Journal of Engineering and Applied Sciences
MEDWELL PUBLICATIONS SINCE 2000

Characteristic Properties of CEB Made of Gypsum Soil

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Key words: Low-cost construction, compressed earth blocks, gypsum soil, chemical stabilization, compressive strength

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Page No.: 3275-3280
Volume: 15, Issue 18, 2020
ISSN: 1816-949x
Journal of Engineering and Applied Sciences

Abstract: Compressed Earth Blocks (CEB) are produced utilizing stabilizing materials to obtain suitable endurance and strength to make proper construction material. Those blocks would be an excellent option for cities and rural areas where gypsum soil is available in abundance. This research paper includes an experimental investigation to find the ability to produce CEB from locally available gypsum soil by using chemical and physical. The effect of using cement as a chemical stabilizer at different cement to soil content with various water mixing content on CEB physical and mechanical properties including compressive strength, water absorption, dry shrinkage and elasticity was studied. The properties of the blocks were carefully examined. The study showed adding ordinary Portland cement to gypsum soil to produce CEB affected its properties by significant increasing. The compressive strength by 30.3% and reducing water absorption by 5.6. Moreover, the dry shrinkage of the blocks was decreased by 35% and the highest rate of shrinking was recorded in the first 3 days and stopped at 14 days. Finally, CEB showed a significant improvement in elasticity when increasing the cement content in the mix.

INTRODUCTION

Regarding the improvement of cities and rural areas in Iraq, that have been destroyed during the battles with ISIS, since, 2014, the urgent raise in the residential buildings interest needs massive quantity of construction materials to be used and prepared. Today, the main problems in most societies are how to reduce energy consumption and control pollution. Therefore, most of the available construction supplies which have massive emissions and energy costs, need to be restored by the environmental and sustainable construction materials that are inexpensive and abundant[1]. The most ancient and commonly used construction material I the old days is the earth construction. This material is well known as cold in summer and toasty in winter. Its contribution can reduce environmental problems and develop living comfort[2].

For economic purposes and when examined what has been done, researchers and craftsmen believe that it is very important to try to enhance the lifetime of the materials used in construction. The sturdiness of CEB is a questionable topic amongst builders. Therefore, to know the potentials and capacity of this type of construction materials designed for building and construction, it is planned to come up with solutions that could enhance the life cycle through knowing how it has been used and its mass treatment. In order to obtain a durable material, a physical and chemical treatment is needed. This treatment would make a great impact on the mechanical properties of it like compressive strength and sensitivity to water. Therefore, a precise research should be conducted to study those conditions considering different parameters including chemical stabilizer content and grading of the material used in it.

The past five decades, a rising interest has been found in using CEB for building construction. Using this type of blocks would maximize the need to use locally available raw materials. These materials usually require fewer efforts to gather and handle. Also, the final product which is CEB need very simple construction technics, meanwhile, offering effective sound and heat insulation characteristics. Besides all of that, a great environmental impact like using renewable resources and reduction in energy consumption could be achieved.

CEB at this time is not considering as a developing country stereotype but many of the western countries like France, Australia, Germany and New Zealand have been adopting CEB as a construction material in more than of 20% of the residential houses construction. It was also noticed that luxury homes have been built using CEB in the last few years. The plan of using this kind of blocks is cost reduction, energy conservation and waste reduction. Meanwhile, CEB also provide a suitable and healthy option as a replacement to traditional masonry blocks. Unfired soil blocks have been used as a conventional constructional material in rural areas because it could be used using local material and without damaging the environment through grinding, wetting ad returning to earth. However, the main issue of it is its vulnerability to water penetration. This issue could be overcome through stabilizing the soil used in CEB using cement materials, lime and fly ash to improve its physical performance[3].

Earth blocks can be considered as one of the earth construction methods that have been universally exploited around the world. There are many advantages of using earth blocks as a building material, one of these advantages is their ability to provide excellent sound proof and thermal isolation and their ability to regulate humidity inside the building[4]. Furthermore, due to the benefits of its abundant sources from the site to service to decrease the overall expenses due to acquiring, manufacturing and transportation.

