graph's slope in the initial linear elastic area.

Cohesion (C) is taken as 0.0000 Mpa. The material's capacity to retain its structural integrity in the face of shear stress is shown by cohesiveness (C), which is the intercept of the stress-strain graph in the linear elastic region. When shear strain (shear strain) is zero, cohesion is determined as the stress (shear stress). Shear Modulus G is 66.01 MPa (9574 psi). G value indicates resistance to shear deformation.

Table 2 Comparison of diagonal test with previous studies

Diagonal Test	Current Research	Previous Research given range
Shear Strength	32.45 psi	4.35 – 43.5 psi (Brignola et al., 2008)
Indirect Tensile strength (Tn)	0.084 MPa	0.01-0.1 Mpa (Brignola et al., 2008)
Modulus of Rigidity (G)	66.01 MPa (9574 psi).	206 Mpa (9574 psi) (Gul et al., 2021)
Coefficient of friction (μ)	0.3	0.5 (Gul et al., 2021)
Cohesion (C)	0	Assumed 0 (Hafeez et al., 2018)

According to Brignola et al. [32], Corradi et al. [33], Ignatakis and Stylianides [34], shear strain ought to be more than 0.03-0.3 MPa for ancient masonry systems when fdt = 0.01-0.1 MPa. In simple terms, too high a value of q might lead to blocks breaking down (Yokel and Fattal, [35]). According to Calderini et al. [36], the value of edge load q should be between 0.15 and 0.20fm.

4. Conclusion

The following conclusions were drawn based on the research findings:

The inclusion of bentonite clay in the soil-clay mixture had a significant impact on the strength of CEBS compared to traditional clay bricks. The addition of bentonite clay resulted in improved compressive strength and flexural strength of the bricks.

The diagonal test results demonstrated that the CEB exhibits good resistance to diagonal cracking. The CEB's yield strength is measured at 11.68 psi, while fracture occurs at 32.45 psi. A higher diagonal shear strain indicates enhanced resistance to crack propagation, implying improved structural integrity. Therefore, the CESB can withstand applied loads without significant failure caused by diagonal cracking.

Future research could focus on further optimizing the proportions of the stabilizing materials and exploring additional properties and applications of CSEB in various construction scenarios. Further research is needed to optimize the proportions of stabilizing materials, conduct long-term durability assessments, evaluate the structural performance, perform life cycle assessments, and conduct cost-benefit analyses. Exploring additional applications of CSEB in different construction elements could further enhance its potential and promote its widespread adoption in sustainable construction practices.

Compliance with ethical standards

Disclosure of conflict of interest

I declare that there is no conflict of interest regarding the publication of this paper.

References

[1] M. Ahmed, S. H. Lodi, S. S. Ali, and N. Alam, “Seismic risk assessment of built environment in Pakistan,” presented at the Proceedings of the Second European Conference on Earthquake Engineering and Seismology, Istanbul, Turkey, 2014, pp. 25–29.

[2] M. Blondet and G. V. Garcia, “Earthquake resistant earthen buildings,” presented at the 13th World Conference on Earthquake Engineering, Paper, 2004.

[3] H. Morris, R. Walker, and T. Drupsteen, “Modern and historic earth buildings: observations of the 4th September 2010 Darfield earthquake,” presented at the Proceedings of the Ninth Pacific Conference on Earthquake Engineering Building an Earthquake-Resilient Society, 2011, pp. 14–16.

[4] H. Guillaud, “Characterization of earthen materials,” *Terra Lit. Rev.*, vol. 21, 2008.

[5] H. Houben and H. Guillaud, “Earth Construction: A Comprehensive Guide, Intermediate technology,” 1994.

[6] H. H. Korkmaz, S. Z. Korkmaz, and M. S. Donduren, “Earthquake hazard and damage on traditional rural structures in Turkey,” *Nat. Hazards Earth Syst. Sci.*, vol. 10, no. 3, pp. 605–622, 2010.

[7] R. Pampuch and R. Pampuch, “A Brief History of Ceramic Innovation,” *Introd. Ceram.*, pp. 1–17, 2014.

[8] U. Rajarathnam *et al.*, “Assessment of air pollutant emissions from brick kilns,” *Atmos. Environ.*, vol. 98, pp. 549–553, 2014.

[9] S. Maithel, “Evaluating energy conservation potential of brick production in India,” *SAARC Energy Cent. Islamabad Pak.*, 2013.

[10] S. M. Kazmi, S. Abbas, M. A. Saleem, M. J. Munir, and A. Khitab, “Manufacturing of sustainable clay bricks: Utilization of waste sugarcane bagasse and rice husk ashes,” *Constr. Build. Mater.*, vol. 120, pp. 29–41, 2016.

[11] E. L. Birch, “A Review of ‘Climate Change 2014: Impacts, Adaptation, and Vulnerability’ and ‘Climate Change 2014: Mitigation of Climate Change’ Intergovernmental Panel on Climate Change.

