

## Original Article

# Influence of cement addition on the index and compaction properties of soil

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### ABSTRACT

Soil stabilization is widely used in geotechnical engineering to improve weak soil properties and enhance its suitability for construction purposes. This study investigated the influence of cement addition on the index and compaction properties of silty clay soil collected from Kamalapur, Dhaka. Portland Composite Cement was used as a stabilizer at 0%, 2%, 4%, and 6% by weight of soil. Laboratory testing included specific gravity, Atterberg limits, and standard compaction tests following ASTM procedures. The results showed that cement treatment progressively modified the soil behavior. Specific gravity increased from 2.65 for untreated soil to 2.68, 2.69, and 2.70 for 2%, 4%, and 6% cement content, respectively, indicating a denser soil-cement matrix. The liquid limit increased from 52% to 56.40%, 58.70%, and 59%, while the plastic limit rose from 26% to 30.5%, 33.31%, and 34.50% with increasing cement dosage. In contrast, the plasticity index decreased slightly from 26.0% for natural soil to 25.9%, 25.39%, and 24.50%, suggesting reduced plasticity and improved stability. Compaction characteristics also improved significantly: The untreated soil had an optimum moisture content of 18% and a maximum dry density (MDD) of 1.26 g/cc, whereas MDD increased to approximately 1.35, 1.44, and 1.54 g/cc at 2%, 4%, and 6% cement content, respectively. Overall, the findings indicate that cement stabilization enhances the physical and compaction characteristics of the studied soil, with 6% cement providing the best overall performance among the tested mixes.

**Keywords:** Cement, Soil stabilization, geotechnical properties, compaction properties

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## INTRODUCTION

Fine-grained soils often create serious challenges in geotechnical engineering because their high moisture sensitivity, compressibility, low bearing capacity, and shrink–swell behavior can reduce the stability of pavements, embankments, and foundations.<sup>[1]</sup> For this reason, soil stabilization is widely used to improve weak *in situ* soils and reduce the cost of excavation and replacement. In chemical stabilization, additives modify soil structure and may create cemented bonds between particles, leading to better strength and durability.<sup>[2]</sup>

Among chemical stabilizers, Portland cement is one of the most commonly used binders because it acts rapidly and can be applied to a wide range of soils. When mixed with water, cement undergoes hydration and produces calcium-silicate-hydrate

and calcium-aluminate-hydrate, while clayey soils may also experience cation exchange, flocculation-agglomeration, and pozzolanic reactions.<sup>[3]</sup> These processes improve interparticle bonding and generally reduce problematic plastic and swelling behavior. However, the degree of improvement depends on factors, such as soil mineralogy, cement content, molding water content, curing conditions, and the presence of organics or sulfates.<sup>[4]</sup>

For fine-grained soils, index and compaction properties are especially important because they provide rapid and economical indicators of engineering performance. Atterberg limits are integral to soil classification and are widely used to interpret compressibility, hydraulic conductivity, compactibility, shrink–swell potential, and shear strength.<sup>[5]</sup>

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Standard compaction testing is likewise fundamental because it establishes the optimum moisture content (OMC) and maximum dry density (MDD), which are essential for design and field quality control.<sup>[6]</sup> Specific gravity is also a basic physical parameter used in evaluating soil phase relationships, such as void ratio and degree of saturation.<sup>[7]</sup>

Previous studies have shown that cement can significantly alter the consistency and compaction behavior of weak soils. Sariosseiri and Muhunthan reported that adding 2.5–10% cement to Washington State soils improved workability, Atterberg limits, compaction characteristics, and strength.<sup>[8]</sup> In a Portland Composite Cement (PCC) study on soft clay, specific gravity increased from 2.527 to 2.574, and MDD increased from 1.26 to 1.33 t/m<sup>3</sup> as PCC content increased to 12%.<sup>[9]</sup>

The present study investigates the effect of PCC added at 0%, 2%, 4%, and 6% on the specific gravity, Atterberg limits, and compaction characteristics of silty clay soil collected from Kamalapur, Dhaka. The purpose is to assess how small cement additions modify the index and compaction properties of this local soil and to identify a suitable treatment level for improved construction performance.

