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The Impact of Mix Holdback Time on Wet Compressive Strength of Compressed Stabilized Earth Blocks

Adeola Ajayi[1], Jacob Oluwoye[2]
[1]Department of Architecture, University of Ibadan, Ibadan, Nigeria
[2]Alabama A & M University, Normal, Alabama, USA
*Corresponding Author: Adeola Ajayi. Email: ayangadeanthonia@gmail.com

Abstract— *Compressed stabilized earth blocks are gaining recognition as a sustainable alternative in the construction industry due to their reduced environmental impact and cost-effectiveness. The mix holdback time is a critical parameter that can significantly affect the final strength and quality of CSEBs. This paper investigates the influence of mix holdback time on the wet compressive strength of compressed stabilized earth blocks (CSEBs). In this study, a series of CSEB samples were prepared with varying holdback times (0 - 120 minutes) before compaction, and their wet compressive strengths were evaluated through wet compressive strength testing procedures. The results observed show a 61% reduction in strength after a two-hour delay which highlights the intricate relationship between mix holdback time and the resulting strength characteristics of CSEBs. This research contributes to an improved understanding of the factors influencing CSEB production and provides valuable insights for optimizing the block manufacturing process to enhance overall structural performance.*

Keywords— *Compressed stabilized earth blocks, wet compressive strength, mix holdback time, sustainable construction, earth-based materials.*

I. Introduction

The construction industry is currently facing unprecedented challenges in terms of environmental sustainability, resource availability, and cost-effectiveness [1]. In response to these challenges, alternative building materials and techniques are being explored to reduce the industry's ecological footprint while maintaining structural integrity. Compressed stabilized earth blocks (CSEBs) have emerged as a promising solution due to their utilization of locally available soil resources, minimal energy consumption, and reduced carbon emissions [2] compared to conventional fired bricks or concrete blocks.

The quality and performance of CSEBs are directly influenced by various production parameters, including soil composition, stabilizer type, compaction pressure, curing conditions, and mix holdback time. Mix holdback time, defined as the duration between the addition of stabilizers to the soil mix and the compression of the blocks, has been identified as a critical factor affecting the final characteristics of CSEBs. During this holdback period, the interaction between the stabilizer and soil particles evolves, leading to changes in the material's microstructure and mechanical properties.

Several studies [3] have investigated the effects of different production parameters on CSEB properties, such as compressive strength, durability, and thermal insulation. However, limited research has been conducted specifically to understand the impact of mix holdback time on the wet compressive strength of CSEBs. Wet compressive strength is a crucial mechanical property, as it determines the block's load-bearing capacity in damp or water-exposed environments.

This study aims to fill this research gap by systematically investigating the relationship between mix holdback time and the wet compressive strength of CSEBs. A comprehensive experimental program has been designed to prepare CSEB specimens with varying holdback times while keeping other production parameters constant. Subsequent wet compressive strength testing will provide insights into how different holdback times influence the material's strength development and potential long-term performance.

II. Materials and Methods

The soil utilized for this research was procured from the Department of Soil Science at Alabama A & M University, situated in Normal, Alabama. Regular construction-grade sand was acquired in a clean and untreated state, having had its clay components removed through washing. The composite soil blend encompassed a mixture of sand, gravel, clay, and silt. The constituents of the soil were composed of gravel (2%), sand (76%), silt (8%), and clay (14%). Once the soil was selected, it went through the drying, screening and sieving process to remove debris and large particles. Pulverization was also done to break lumps and homogenize the soil types to achieve a consistent mixture.

The stabilizer used in this study was Ordinary Portland Cement (OPC), specifically grade 42.5R. This type of OPC was procured from the Cement Laboratory within the Department of Civil Engineering at Alabama A&M University, located in Normal, Alabama, USA. The selected OPC adheres to standards [4]. Batching of the OPC was carried out within a controlled environment at room temperature, and the material was stored in a dry and cool space prior to initiating the block production process.

