Mansoura University
Faculty of Engineering
Mansoura Engineering Journal

Compressive Strength and Water Absorption of CSEB Mixtures

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KEYWORDS:
Compressed soil blocks, CSEB, building units, water absorption.

***Abstract*— Currently, there is a crucial demand to construct affordable housing which can be achieved by producing building materials that are characterized as low cost and environmentally friendly sustainable materials. Many researches have been carried out to develop such materials. One of the most common trends in this regard is using stabilized soil that can be compressed in steel moulds to produce masonry units. The produced units are therefore named "Compressed Stabilized Earth Blocks; CSEB". However, there is still necessity to better understand their physical and mechanical properties under different service conditions in order to evaluate the viability of such masonry units. The experimental program designed for this study included casting 96 50mm cubes. Specimens were categorized according to different proportions of silt, sand and stabilizing materials. The stabilizing materials used were cement, bitumen, and white gluten. Specimens were tested in compression to determine their compressive strength at 7 and 28-day. Specimens were also tested to determine the water absorption of each mixture. Results show that cement is the best stabilizing material among the examined materials. There is a specific percentage of stabilizing material that gives the maximum compressive strength, after which adding more stabilizing material reduces the compressive strength**

I. INTRODUCTION

EARTH as a construction material has been used for thousands of years by civilizations all over the world. Different techniques have been developed, where the methods used vary according to the local climate and available raw materials as well as local traditions and customs. Methods derived from the traditional techniques are being developed to improve the quality of earth construction and broaden the potential for its application.

Over the past fifty years Compressed Stabilized Earth Blocks (CSEB) have developed and has been increasingly used, especially in developing countries. CSEB are units made of a clayey soil with variable quantity and quality of clay depending on the construction site. This makes it a big challenge because the strength of the produced units depends on the specifications of the available soil at the construction site. The used clay fraction is generally less than that in earth used for adobe blocks. Considerable variations in the composition of earth makes the measurement of compressive strength, and other physical characteristics of compressed earth blocks an important quality control measure for manufacturers and builders. Compaction of moist soil, often combined with 4–10% cement stabilization, significantly improves compressive strength and water resistance in comparison with traditional adobe blocks, fired clay and concrete block units [1-5]. The cost of earth block wall system was found to be much cheaper than conventional systems [6-8]. The blocks being made and cured on site saves the

Received: (19 September, 2020) - Revised: (18 December, 2020) - Accepted: (20 December, 2020)
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transportation costs and fuel used in the production process.

The production of good quality blocks requires a good quality control for the mix proportions and the production process. CSEB usually contains clay (non-expansive), silt powder, sand, water and a binding (stabilizing) material. The use of cement as a stabilizing material is common and in some cases lime can be used by itself [9, 10] or can be used in combination with cement [10-12],. Any small variation in one or more of the ingredients of the mixture can significantly affect the properties of the produced units [4, 5, and 13]. Adding pozzolans or fibers to the mix with small quantities can significantly affect the properties of the CSEB [7, 8, and 14].

II. EXPERIMENTAL PROGRAM

In order to study the properties of the CSEB and the factors affecting its compressive strength, a comprehensive series of compression tests were carried out at the laboratories of the Egyptian Russian University. The experimental program included studying different variables namely; the mix proportions, the type of stabilizing material and the effect of grinding the silt.

The experimental program designed for this research included casting of 96 50mm cubes. Specimens were categorized according to different proportions of silt, sand and stabilizing materials. The main purpose is to identify the optimum mix proportion and stabilizer type that achieves maximum compressive strength and minimum water absorption with the least possible cost.

Specimens were tested in compression to determine its compressive strength at 7 and 28-day age. Specimens were also tested to determine water absorption of each mixture. The results were then analyzed to obtain the optimum mixing proportions and stabilizer type that gives appropriate compressive strength and water absorption with reasonable cost. Fig. 1. shows a flow chart of the experimental program.

III. MATERIALS USED

Different materials were used in manufacturing the compressed soil earth blocks used in the experimental program namely; Silt, sand, cement, gluten and bitumen.

