DETERMINATION OF OPTIMUM CEMENT CONTENT FOR STABILIZATION OF SOIL - A CASE STUDY

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ABSTRACT

This study investigates the effect of cement on the performance of soil, collected from Sothern University Bangladesh Campus, Mehedibag, Chittagong. The addition of cement was found to improve the engineering properties of available soil in stabilized forms specifically strength characteristic. Therefore, laboratory tests such as compaction, Atterberg limits, unconfined compressive strength tests for different percentages of cement content and original soil samples were performed. These test results show that the soil can be made lighter which leads to decrease in dry density and increase in moisture content due to the addition of cement with the soil. Besides that the unconfined compressive strength and shear strength of soil can be optimized with the addition of 3% cement content measuring by weight.

Keywords: Cement; unconfined compressive strength; Atterberg limits; index properties; strength properties

INTRODUCTION

Every civil engineering structure, whether it is a building, a bridge, or a dam, is founded on or below the surface of the earth. Foundations are required to transmit the load of the structure to the soil of sufficient strength. For small structure, shallow foundations are provided generally. If the soil of shallow depth is unstable then the soil is to be stabilized. Similarly in case of rigid and flexible pavement, often it is required to stabilize the sub base and base layer. Stabilization is the process of blending and mixing materials with a soil to improve the soil's strength and durability. The pavement soil qualities will be improved by thoroughly mixing and compacting with additives include portland cement, fly ash, bitumen, and combinations of any of the additives [3]. The properties of all the pavement layers are considered in the design of the flexible pavement system [5].The type of the additive and the amount required are dependent upon the soil classification and the degree of improvement desired [4]. Cement has been found to be effective in stabilizing a wide variety of soils, including granular materials, silts, and clays; by products such as slag and fly ash; and waste materials such as pulverized bituminous pavements and crushed concrete. Generally, the stabilization concept can be dated 5000 years ago. Treated earth roads were used in ancient Mesopotamia and Egypt, and that the Greek and Roman used soil-lime mixtures [1]. The first experiments on soil stabilization were achieved in the USA with sand/clay mixtures around 1906. In the 20th century, especially in the thirties, the soil stabilization relevant to road construction was applied in Europe [2].

Cement-modified soil is typically used to improve subgrade soils or to amend local aggregates for use as base in lieu of more costly transported aggregates. The improved engineering characteristics of materials which are treated with cement provide important benefits to Portland cement concrete (rigid) and asphalt (flexible) pavements.

The role of hydraulic cement such as portland or slag cement is to bind soil particles together, improve compaction, and decrease void spacing, improve the engineering properties of available soil such as, unconfined compressive strength, modulus of elasticity, compressibility, permeability, the drying rate, workability, swelling potential, frost susceptibility and sensitivity to changes in moisture content (Leonards, 1962; Woods, 1960; Robert et al., 1971). Cement can be used to stabilize any type

of soil, without those having organic content greater than 2% or having pH lower than 5.3 (ACI 230.1R-90 1990).
The objectives of the study are given below:

- To classify the soil according to MIT.
- Correlate maximum dry density and optimum moisture content with various % of cement in soil.
- To show the effect of cement on unconfined compressive strength of soil and determine the optimum cement content.

Materials and Methods
Specification of soil
The collected soils were hard and it was pulverized manually by hammer. Then the soils were screened through the sieve of 4.75 mm aperture before preparing the specimens for testing. According to the MIT classification systems, the soil is classified as silty sand.
The particle size distribution of the original soil is shown in the Figure 1.

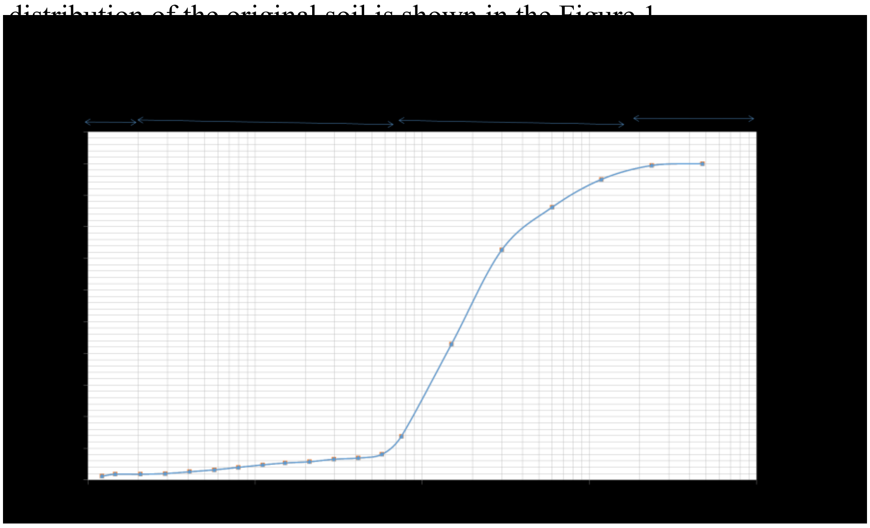


Fig. 1: Particle size distribution of original soil

Preparation of Testing Samples
The collected soils and cement contents were oven-dried at 105 ^{0}c overnight to remove moisture and repress microbial activity. Then the oven dried samples were mixed thoroughly by hand in a large tray in a dry state.