Soil stabilization can be done by adding inactive materials to increase the friction or cohesion resistance, increasing the density of soil, increasing materials for chemical and physical changes of the soil, reducing the groundwater surface and replacing poor soil. Generally, soil stabilization can be carried out in two ways, namely mechanical and chemical stabilization[5]. Mechanical stabilization can be defined as a method of increasing the bearing capacity of soil by improving the structure and repairing the physical properties. Stabilization could be doe using various mechanical equipment such as rollers. Meanwhile, chemical stabilization is a method to increase the strength and bearing capacity of soil by reducing or eliminating the unfavorable physical properties of soil and mixing soil with chemicals[6]. In Iraq, the soil that has high gypsum content is placed in barren regions that extend over >30% of Iraq total area. The Chemical composition of the gypsum is ($CaSO_4.2H_2O$)[7]. There are two main categories of gypsum soil. The first category consists of ($CaSO_4.2H_2O$) as gypsum, ($CaSO_4$) as anhydrite and (light-colored, a fine-grained) as alabaster. The second category is formed by one or more of these points:

- Dissolution of primary rocks
- Evaporation of groundwater

For these reasons, gypsum soil cannot be directly used in construction works. Therefore, there are many methods used to enhance its mechanical, chemical properties. One of these methods is using the Portland cement and static compaction to stabilize the soil and obtain construction materials with good attributes[8].

MATERIALS AND METHODS

The main purpose of stabilizing CEB is to enhance its resistance to water absorption and improve its compressive strength. In this study, locally available raw materials have been used to produce stabilized CEB. The CEB were analyzed to examine its properties. The materials that have been used were gypsum soil and ordinary Portland cement. The physical and chemical properties of these materials were investigated to get to know its effect on the final product.

Soil: The gypsum soil that has been used in this research was obtained from Samarra city. The particle size distribution of it was computed as shown in Fig. 1 using

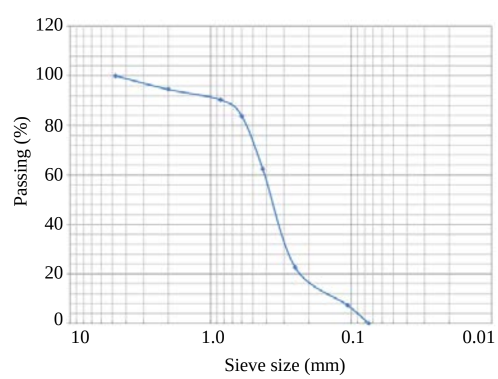

Fig. 1: Particle size distribution of the gypsum soil

Table 1: Physical and chemical characteristics of the soil

Characteristics	Results (%)
GS	2.61
LL	22.50
PI	4.80
Optimum moisture content	12.00
Al_2O_3	18.20
SiO_2	9.40
Fe_2O_3	3.40
CaO	65.45
MgO	2.30
Na_2O	0.32
SO_3	0.93
Pb	0.12
Cl^-	0.28
Zn	0.35
Organic content	5.50
pH-value	7.78

Table 2: Physical characteristics of the cement

Characteristics	Results
Specific surface area ($m^2\ kg^{-1}$)	263
Initial setting time (h: min)	1:10
Final setting time (h: min)	4:50
Compressive strength (MPa)	
3 day age	22.7
7 day age	28.9

Table 3: Chemical composition of the cement

Oxides composition	Content (%)
SiO_2	12.3
$Al2O_3$	5.1
SO_3	0.9
Loss on Ignition (L.O.I)	0.53
Insoluble material	1.01
Lim Saturation Factor (L.S.F)	0.5

analysis of grain size, as stated in GB/T 50123-1999[9]. Other tests were conducted to come to know the characteristics of the soil used in the research. These tests were Liquid Limit (LL = 22.5%), plasticity index (PI = 4.8%) and standard compaction test (BS: 1377-4, 1990) and Table 1 represents the optimum values. Chemical tests were also conducted to determine the mineral combination. The results display that the soil consists of calcite ($CaCO_3$), quartz (SiO_2) and albite ($NaAlSi_3O_8$) grains. Table 1 represents the soil chemical composition[3].

Cement: Ordinary Portland Cement (OPC) produced in Kurdistan-Iraq commonalty familiar as (Bazian) has been used in this research to prepare the CEB mixtures. The chemical and physical tests results are shown in Table 2 and 3, respectively. These tests of the cement were conducted following the IOS No. 5/1984[3].

A total of five groups of compressed earth block manufacturing with reference to cement size in the mix (i.e., 5, 10, 15, 20 and 25% cement to total weight of dry soil) were tested. The air-dried soil moisture content of was firstly detected to make sure how much of extra water is required for the manufacturing of CEB. Also, three different water content for each category was considered

Fig. 2: Samples preparation

(i.e., 9, 11 and 13% water by dry weight of soil). In total, 15 different batches were considered in this study with a total of 90 samples as six samples for each batch.