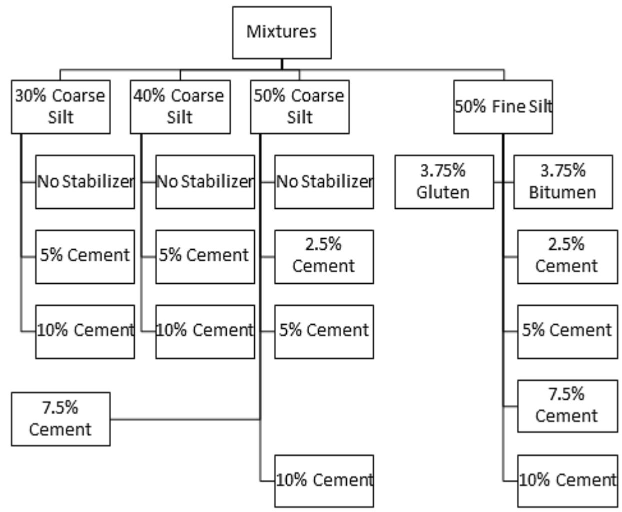
Two samples were taken from two different locations of the Egyptian Russian University's fields. The samples of soil were first taken and the laboratory tests were carried out to ensure the adequacy of the available samples. Atterberg limits were obtained for the samples using Casagrande apparatus and the liquid limit was calculated to be 29.3 on average.

. The soil was then classified according to AASHTO M 145 procedures and both soils were classified as A-1-B. Table (I) shows the sieve analysis results used for the classification of the two different samples of soil.

Medium clean sand was used in the manufacturing of the building units; the sand use had a nominal maximum size of 2.36 mm and specific gravity of 2.56. The percentage of fine materials was measured in the sand sample and was found to be less than 2 % by weight of the sand sample.

The cement used in the experimental work was ordinary Portland cement CEMI 42.5N from Suez Company and the production date was less than one month old.

Regular tape water was used in all the stages of the experimental program.



IV. MIX PROPORTIONS

Based on the data obtained from literature [3-5,7,8] the range of silt used for manufacturing the CSEB units were found to vary from 25%-40% by weight of the total weight of units. Accordingly, preliminary samples were cast to identify the best mixing proportions which leads to the highest compressive strength of the samples.

TABLE I.
SIEVE ANALYSIS OF SOIL.

Sieve #	Weight passing (gms)	
	Soil 1*	Soil 2**
10	4968	185
40	465	152
200	35	262

*Total weight of sample is 6064 gms
**Total weight of sample is 4002 gms

Specimens having 20%, 30%, 40% and 50% coarse silt ratios were chosen for the experimental program. The samples with 20% silt were excluded because all the three samples did not show any cohesion and failed after de-molding.

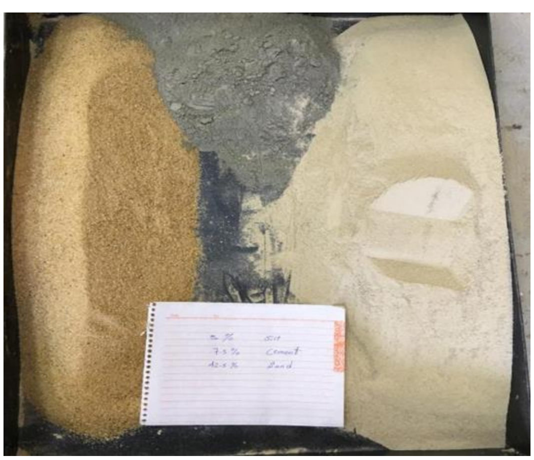
The cement content in building units has a vital role in both the compressive strength of the units, its durability and its overall cost. Consequently, this factor was considered in the study, where, the experimental program included a sample with no cement and four different cement ratios namely; 2.5%, 5%, 7.5% and 10% by weight. Fig. 2. shows a sample's mixing ingredients.

The form of silt affects the compressive strength of the produced units. Therefore two different forms of silt were used in the experimental program namely coarse and fine silt, Fig. 3. shows the two different forms of used silt.