- The index properties of the collected soil samples are determined.
- Soil is classified according to MIT soil classification system.
- Laboratory tests standard proctor test, Unconfined compression test are done for only soil sample and soil mixed with 3%, 6%, 9%, 12% cement respectively.
- Optimum moisture content obtained from standard proctor test is used preparing the test specimen of unconfined compression test. The sample for unconfined compression test is cured for 1 day, 7days, 14 days and 28 days.
- Finally the unconfined compressive strength variation of soil for different curing period is analysed and an optimum value of cement content is determined.

RESULTS
From the grain size analysis, specific gravity test and Atterberg limit test, following properties of soil are found. Figure 2 shows that liquid limit of soil increases gradually with the increases in percentage of cement content. This improvement of liquid limit attributed that more water is required for the cement treated soil to make it fluid. This change of atterberg limit is due to the cation exchange reaction and flocculation–aggregation for presence of more amount of cement, which reduces plasticity index of soil.

Table 1: Index Properties of Soil

Properties	**Values**	Properties	Values
MIT classification	Silty sand	Coefficient of curvature (Cc)	0.873
Specific Gravity (G)	2.75	Liquid limit (wl)	16.6%
Effective size (D10)	.063 mm	Plastic limit (wp)	15.87%
Fineness modulus	1.0368	Plasticity index (Ip)	0.73%
Uniformity coefficient(Cu)	3.492		

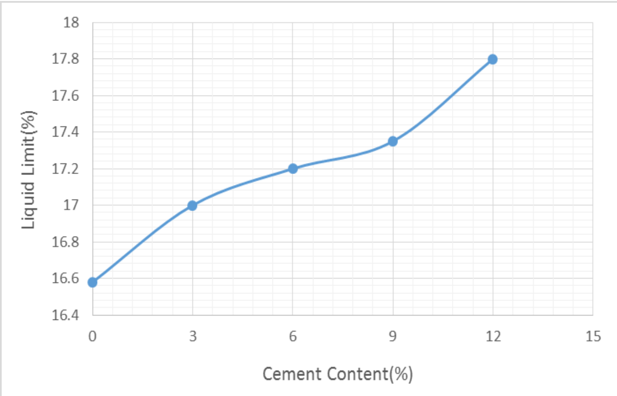


Fig 2: Variation of liquid limit with cement content

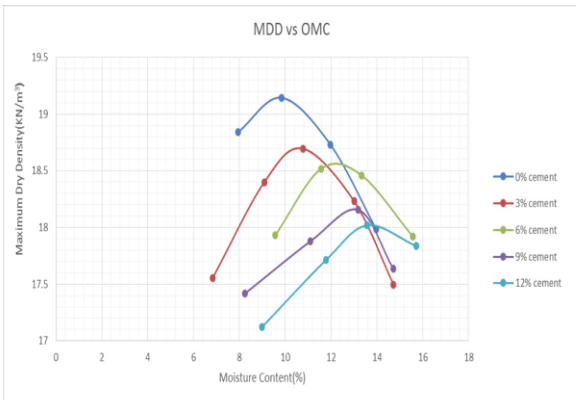


Fig 3: Correlation between Maximum Dry Density and Optimum Moisture Content with various % of cement in soil