In this study, locally available gypsum soil and ordinary Portland cement were used for the preparation of CEB samples. In order to break the clods of the soil, the soil was firstly air-dried and sieved through sieve No. 4 and then characterized for its chemical composition, consistency limits and grading curve[10]. Ordinary Portland cement type 1 was used for the chemical stabilization. CEB production implementing the chemical stabilization of the soil by adding cement by weight of soil for different Water-Sad (W/S) mixing ratios and its effect on compressive, absorption, shrinkage and elasticity was examined.

The production of the specimens included gathering, mixing, laying admix, static compacting and extraction of the CEB. In details, the soil was air-dried then the required amount of cement to it was added and the mixt was blended until a homogeneous mixture was obtained. The next step was adding the required amount of water depending on the W/S ratio used and then further mixing is applied. The mixture was then put in the block mod which was then capped with a plastic foil and left for one day before de-molding. Then the blocks were left in the laboratory at room temperature as shown in Fig. 2 until the testing time. Static compaction was used in this study instead of vibration or dynamic compaction. The blocks were kept at a density of 2100 kg m^{-3}.

Tests were done according to the RILEM TC 153 recommendations[11]. Compressive strength was determined for the prepared samples at the age of 28 days. The modulus of elasticity represented by the initial tangent of the stress-strain diagram was obtained ad determined. The stabilization impact on water absorption and shrinkage was also researched. Dry shrinkage was computed on the specimens. The test procedure was letting the blocks dehydrate in the laboratory at 65% R.H and 25_C. Then, the shrinkage (difference in length) was gaged with a digital gauge (Fig. 3 and Table 4).

Fig. 3: Samples after compaction and ready for testing

Table 4: Sample numbering

Group No.	Cement/soil ratio (%)	Water/soil ratio (%)	No. of samples
1	5	9	6
		11	6
		13	6
2	10	9	6
		11	6
		13	6
3	15	9	6
		11	6
		13	6
4	20	9	6
		11	6
		13	6
5	25	9	6
		11	6
		13	6

RESULTS AND DISCUSSION

Compressive strength: Figure 4 presents the results of the compressive strength of CEB versus cement content for different water contents at the age of 28 days[12]. In general, the study showed a significant increase in blocks compressive strength when the cement content increases and for all water mixing content. Further, the highest increase in compressive strength took place at 25% of cement and 13% mixing water content of 30.3% increase.

This increase is due to the cement hydration outputs that close the gaps of the matrix and enhances the block structural rigidity by making a massive number of bonds connecting soil particles. Figure 5 indicates that the compressive strength increases when the water content increases. The increase in compressive is likely to be happening when blocks are molded on the wet margin than on the dry margin of the OPC of the soil which is

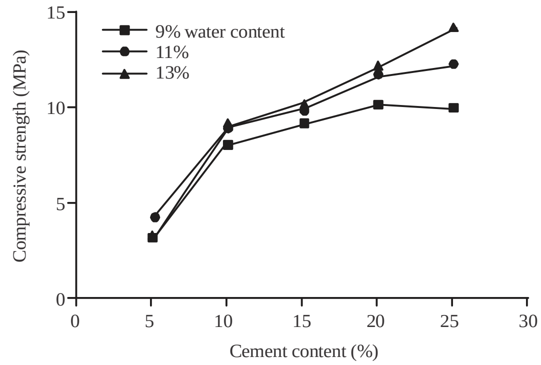

Fig. 4: The relationship the cement content and the compressive strength

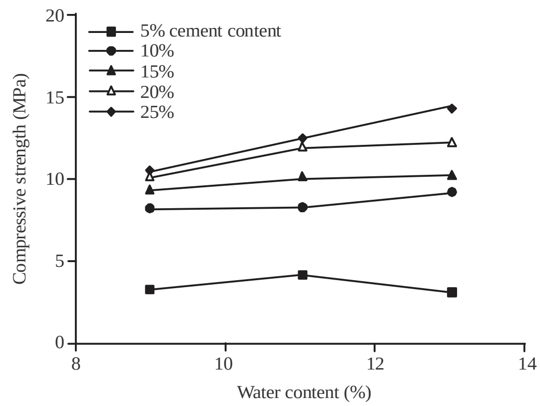

Fig. 5: The relationship between the water content and the compressive strength

Fig. 6: Samples testing

12%. This could be explained due to the extra amount of water required for the hydration of the cement[13] (Fig. 6).