Fig. 2. Sample of CSEB mix ingredients.

For the coarse silt, the silt was brought as hard bulky pieces from the site and then was submerged in water for 24 hours to soften it and make it more workable and can be easily crumbed by hand. While for the fine silt, the hard bulky pieces was mechanically grinded at the lab to produce fine silt.

A. Coarse silt



B. Fine silt (grinded)

Fig. 3. Different forms of silt.

The mixes which were made without any stabilizing materials experienced severe disintegration after exposure to water. As a result, stabilizing materials were proposed to be used to overcome this problem. Cement was the first choice as stabilizing material as it represents the most common and available stabilizing material in the market. Also, bitumen and gluten were used as a stabilizing material in some specimens to compare its effect on the compressive strength when compared with the cement.

Tests were carried out to identify the optimum amount of silt that can be used in the specimens. Three different coarse silt contents were examined; namely 30%, 40% and 50% by weight. These mixes were used with different cement ratios as well. Three different stabilizing materials were used; namely Cement Bitumen and Gluten. Cement was used with four different percentages (0, 2.5, 5, 7.5 & 10 by weight) whereas the bitumen and gluten were used with only one percentage. For the bitumen and gluten, the materials were diluted by the ratio 1:2 (1 stabilizing material: 2 water).

V. Results and Analysis

A. Compression Test

All the specimens were tested under compression using universal testing machine. The tests were carried out according to ASTM C109. Specimens were tested either at 7-days age or at 28-days age. Table II shows the compressive strength of the tested specimens where a coding system was used in order to have a short identification for the specimens. The adopted coding system is as follows:

1. First figure (number) expresses the percentage of silt in the specimens.
2. Second figure (letter) identifies the type of stabilizer (C= cement, B = Bitumen, G= Gluten).
3. Third figure (number) expresses the percentage of stabilizer in the specimen.
4. Fourth figure (letter) identifies the state of soil (F = fine, C =coarse)
5. Fifth figure (number) shows the number of specimen within this batch.

For the specimens with gluten or bitumen as binding materials, the specimens were tested at 7-days age only as there was no need to test specimens at 28-days as these materials do not need time to gain strength as in case of cement. For the specimens with cement as a binding material, samples with different mix ratios were first cast as preliminary stage, and based upon the results obtained from 7-days age testing of the specimens the optimum mix proportions (with the highest results) were cast again to test them after 28-days age. For these two reasons, there are many empty spaces in the previous table at 28-days age compressive strength.

Fig. 4. shows the effect of varying the percentage of silt on the specimen compressive strength at no cement. The results of the 7-day compression tests showed that the mix containing 50% ground silt, 7.5% cement and 42.5% sand had the maximum compressive strength among all the specimens.

TABLE II.
COMPRESSIVE STRENGTH OF SPECIMENS

Coding	Average Compressive Strength (7- day) MPa ± STDV	Average Compressive Strength (28- day) MPa ± STDV
50-C-10-C	7.0±0.2	10.8±0.7
50-C-7.5-C	5.7±0.3	10.3±0.2
50-C-5-C	5.2±0.4	8.2±0.2
50-C-2.5-C-	4.8±0.1	6.0±0.3
50-C-0-C	6.7±0.1	-
40-C-10-C	6.9±0.4	-
40-C-5-C	5.7±0.2	-
40-C-0-C	6.4±0.2	-
30-C-10-C	6.4±0.4	-
30-C-5-C	4.8±0.2	-
30-C-0-C	6.0±0.2	- -
50-C-10-F	-	9±2.12
50-C-7.5-F	7.6±0.2	12.7±.3
50-C-5-F	4.7±0.1	10.0±0.2
50-C-2.5-F-1	5.2±0.2	6.8±0.6
50-B-3.75-F	4.0±.6	-
50-G-3.75-F	7.8±0.3	-