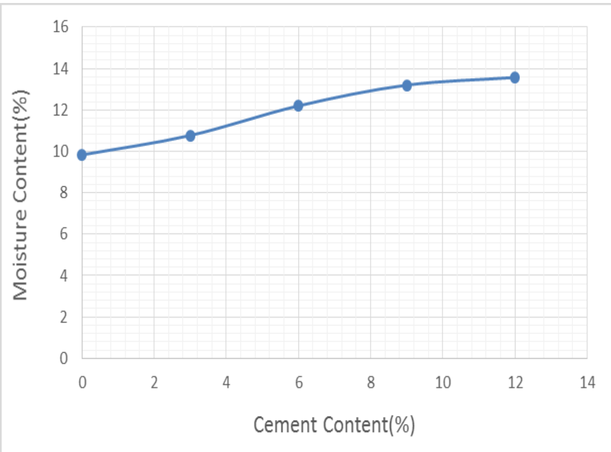


Fig 4: Variation of OMC with cement content

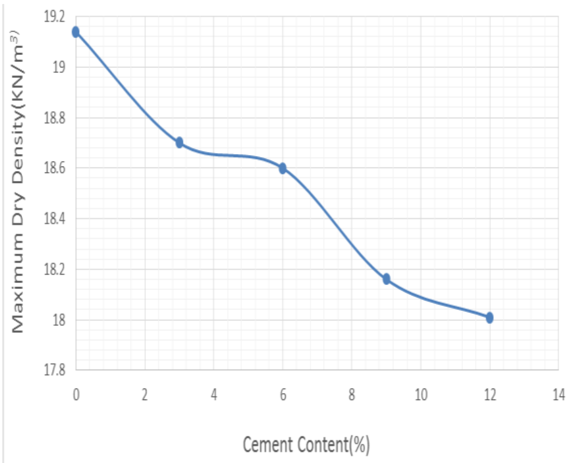


Fig 5: Variation of MDD with cement content

The variation of optimum moisture content and maximu
soil is shown in figure 3. This figure represents the maximum dry density of soil decreases gradually with an increase of cement content. It is the result of initial coating of soils by cement to form larger aggregate, which consequently occupy larger spaces.

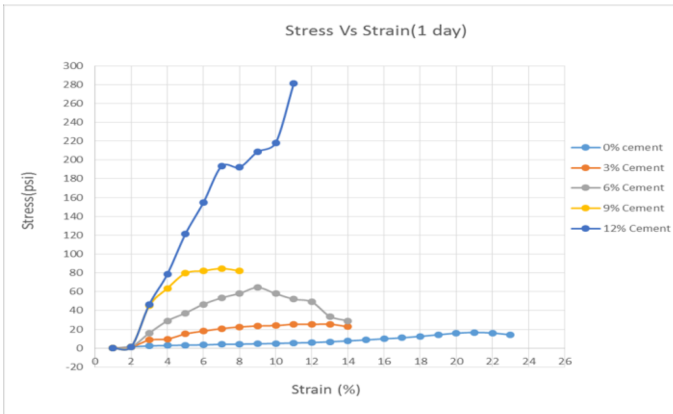
On the other hand, the optimum moisture content of soil increases with increase cement content, because cement is finer than the soil. The increase of water content was also attributed by the pozzalanic reaction of cement with the soil.

Strength Characteristics

Unconfined Compressive Strength (UCS)

The test result of unconfined compressive strength is shown in Figure 5. This figure illustrates the stress-strain behavior of original and cement treated soil under vertical load. Initially the stress is rapidly increases with the increase of strain but in case of soaking untreated soil sample, stress increases gradually with the increase of strain. After attaining the peak stress, it decreases with the increase of strain for all the combination of cement and soil. Approximately all the specimen shows shear failure after observing the failure plane of specimens.

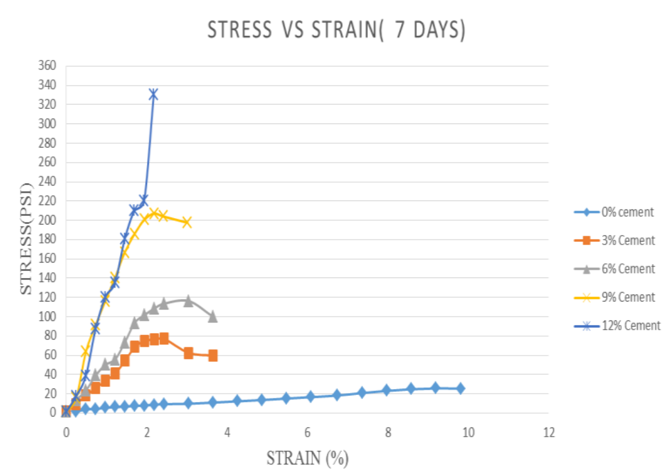
- Fig: 6(a) shows the variation of compressive strength of soil for different percentages of cement for curing period 1 day.



Cement content(%)	Unconfined Compressive strength(psi)	% increase in UCS
0	14.259	
3	22.749	59.54
6	29.093	104
9	70.054	391.3
12	281.139	1871.66

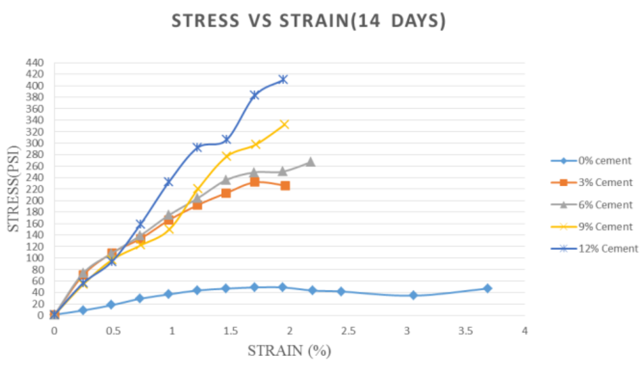
Fig: 6(a)

- Fig: 6(b) shows the variation of compressive strength of soil for different percentages of cement for curing period 7 days.