## MATERIALS AND METHODS

### Collection of Materials

Cement mainly contains lime, silica, alumina, and iron oxide. These compounds control the strength, setting time, and durability of cement. Various types of cement are available in the market. For this study, PCC was collected from the malibagh market, Dhaka. Cement mixing with soil, known as soil cement stabilization. It is used to improve the strength and durability of weak soils. In addition, Soil samples were collected from Kamalapur, Dhaka, at depths of 5 feet and 10 feet. The area mostly contains silty clay-type soil. The soil shows medium to high plasticity and moderate compressibility. It allows water to drain slowly because of its clay content. Proper soil testing is needed before any construction work. To improve its engineering behavior, the soil was stabilized using different percentages of cement (0%, 2%, 4%, and 6%). Basic physical properties, such as specific gravity, liquid limit (LL), plastic limit (PL), and plasticity index (PI) were determined in accordance with ASTM standards.

### Preparation of Soil Samples

Locally available cement was used as a stabilizing agent to improve the untreated soil. Different cement contents (0%, 2%, 4%, and 6%) were mixed with the soil for stabilization. The standard compaction test, following ASTM D698, was conducted to evaluate the effect of cement on the soil's behavior and to determine the MDD and OMC. The hydrometer test, following ASTM D7928-21, was performed to determine the grain size distribution of the fine-grained

portion of the soil. This analysis provides information on the relative percentages of silt and clay, which play a significant role in assessing the soil's plasticity, compressibility, and overall engineering properties.

### Test Procedures

Experiments were carried out using four proportions. For the laboratory test, PCC cement was used as a stabilizer to treat the soil samples. Trials with varying proportions of cement: 0%, 2%, 4% and 6%, respectively, were used to determine the optimum cement content for gaining maximum strength. The amount of soil required for each test was measured. Before conducting the tests, the soil was mixed with the additives according to the specified proportions. Different test procedures are presented in below section.

#### *Specific gravity test*

The specific gravity test was conducted to determine the ratio between the weight of soil solids and the weight of an equal volume of water. This test helps to identify the soil type and provides necessary data for evaluating parameters, such as void ratio, porosity, and degree of saturation. The test was carried out following the standard procedure outlined in ASTM D854, using a pycnometer to measure the specific gravity of the soil samples with varying cement content. Approximately 50 g of oven-dried soil (passed through the sieve no. 10) was placed in the pycnometer at various ratios. Then, distilled water was added to fill the pycnometer, and the entrapped air was removed by gentle shaking. The pycnometer was weighed after reaching a constant temperature. The same procedure was repeated with water only to determine the reference weight. Using these measurements, the specific gravity of the soil solids was calculated.

#### *Atterberg limit test*

Atterberg limits indicate the moisture levels at which the behavior of soil changes from one phase to another. According to ASTM D4318-17, tests for LL, PL, and PI were conducted to investigate the soil's consistency characteristics at varying cement contents (0%, 2%, 4%, and 6%, respectively). The Casagrande apparatus was used to determine the LL, where a soil paste was continuously sheared until the groove closed at 12 mm. After that, the corresponding moisture content was recorded. The PL was determined by rolling soil threads to a diameter of approximately 3 mm, at which point they began to crumble. The PI was calculated as the difference between the LL and PL.

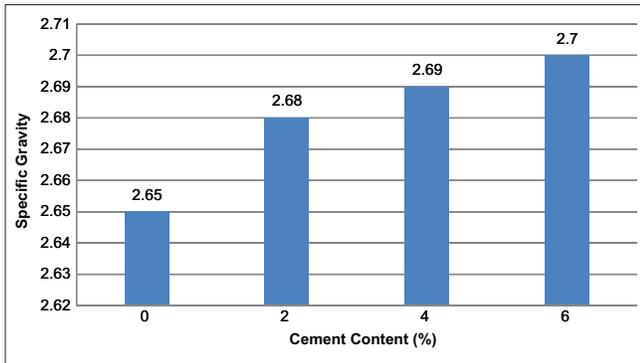
#### *Standard compaction test*

The standard compaction test (ASTM D698) was performed to determine the relationship between the moisture content and dry density of soil. This test helps to identify the OMC at which the soil attains its MDD under a specific compactive effort. The soil samples with different ratios were carefully

**Table 1: Atterberg limit of composite soil**

Soil (%)	LL (%)	PL (%)	PI (%)
0	52	26	26
2	56.40	30.5	25.9
4	58.70	33.31	25.39
6	59	34.50	24.50

LL: Liquid limit, PL: Plastic limit, PI: Plasticity index

**Figure 1:** Specific gravity of composite soil

prepared before conducting the subsequent experiments. Four types of soil samples with different water contents were tested at ratios of 0%, 2%, 4%, and 6%, respectively. This test is important as it provides key data on the soil's compaction characteristics, which directly affect its strength, stability, and overall suitability for construction.