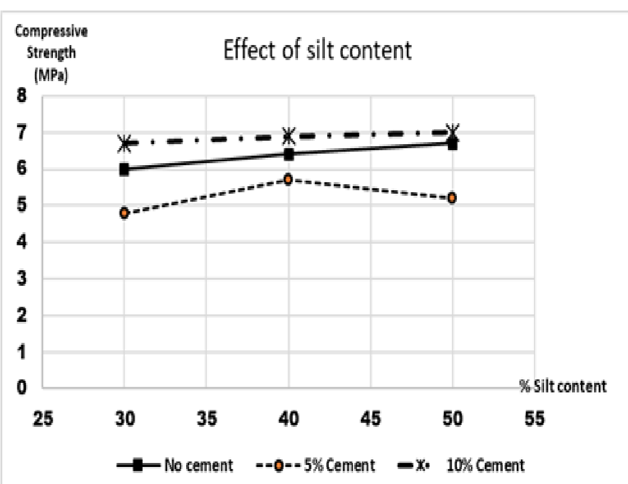


Fig. 4. Effect of silt content on compressive strength with different cement ratios.

The results of the 28 days compression tests showed that the mix containing 50% grinded silt, 7.5% cement and 42.5% sand had the maximum compressive strength among all the specimens with other different mixing ratios as can be seen in Fig. 5 which confirms the results obtained from the 7-day tests.

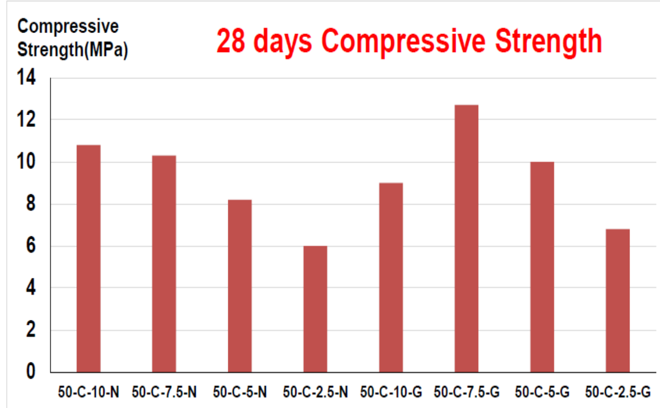


Figure 5 compressive strength at 28-day age.

B. The Effect of Stabilizing Material

Since the cement is the only stabilizing material (used in this project) that requires time to be completely hydrated so it is possible to compare the compressive strength of the 7-day specimens of the bitumen and gluten to that of 28-day of cement specimens as shown in Fig. 6., while Fig. 7. shows the effect of cement content on the compressive strength of units in both cases; using fine silt and coarse silt.

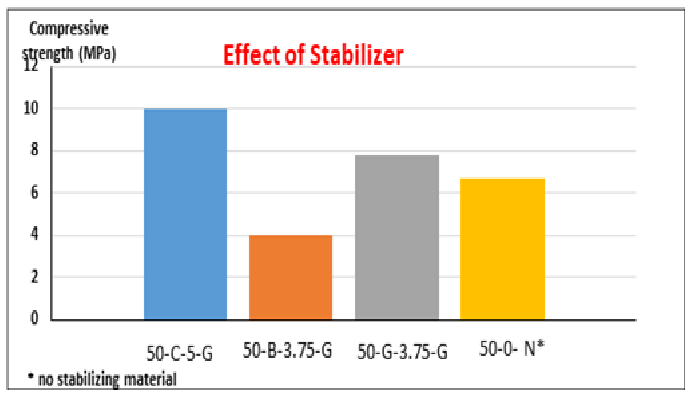


Fig. 6. Effect of stabilizer on compressive strength at 28-day age.

