CEMENT STABILIZATION OF THE CENTRAL RIFT VALLEY SOILS IN ETHIOPIA

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ABSTRACT

The design criteria of a soil-cement mixture requires attainment of a minimum unconfined compressive strength value of 1.4 MPa. In this study a silty soil of known physical properties is mixed with different percentages of portland cement and the engineering properties of the mixture are closely investigated in the laboratory. Block specimens are prepared, cured for various days and tested to failure to determine the unconfined compressive strength, split tensile strength, water absorption capacity. A few block specimens were also subjected to a repeated cycles of wetting and drying in order to simulate the seasonal variation of moisture and temperature in the field. With the increase in cement content, the compressive and split tensile strengths are observed to increase. Finally, the economically feasible optimum cement content for use in soil-cement block is recommended in accordance with the design criteria stated above.

INTRODUCTION

Over 85% of the Ethiopian population live in rural areas. The universal housing in rural Ethiopia are tukuls. Usually, these tukuls are round and their construction appears simple when executed by local skilled craftsmen. The walls of these tukuls are built of logs or tree branches, fixed into the ground and with a face work of twigs as a cover. The walls can either be left in this condition or they may have a coating of one or more layer of earth called "chicka". The roof is made of limited kinds of straws. At present, one of the major problems in the rural areas is the continuous cutting of trees and burning of bushes and thick grass areas. There is a great fear that there will be scarcity of such building materials in the future.

Although available in limited areas, these materials have to be transported over a long distance incurring heavy costs. In these cases, one will be compelled to look for other substitutes at lower cost.

A more realistic look at the situation in the light of the statements above would indicate that soil stablized with cement and lime deserve much attention than they so far have had. Soil is the most widely used building material in Ethiopia, yet it is almost invariably ignored. The use of cement and lime to stablize soil, the use of improved but simple machines for compacting soil blocks have become common elsewhere. Attention may be drawn to these stablizers and others, small quantities of which provide suitable stability against the penetration of water. The use of these could also be encouraged not only for stabilizing soil but also for protecting wood and grasses from destruction.

Stabilization of soils is defined as a hardened material formed by curing a mechanically compacted intimate mixture of pulverized soil, portland cement and water.

TEST PROGRAMME

The experimental procedures adopted in this study is divided into two, namely;

(a) tests for suitability of soils: — i.e., determination of physical properties of the natural soil, and

(b) investigation of the soil-cement mixture.

All the tests were made at the Soil Mechanics Laboratory of the Faculty of Technology, Addis Ababa University.

The natural soils are obtained in the vicinity of Lake Zeway area. These soils were dried in the sun and pulverized manually and sieved through sieve No. 10. The stabilizer used as binding agent was portland cement manufactured by the Ethiopian Cement Corporation.

TESTS FOR SUITABILITY OF SOILS

Determination of Physical Properties of Soil

In the first stage of the study, physical properties of the natural soil were determined. Pertainent characteristics of this soil are summarized in Table 1.

Table 1: Characteristics of the Soil

Physical Properties of the Soil	Result
Atterbeg limits and indices:	
Liquid limit	32%
Plastic limit	29%
Shrinkage limit	49%
Plasticity index	3%
Grain size distribution:	
Sand particles	52%
Silt particles	44%
Clay Particles	4%
Group classification for the soil:	
Unified soil classification	ML
Moisture-Density relationship:	
Optimum moisture content	30.5%
Maximum dry density	1.25 kg/cm^3
Specific gravity	2.59

Preparation and Testing of Stabilized Soil-Cement Blocks

The next stage of the investigation is concerned with the stabilizing effect of the soil with the addition of cement.

The study was made with the addition of 2.5%, 7.5%, 10% and 12.5% of cement by dry weight of soil. For the unconfined compressive and durability tests, three specimens for each percentage of cement content were made for curing at, 28 and 60 days.

Mixing and Molding

In this test programme 18 kg of the screened dry soil was taken for different percentages of cement content. The required quantity of cement was then mixed with the dry soil for about ten minutes. After thorough dry mixing of the dry soil and the cement, optimum percentage of water by dry weight of the mixture was added. The optimum amount of water is determined from the water content versus density relationship curve. Both the dry and wet mixing were carried out manually.

After mixing with water, test specimens were prepared by the use of the molding apparatus called Ellson-Block Master Machine, immediately after each batch of the material was mixed.

CURING AND TESTING OF BLOCKS SPECIMENS

Proper curing is an essential step in obtaining hardened effects of the blocks. The specimens were left at room temperatures for air drying for 24 hours, but covered with grass. The blocks were then cured by sprinkling daily for 7, 28 and 60 days in order to simulate the field condition.

After each curing period, specimens were unwraped and immersed in water for 24 hours. Then they were tested for unconfined compressive strength at the loading rate of 2.5mm per minute. The test results are given in Table 2, and shown in Fig. 1.