Clean water was sourced from the laboratory's tap and utilized to thoroughly mix the materials until a state of homogeneity was achieved. Additionally, the water temperature during the blending process was approximately 23°C. The primary objective of the mixing process revolved around ensuring the uniform dispersion of water and stabilizer

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throughout the mixture. Consistency played a pivotal role in achieving accurate sampling, which necessitated uniformity in proportioning, mixing, and wetting stages. Proportioning of soil and stabilizer followed a weight-based approach. For precision, a 20 kg capacity electronic scale, capable of accuracy up to approximately 0.05 grams, was employed for each measurement. A machine mixer was utilized to blend both the dry and wet components. Dry mixing persisted for approximately three to four minutes, succeeded by the gradual addition of consistent quantities of water (12% by weight) to the dry soil and stabilizer mixture.

After the wet mixing, the mixture was then withheld from compaction with different holdback time intervals of 5 minutes, 30 minutes, 60 minutes, 90 minutes and 120 minutes, to investigate the time-dependent effects on wet compressive strength. The control mix was compacted immediately after wet mixing.

Each mix batch were thereafter compacted at 6 MPa using Alabama Brick block making machine obtained from North Birmingham, AL. The stabilized soil mix was manually placed into the mold, and the compaction was carried out after varying holdback times. Specimens were then demolded carefully to prevent damage and were labeled according to their corresponding holdback time.

The blocks were then covered using some polythene sheets, with the primary curing periods ranging from seven to fourteen days, which was followed by a period of secondary curing which lasted 28 days.

This procedure was followed by wet compressive strength testing of the CSEB samples, determined using standard testing procedures. Specimens from each holdback time group were immersed in water for a specific duration to simulate damp conditions. After the immersion period, the specimens were tested in a universal testing machine and the maximum load at failure was recorded. This process was repeated for multiple samples from each holdback time group to ensure statistical validity.

III. RESULTS AND DISCUSSION

The results of the sieve analysis conducted on the samples utilized in this study are displayed in Figure 1. The AASHTO soil classification system [5] was employed to classify these samples. According to this classification system, each sample exhibited a passage of less than 35% through the 75 µm sieve, placing them within the category of granular materials. These findings are consistent with the 29.25% reported by [6].

Specific gravity, moisture content, liquid limit, plastic limit, and plasticity index were determined as 3.3, 17.7, 53.4, 59.5, and 6.1%, respectively. These values enabled the classification of the soil using the Atterberg Limits. The analysis revealed a substantial moisture content in the soil, along with elevated liquid and plastic limits. These characteristics indicate a high level of plasticity, suggesting that the soil possesses resistance against becoming brittle and disintegrating easily. This plasticity signifies its suitability for the production of compressed earth blocks.

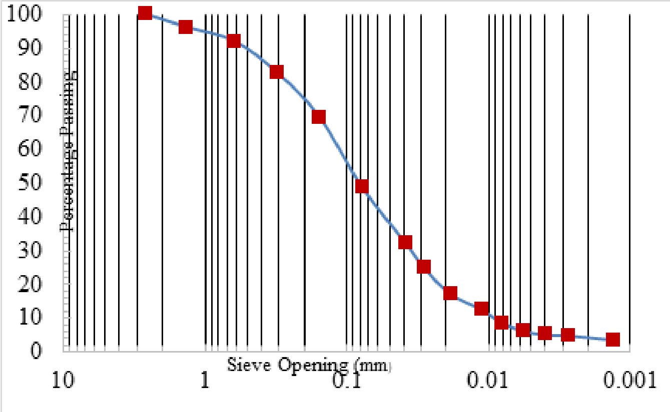

Fig. 1: Particle size distribution

The chemical properties obtained for PKSA and OPC used in this study are shown in Table 1. In comparison with ASTM standards [5], the properties of OPC was found to be higher than the minimum requirements.