[12] H. Zhang *et al.*, “Air pollution and control action in Beijing,” *J. Clean. Prod.*, vol. 112, pp. 1519–1527, 2016.

[13] H. Fathy, *Architecture for the poor: an experiment in rural Egypt*. University of Chicago press, 2010.

[14] J. Norton, *Woodless Construction: Unstabilised earth brick vault and dome roofing without formwork*. Lund Centre for Habitat Studies, 1997.

[15] J. Kennedy, *Building Without Borders: sustainable construction for the global village*. New society publishers, 2009.

[16] E. Christoforou, A. Kylili, P. A. Fokaides, and I. Ioannou, “Cradle to site Life Cycle Assessment (LCA) of adobe bricks,” *J. Clean. Prod.*, vol. 112, pp. 443–452, 2016.

[17] “Earth construction: Lessons from the past for future eco-efficient construction,” *Constr. Build. Mater.*, vol. 29, pp. 512–519, Apr. 2012, doi: 10.1016/j.conbuildmat.2011.10.054.

[18] G. Minke, *Building with Earth: Design and Technology of a Sustainable Architecture Fourth and revised edition*. Birkhäuser, 2021.

[19] S. Pollock and P. Susan, *Ancient mesopotamia*, vol. 1. Cambridge University Press, 1999.

[20] B. Berge, *Ecology of building materials*. Routledge, 2007.

[21] L. Holliday, C. Ramseyer, M. Reyes, and D. Butko, “Building with Compressed Earth Block within the Building Code,” *J. Archit. Eng.*, vol. 22, no. 3, p. 04016007, Sep. 2016, doi: 10.1061/(ASCE)AE.1943-5568.0000198.

[22] M. Islam and N. Hoque, *Earthen housing for better adaptation to climate change in Bangladesh*. 2009.

[23] “Earthquake Resistance of Adobe Reinforced by Low Cost Traditional Materials.” https://www.jstage.jst.go.jp/article/jnds/32/1/32_1_1/_article/-char/ja/ (accessed Mar. 05, 2023).

[24] A. Mesbah, J. C. Morel, P. Walker, and K. Ghavami, “Development of a Direct Tensile Test for Compacted Earth Blocks Reinforced with Natural Fibers,” *J. Mater. Civ. Eng.*, vol. 16, no. 1, pp. 95–98, Feb. 2004, doi: 10.1061/(ASCE)0899-1561(2004)16:1(95).

[25] C. Galán-Marín, C. Rivera-Gómez, and J. Petric, “Clay-based composite stabilized with natural polymer and fibre,” *Constr. Build. Mater.*, vol. 24, no. 8, pp. 1462–1468, Aug. 2010, doi: 10.1016/j.conbuildmat.2010.01.008.

[26] C. L. Hwang and T. P. Huynh, "Investigation into the use of unground rice husk ash to produce eco-friendly construction bricks," Construction and Building Materials, vol. 93, pp. 335-341, Sep. 2015.

[27] P. Xu et al., "Microstructure and strength of alkali-activated bricks containing municipal solid waste incineration (MSWI) fly ash developed as construction materials," Sustainability, vol. 11, no. 5, p. 1283, Mar. 2019.

[28] U. Javed et al., "Sustainable incorporation of lime-bentonite clay composite for production of ecofriendly bricks," Journal of Cleaner Production, vol. 263, p. 121469, Aug. 2020.

[29] B. Alam et al., "Experimental assessment of diagonal shear parameters of dry stacked block masonry built with self-interlocking compressed earth blocks," Int. J. Magn. Reson. Imag., vol. 1, no. 1, 2022.

[30] J. M. Pérez and M. Romero, "Microstructure and technological properties of porcelain stoneware tiles moulded," undefined, 2014.

[31] A. Brignola et al., "Identification of shear parameters of masonry panels through the in-situ diagonal compression test," International Journal of Architectural Heritage, vol. 3, no. 1, pp. 52-73, 2008.

[32] M. Corradi et al., "Experimental study on the determination of strength of masonry walls," Construction and Building Materials, vol. 17, no. 5, pp. 325-337, 2003.

[33] C. Ignatakis and K. Stylianides, "MECHANICAL CHARACTERISTICS OF VIRGIN AND STRENGTHENED OLD BRICK MASONRY- EXPERIMENTAL RESEARCH," Masonry International, 2004.

[34] F. Y. Yokel and S. G. Fattal, "Failure hypothesis for masonry shear walls," Journal of the Structural Division, vol. 102, no. 3, pp. 515-532, 1976.

[35] C. Calderini et al., "The use of the diagonal compression test to identify the shear mechanical parameters of masonry," Construction and Building Materials, vol. 24, no. 5, pp. 677-685, 2010.