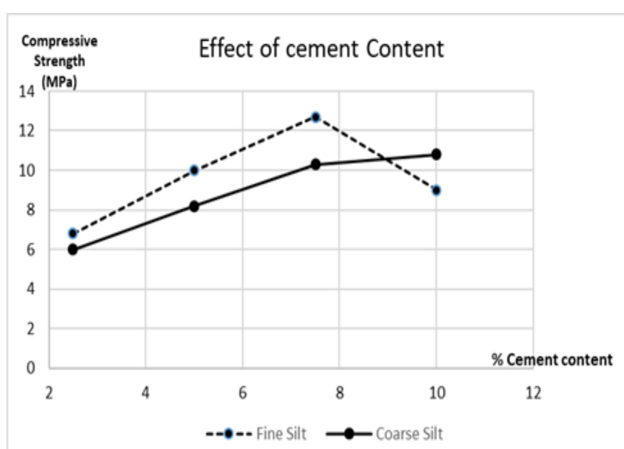


Fig. 7. The effect of cement content on the compressive strength of units at (7-day) age.

When comparing the results of 7-day to that of 28-day, at the beginning the gluten specimens showed superior results but at 28-day the cement specimens showed the superior results because at early age the cement was not totally hydrated but after almost complete hydration the specimens gained the full strength and passed that of the gluten specimen which had constant strength gained at earlier stages without increasing later. It should be noticed here that the compressive strength of CSEB composed of 50% grinded silt ,7.5% cement exceeded the limits stated by Egyptian standard specs ES:1292- 1/2015 for load bearing concrete masonry units [16] as well as ES4763/2006 for building bricks masonry units made from clay [17].

C. Absorption

The absorption of the specimens was measured with two different techniques; the first one was the standard absorption test according to ASTM C1585. Table III shows the results of absorption test

For the specimens with cement as a stabilizing material, although there is a difference in water content ratios (from13% to 16.8%) but it was noticed that the specimen with higher water contents had lighter weights than the ones with lower water content. This can be explained as those ones have more voids (specimens had same volumes and different weight) which were filled with water leading to the high absorption of the specimens. This difference in weights can be attributed to the compaction which can be different from one specimen to another. For the specimens where bitumen or gluten was used as a stabilizing material, the specimens were totally failed as can be seen in Fig. 8.

Fig. 8. Failure of Bitumen and Gluten Specimens due to water absorption.

This failure can be explained that the properties of both substances had been negatively influenced by the rise in temperature (when dried in the oven). The increase in temperature reduced the cohesion property of the substances.

TABLEIII
WATER ABSORPTION

Coding of Sample	Average Water Content %± STDV
50-C-7.5-N	14.8 ± 0.15
50-C-10-G	16.8 ± 0.57
50-C-2.5-N	13 ± 0.30
50-C-5-G	14.3 ± 0.38
50-C-2.5-G	16.7 ± 3.1 *
50-C-5-N	15.3 ± 0.58
50-G-3.75-G	F**
50-B-3.75-G	F

*only two specimens
** failed in the absorption test

The capillary absorption test is thought to be more realistic to evaluate the influence of rain and storms on the CSEB units, and was adopted by several researchers [12,20], consequently this test was used as the second technique to measure the absorption of the specimens. The test was conducted according to African Regional Standards for Compressed Earth Blocks ARS 674:1996 [19]. Table IV shows the capillary absorption test results.

This test compares the absorption of the specimens by calculating absorption coefficient, which corresponds to the speed of absorption. This coefficient is more representative of the behavior of masonry subjected to a violent storm than its absorption capacity measured at saturation.

TABLE IV.
CAPILLARY ABSORPTION TEST RESULTS

#	Coding	Absorption coefficient (gm/cm^2/min)
1	50-C-7.5-N	7.6
2	50-C-10-G	12.7
3	50-C-2.5-N	6.3
4	50-C-5-G	15.2
5	50-C-2.5-G	10.1
6	50-C-5-N	10.1
7	50-G-3.75-G	2.5
8	50-B-3.75-G	10.1

D. Effect of fine silt

For the 7-day compressive strength, the specimens with 7.5% cement showed a significant increase in compressive strength (33%) when the silt was grinded, for the specimens with 2.5% cement the increase in compressive strength was only 8% which can be considered insignificant, While for the specimens with 5% cement there was a significant reduction in compressive strength (20%) when grinded silt was used.