Table 2. Effect of Cement and Curing on Unconfined Compressive Strength of Stabilized Specimens

Amount of Cement %	7 Days MPa	28 Days MPa	60 Days MPa
2.5	1.3	1.6	1.9
7.5	2.8	3.1	4.2
10.0	2.9	4.2	4.6
12.5	2.9	5.0	6.3

N.B. The values shown in the above table represents an average of three blocks.

Durability Test

In actual practice, stabilized soils used for external purpose will be subjected to drying and wetting during the dry and rainy seasons, respectively. The cause of wetting and drying have effects of disintegration some of the compacted soil particles causing loss in weight. The total loss in weight is then calculated as a percentage of the original dry weight of the stabilized soil blocks.

The soil specimens were subjected to 28 days curing and then 12 cycles of drying the specimen in oven at 71°C for 42 hours and then immersed in water for 5 hours to be followed by one hour of drainage and of removal of lossened material from the specimen surface. The results are given in Table 3, and shown in Fig. 2.

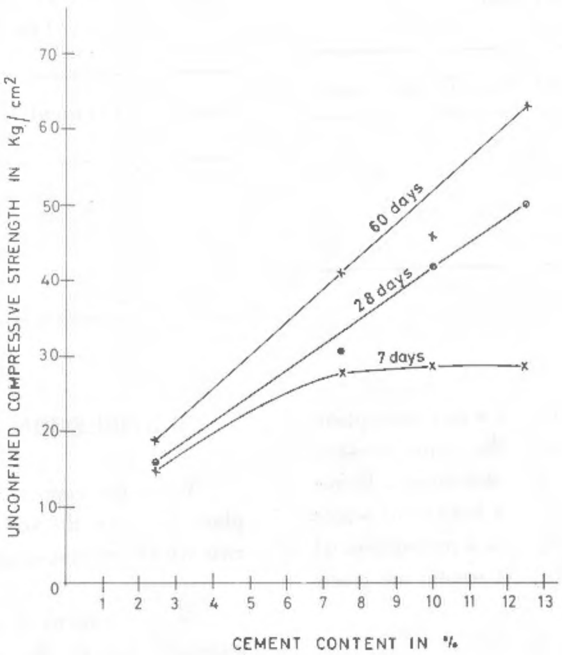

Fig. 1 Effect of Cement and Curing on Unconfined Compressive Strength

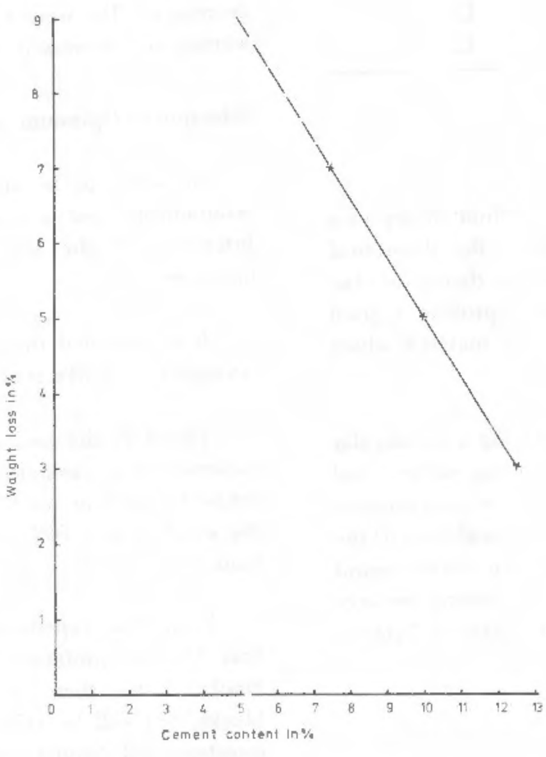

Fig. 2 Effect of Cement on Durability

Table 3. Effect of Cement Content on Durability of Stabilized Specimens

Amount of Cement %	Aged in Days	Weight Loss%
2.5	28	
7.5	28	7
10.0	28	5
12.5	28	3

Water Absorption

In order to investigate the effect of water absorption of the stabilized soil blocks during the rainy season, similar test has to be conducted in the laboratory. Therefore, the specimens were immersed in a bucket of water for 24 hours. Then the gain in weight as a proportion of the dry weight was expressed. The test results are given in Table 4, and shown in Fig. 3.

Table 4. Effect of Cement Content on Water Absorption of Stabilized Specimens

Amount of Cement %	Water Gain in % After 28 Days
2.5	16
7.5	14
10.0	13
12.5	12

Split-Tensile Strength Test

This type of test is an indirect method of applying tension in the form of spliting. Since the theoretical analysis of the split test is based on the theory of elasticity it is logical that the test would provide a good indication of the tensile strength of the material which behave elastically to failure.

The split test is conducted by placing a rectangular specimen horizontally between two loading surfaces and loading the specimens along two opposite generatrices. In order to accommodate a possible non-parallelism of the generatrices of the rectangular block, two simple round bars were interposed between the two loading surfaces and rectangular specimens. The result is given in Table 5, and shown in Fig. 4.