TABLE 1: Chemical composition of OPC

Chemical Constituents	OPC (%)
SiO_2	19.21
Al_2O_3	3.57
Fe_2O_3	4.80
SO_3	1.96
MgO	1.71
K_2O	0.37
Na_2O	0.33
CaO	65.70
$SiO_2 + Al_2O_3 + Fe_2O_3$	27.58
LOI	1.25
Specific Gravity	3.12

Table 2 and Figure 2 show the mean values corresponding to the experimental results. Three block specimen samples are averaged for each point. As the holdback time increased from 5 to 120 minutes, at 28 days, WCS decreased at the range of 5.28 - 2.07 MPa (which is approximately a 61% loss).

TABLE 2: Wet compressive strength values (28-day) of CSEBs compacted at various holdback times

Time (mins)	WCS 28-day (MPa)
Control	9.84
5	5.28
30	5.13
60	4.41
90	2.59
120	2.07

The results indicate that the blocks that were compacted immediately after wet mixing exhibited 14% higher strength and resilience compared to the blocks that underwent a holdback period of 60 minutes before compaction. This observation is particularly evident when the wet mixing process was completed within 30 minutes. Other researchers have reported similar results. As an example, a researcher [7] found that strength diminished by 50% after two hours. Additionally, the samples that were compressed in 20 minutes of mixing with water showed a 30 to 40% increase in strength compared to the blocks compacted after about 45 minutes [8].

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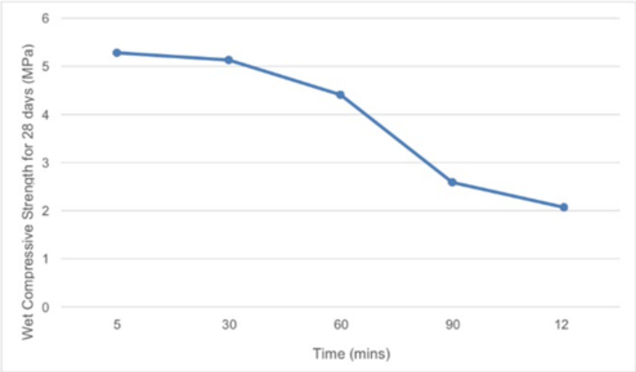

Fig. 2: Decline of WCS with Increase in Holdback Times of CPBs

A researcher [10] used 45 minutes as a yardstick to approximate the time when OPC is beginning to set. When OPC is used as a stabilizer, results show that a gradual reduction in strength should be expected. It is therefore recommended to compact OPC stabilised blocks between 20 to 45 minutes of mixing. Still, mixing batches for hourly production is a common field practice that ends up not being used up immediately. According to this discussion, production methods used during block production can significantly affect the final product's quality. Thus, all stages of CSEB production should be conducted with equal degree of supervision, competence, and skill.

IV. Conclusion

A gap in compaction times after mixing the soil and stabilizers with water could result in significant reductions in the strength of block. Consequently, the strength of CSEBs decreased by 61% after two hours of delay. A block compacted within 30 minutes of wet mixing, on the other hand, was 14% stronger than a block compacted after 60 minutes. Also, it is recommended to plan smaller groups or sets of wet mixes to be compacted in the space of 30 minutes rather than an hour. It is therefore not recommended to compact wet mixes for more than 60 minutes.

The findings of this research hold significance for the optimization of CSEB production processes. By understanding the intricate interplay between mix holdback time and wet compressive strength, designers, engineers, and manufacturers can make informed decisions to enhance the overall quality and durability of CSEB structures. Ultimately, this study contributes to advancing sustainable construction practices and promotes the adoption of earth-based materials in modern building systems.

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CRediT authorship contribution statement

****Oluwoye J.: Review and editing*

Conflicts of Interest

The authors declare that they have no conflicts of interest to report regarding the present study

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