On the other hand, all the 28-day specimens showed an increase in the compressive strength when the grinded silt was used except the specimens with cement content of 10%. The increase in compressive strength was 13%, 21% and 23% for specimens with cement content of 2.5%, 5% and 7.5% respectively. While the reduction of compressive strength for the specimens with 10% cements content was 5% which can be considered insignificant. Fig.9-12. shows the effect of grinding silt in samples with different cement content as both 7-day and 28-day ages.

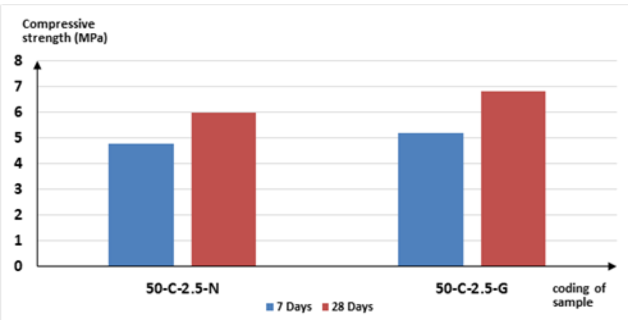


Fig. 9. Effect of grinding silt (2.5% cement)

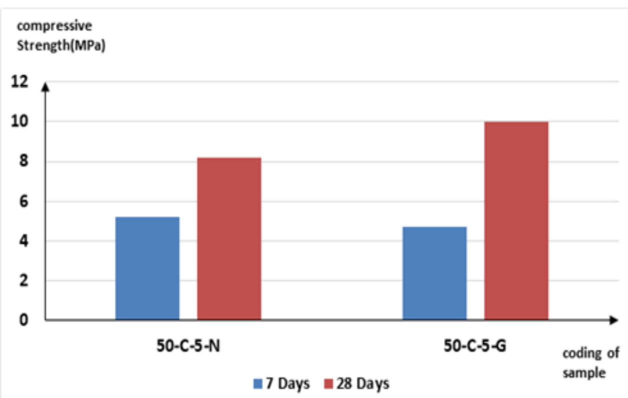


Fig.10. Effect of grinding silt (5% cement)

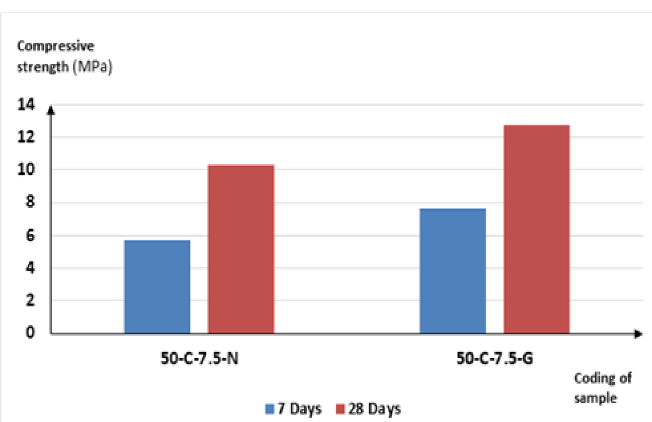


Fig. 11. Effect of grinding silt (7.5% cement)

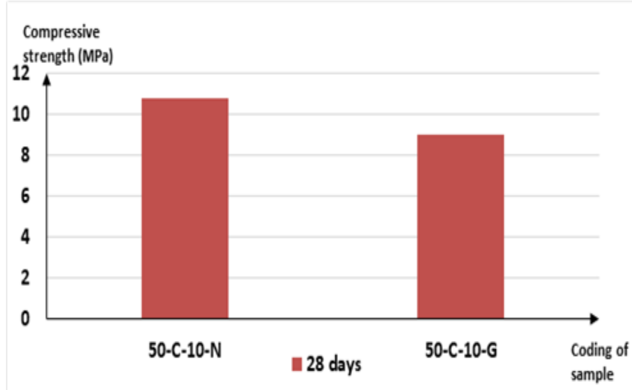


Fig. 12. Effect of grinding silt (10% cement)

The experimental results shows that there is a certain ratio of cement which gives the highest compressive strength after which adding more cement to the mix leads to reducing the compressive strength (inflection point) as obtained from the specimens with grinded silt.