Cement content(%)	Unconfined Compressive strength(psi)	% increase in UCS
0	24.252	
3	59.595	145.73
6	100.159	68
9	197.515	97.20
12	330.598	67.37

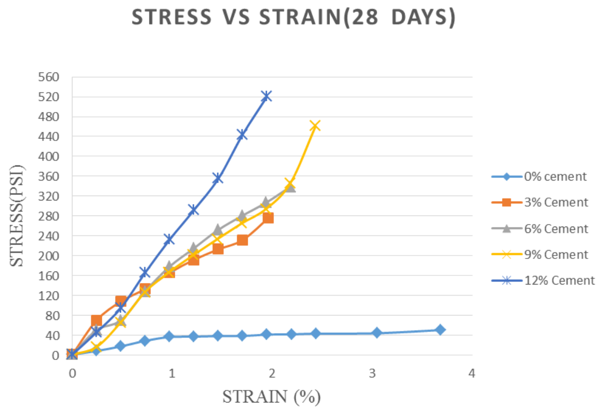
- Fig: 6(c) shows the variation of compressive strength of soil for different percentages of cement for curing period 14 days.



Cement content(%)	Unconfined Compressive strength(psi)	% increase in UCS
0	46.84	
3	226.14	382.79
6	267.24	18.17
9	331.90	24.19
12	410.31	23.62

Fig: 6(c)

- Fig: 6(d) shows the variation of compressive strength of soil for different percentages of cement for curing period 28 days



Cement content(%)	Unconfined Compressive strength(psi)	% increase in UCS
0	50.84	
3	276.14	443.15
6	339.09	22.79
9	460.9	35.92
12	520.31	12.88

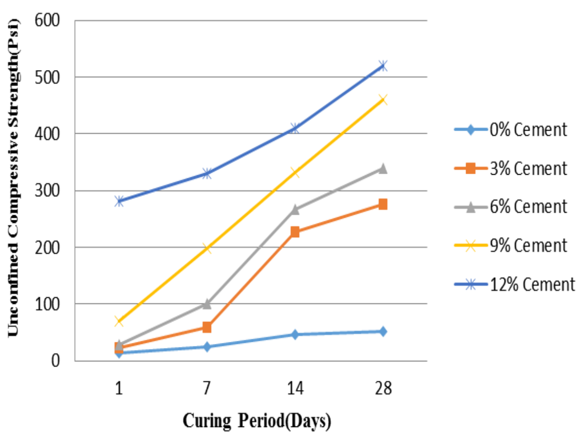


Fig 7: Variation of Unconfined Compressive Strength at different percentages of cement for different curing periods.

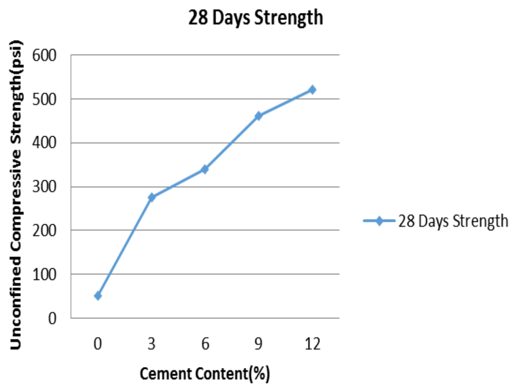


Fig 8: Unconfined Compressive Strength variation with cement content

From Fig: 7 it is observed that strength increases rapidly at 3% cement content where strength does not increase rapidly for other percentages of cement. Again fig:8 also shows the shows the same pattern.

CONCLUSIONS

A study has been conducted to investigate the fundamental properties such as consistency, compaction, compressive strength characteristics of untreated and cement treated soil. It can be concluded that there is an improvement of geotechnical properties of cement treated soil. The following conclusions, based on the test results in this study, are drawn.

- According to MIT classification system, this soil is silty sand.
- The maximum dry density of soil decreased with the addition of cement and value of optimum moisture content of cement treated soil increased because of the pozzalonic action of cement and soil, which needs more water.
- Comparing with the 28 days unconfined compressive strength, strength increases 5.43 times for using 3% cement, 6.67 times for 6% cement, 9.65 times for 9% cement and 10.4 times for 12% cement.
- From the economic consideration and the strength required in field, the optimum cement content is 3% as strength increases rapidly for adding 3% cement compared to other percentages of cement content.

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