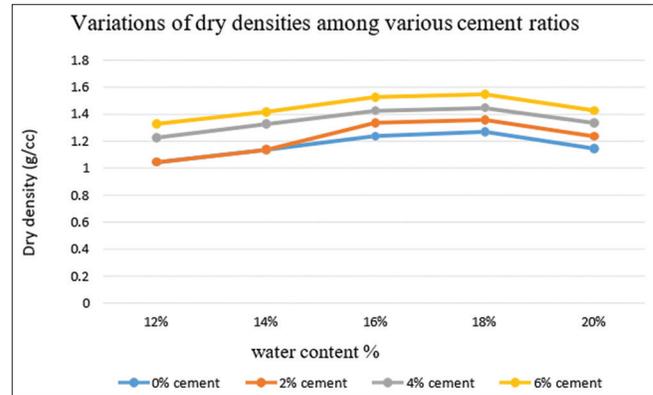
## RESULTS AND DISCUSSION

### Specific Gravity of Composite Soil

Specific gravity of composite soil mixed with different proportions of cement are shown in Figure 1. It is shown that the soil's properties changed gradually with increasing cement content. The specific gravity increased from 2.65 in the natural soil (S-1 sample) to 2.70 at 6% cement mixed with soil (S-4 sample), which demonstrates a denser particle arrangement as cement bonds with the soil. Specific gravity increases due to heavier particles of cement than most soil particles for the same volume.

### Atterberg Limit Test

The Atterberg limit of composite soil is presented in Table 1. The LL also rose slightly from 52% to 59% with increasing cement addition, suggesting that more water is required for the soil to reach a flow state due to the formation of cementitious compounds. The PL followed a similar trend, increasing as cement was added, meaning the soil needs more moisture to become workable. As a result, the PI decreased, which reflects a reduction in the soil's plastic behavior. Lower plasticity is beneficial because highly plastic soils tend to shrink, swell, and deform more easily. Overall, the results show that cement

**Figure 2:** Dry densities versus water content for various cements

treatment makes the soil less plastic and more stable, improving its suitability for construction and load-bearing applications.

PL was found to remain almost unchanged with the addition of cement, varying only from 26% at 0% cement to 34.5% at 6%. This slight change indicates that the soil's water-holding capacity in the liquid state was not significantly influenced by cement.

### Standard Compaction Test

The Proctor test was first carried out on the untreated subgrade soil following the AASHTO T- 180 standard to determine its OMC and MDD, as presented in Figure 2. The OMC was found to be 18%, and the corresponding MDD was 1.26 g/cc.

After that, the soil was mixed with different proportions of cement and tested again. The MDD increased consistently with cement addition. The untreated soil reached a peak dry density of about 1.26 g/cc, while the mixes with 2, 4, and 6% cement reached roughly 1.35, 1.44, and 1.54 g/cc, respectively. That steady rise shows a clear improvement in the soil's ability to compact as more cement was introduced. Variation of dry densities are shown in Figure 2.

## CONCLUSION

The study concludes that cement addition significantly improved the index and compaction properties of the Kamalapur silty clay soil within the tested range of 0–6%. Specific gravity increased from 2.65 for untreated soil to 2.70 at 6% cement, indicating denser solid particles in the stabilized mix. The Atterberg limits showed that the LL increased from 52% to 59%, while the PL increased from 26% to 34.50% as the cement content rose. Consequently, the PI decreased slightly from 26.0% to 24.50%, suggesting reduced plastic behavior and better dimensional stability. Compaction characteristics also improved markedly: The MDD increased from 1.26 g/cc in untreated soil to about 1.35, 1.44, and 1.54 g/cc at 2%, 4%, and 6% cement, respectively, while the untreated soil had an

OMC of 18%. Overall, the results demonstrate that cement stabilization enhances soil densification, reduces plasticity, and improves engineering performance, with 6% cement giving the best overall performance among the tested proportions.

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