Fig. 13. shows a relation between the cement content and the compressive strength of the specimens, the curve gives an approximate value for the optimum cement ratio of 7.5%. Although, at this ratio of cement (7.5%) the non-grinded silt did not drop but the rate of gaining strength decreased. in other words, the slope of the curve decrease which means that the addition of extra cement contents might not be worth the expected increase in compressive strength.

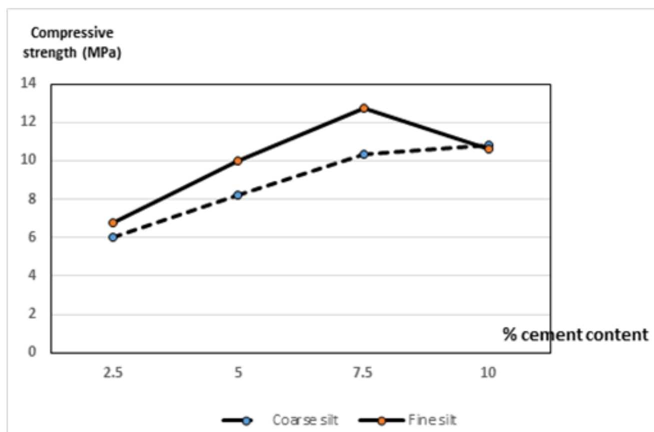


Fig. 13. Relation between Cement content and compressive strength at 28-days age.

VI. CONCLUSIONS

- The use of Compressed Soil Earth Blocks is an economical alternative for conventional building units that can be used efficiently in construction. It can be easily produced in the construction sites.
- For the stabilizing material in CSEB, there is an optimum percentage to be added to the mix that produces units with highest compressive strength and beyond this ratio the specimens will experience strength degradation; this ratio for cement was found to be 7.5% by weight in this study.
- The optimum percentage of fine silt is 50% by weight.
- Grinded silt gives 23% higher compressive strength than coarse silt.

- Cement is considered the most cost- effective stabilizing material when compared with the other used stabilizing materials in this study.

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Title Arabic:

مقاومة الضغط و امتصاص المياه لخلطات بلوكات التربة المضغوطه

Arabic Abstract:

يوجد حاليا طلب أساسي لبناء مباني منخفضة التكاليف و يمكن تحقيق ذلك عن طريق إنتاج مواد بناء تتميز بكونها منخفضة التكلفة و صديقة للبيئة و مستدامة. تم إجراء العديد من الأبحاث لتطوير مثل هذه المواد. من أكثر الاتجاهات شيوعًا في هذا الصدد استخدام التربة المضغوطة التي يمكن ضغطها في قوالب معدنية لإنتاج وحدات البناء. وبالتالي فإن الوحدات المنتجة تسمى "قوالب التربة المضغوطة؛ CSEB". ومع ذلك ، لا تزال هناك ضرورة لفهم خواصها الفيزيائية والميكانيكية بشكل أفضل في ظل ظروف التشغيل المختلفة من أجل تقييم جدوى وحدات البناء هذه. تضمن البرنامج التجريبي المصمم لهذه الدراسة صب 96 مكعب بمقاس 50 مم. تم تصنيف العينات وفقًا لنسب مختلفة من الطمي والرمل ومواد التثبيت. وكانت مواد التثبيت المستخدمة هي الأسمنت والقار والغلوتين الأبيض. تم اختبار العينات في الضغط لتحديد قوة الانضغاط عند عمر 7 و 28 يومًا. كما تم اختبار العينات لتحديد امتصاص الماء لكل خليط. أظهرت النتائج أن الأسمنت هو أفضل مادة مثبتة بين المواد التي تم فحصها. كما أثبتت التجارب أن هناك نسبة مئوية محددة من مادة التثبيت التي تعطي أقصى مقاومة للضغط ، وبعد ذلك يؤدي إضافة المزيد من مواد التثبيت إلى تقليل مقاومة الضغط