Water absorption: Figure 7 presents the water absorption of the CEB versus cement content. It can be

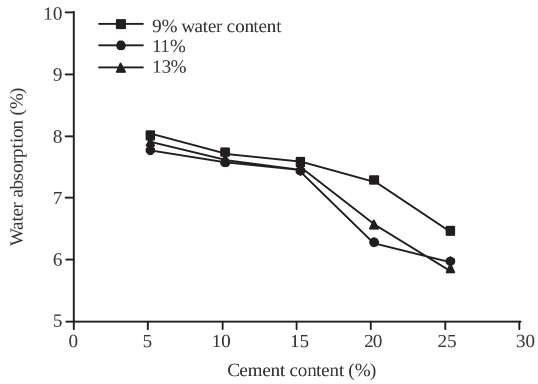

Fig. 7: The effect of cement content on the water absorption

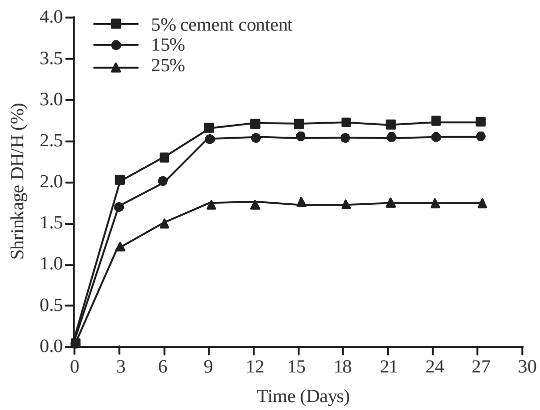

Fig. 8: The effect of cement content on the development of dry shrinkage

noticed that water absorption stayed at 8% when using only 5% of cement content. This value according to (IS: 1725, 1982)[14] which a value of 15% for water absorption to describe a suitable quality of blocks. Then when the cement content was increased, CEB had presented a steady decrease in the water absorption. The value of water absorption has reached less than 6%. This reduction could be due to the micro-level changes happening in the blocks structure. When cement interact with water, side products would form. These products will filling the voids and block the continuing channels in the structure of the blocks causing a reduction in water absorption.

Shrinkage: Figure 8 shows a normal variation of dry shrinkage happening through a period of time for CEB with only 5, 15 and 25% of cement content. It can be seen that shrinkage raise significantly and quickly in the first 3 days for specimens and then almost stop after 13 days[15]. Therefore, compressed earth block curing is very crucial at the begging and important to decrease dry shrinkage. Further, when comparing the shrinkage of CEB

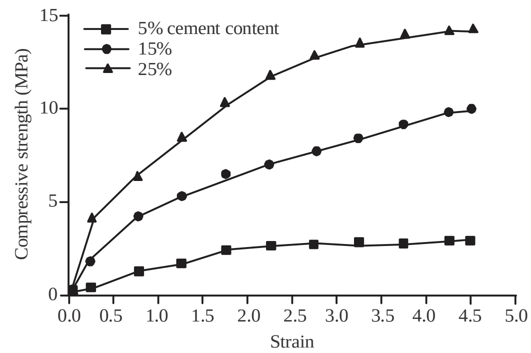

Fig. 9: Stress-stain diagram for the CEB samples under compressive forces

at the age of 27 days for 25 and 15% with the 5% of cement content, the shrinkage was decreased by 35 and 7% for cement content of 25 and 15%, respectively. As expected, the higher the cement content, the smaller the shrinkage[16].

Elasticity: The modulus of elasticity was calculated for CEB with only 5, 15 and 25% of cement content as shown in Fig. 9 using the stress-strain diagrams. It could be seen that increasing the cement content in the mix increases the slope of the curve and hence the elastic modulus of the material increases from 1.8 GPa for 5% to 5.75 GPa for 25% cement content[17].

CONCLUSION

This experimental study on CEB produced using locally available gypsum soil and ordinary Portland cement in different percentages has shown the great characteristics of it. The study shows a significant improving in the compressive strength. Herein, it is found that cement is greatly valuable in developing the strength of the CEB due to stabilizing the gypsum soil. This increase in strength would be a good indicator of building construction material with high performance and durability[18]. Further, Optimum moisture content should always be determined to obtain higher strength and durability by using water mixing content slightly higher than the optimum moister content of the soil. Also, the low water absorption of the blocks indicates that this type of blocks is appropriate for building design at direct contact with water such as rainwater in humid regions. The study results also show a need to work at the percentage of CEB raw materials and their quantities to achieve a building blocks with great attributes. The use of cement would allow the use of soil with high gypsum content than normally being.

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