Table 5. Effect of Cement of Splitting Tensile Strength of the Stabilized Specimens

Amount of Cement %	Split Tensile Strength in MPa After 28 Days
2.5	
7.5	0.2
10.0	0.3
12.5	0.4

DISCUSSION OF THE TEST RESULTS

When the cement is added to the soil, reactions take place between the soil minerals and the cement constituents which are responsible for the stabilization of the soil.

As the cement is increased, the compressive strength increases due to the adherence effect between the soil minerals and the cement constituents takes place with a water film surrounding them thus forming a semi-rigid structure having high strength. The curing of the specimens for a longer period helps the initial and final setting of the cement causing increases in strength. The absorption characteristics is also affected by the forming semi-rigid structural effect of the stabilized specimens. As the cement content increased, the absorption capacity decreased. The weight loss after 12 cycles of drying and wetting also decreased as the cement increased.

Selection of Optimum Cement Content

In order to be able to select the cement content economically for a soil of similar nature in the field. Inference of the test results to the specification is necessary.

It is specified that a minimum average compressive strength of 1.4 MPa at 28 days should be attained.

Therefore the cement content should be selected at a minimum unit strength of 1.4 MPa. Thus, 5% cement content should be used. In durability test, it is seen that the weight loss is 10% which is equal to the recommended limit.

From this experimental investigation, it is inferred that 5% can preferably be used as the stabilized soil blocks. Lower than 5% will be used as the stabilized soil blocks; but will be affected by the seasonal variation of moisture and temperature which are the prevalent condition of soils in Zeway area.

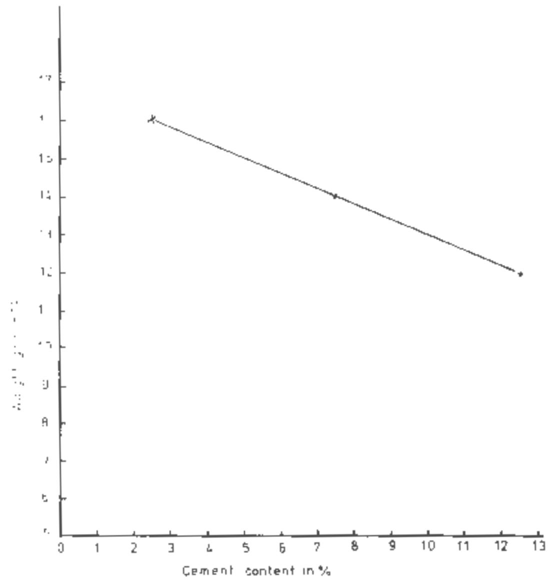

Fig. 3 Effect of Cement on Water Absorption

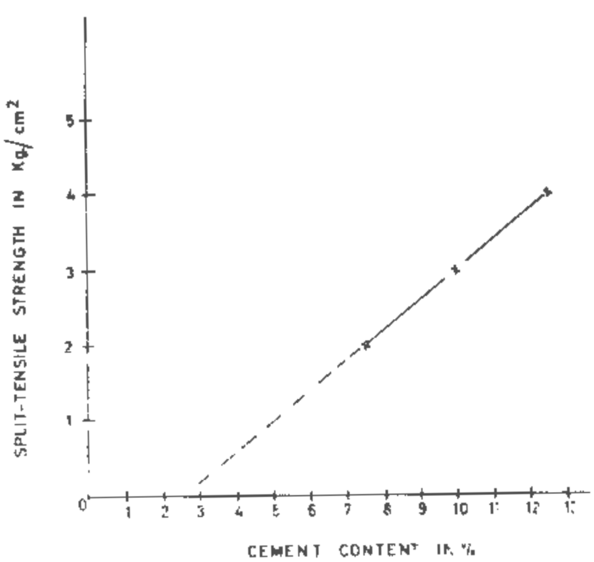

Fig. 4 Effect of Cement on Split-Tensile Strength

Fig. 5 School Constructed of Soil-Cement Mixture Block

Practical Application of the Result of the Investigation

A school constructed of soil-cement mixture block walls, in 1970 at Zeway, 165 km south of Addis Ababa, is still in sound condition as shown in Fig. 5. In spite of exposure to heavy rainfall, and of too short eaves, the school is seen to be structurally in sound condition.

CONCLUSIONS

Even though the studies in this investigation are limited, conclusions based on the results of this investigation may be stated as follows:

1. The increase in cement content and in curing period has a considerabl effect in the increase of the unconfined compressive strength and split tensile strength. Curing the specimens above 28 days causes very small rate of gain in strength.

2. The percentage of weight gain during the water absorption test decreases with the increase in cement content.

3. Repeated cycles of drying and wetting demonstrated the decreases in weight loss with the rise of cement contents.

4. Cement contents varying from 5% – 7.5% give effective results for the soil under investigation and may be recommended for use as walling material for single storey buildings. These low requirement of cement content were verified by field trials. The future of soil stabilization for low-cost building construction in Ethiopia seems to be bright.

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