# Immediate and long term effects of compaction on the stress-strain behaviour of soil

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**Abstract.** This paper explores whether delay in construction after compaction can benefit from the gain in soil's strength and stability point of view. An experimental investigation has been carried out to examine the gradual development of soil's shear strength by ageing of mechanically compacted soil at three relative densities. In order to separate the gain in strength due to ageing from that occurring from the reduction in soil moisture, the soil samples prepared in moulds were kept in desiccators for different periods of time (1, 9 and 17 days) before testing unconfined compressive strength test. The soil in densely compacted state is found to gain in strength due to ageing faster than that in medium compacted state. Only due to ageing of 9 days or more, unconfined compressive strength of compacted soil is found about 1.7 to 2.4 times of that attained in day 1 after compaction.

## 1. Introduction

Compacted fills are often studied to investigate its vulnerability from liquefaction and moisture induced collapse point of view [1-5]. Shearing of soil can cause different types of changes in soil properties; strength, stiffness and stability, soil water potential, etc. The effect of ageing on the behaviour of remoulded soil had been studied from strength and stability point of view by several researchers mostly for agricultural applications [6- 8]. It can be noted that agriculturists concentrate mainly on the behaviour of top soil only. However, progressive increases in soil parameters (including strength, soil water potential) were also observed upon ageing since disturbance [8, 9]. During field work, greater resistance was experienced while penetrating probes in soil after some degree of ageing after remoulding [10]. This also indirectly indicates that the resistance of remoulded soil increases gradually during ageing. However, such increases in soil's stiffness and strength in nature are resulted from both desaturation and ageing. The influence of ageing need to be investigated in the laboratory only.

However, in different civil engineering projects, soil is mechanically compacted and thus becomes remoulded. During compaction, soil gets remoulded and attains greater strength and stiffness. Moreover, the compacted soils can gain additional strength due to ageing [6-11]. To date, very few investigations on soils those are not classified as sensitive were carried out, though several attempts studying the effect of ageing on regaining strength, stiffness and compressibility of sensitive clay are found [9, 12].

Previous studies investigated the effect of ageing by keeping the specimens under consolidation pressure for different periods of time [12, 13]. Increase in shear strength and decreases in pore water pressure, failure strain and angle of internal friction were noted during the experiments on specimens kept under consolidation pressure for longer periods. The objective of the present study is to extend the knowledge regarding the influence of ageing on the stress-strain relation and shear strength of low plastic silt due to compaction.

## 2. Experimental Program

An experimental investigation has been carried out to examine the gradual development of soil's shear strength by ageing of mechanically compacted soil at three relative densities.

### *2.1. Methodology*

The gradual development of shear strength of low plastic silt due to mechanical compaction was studied. The soil was compacted in mould (38 mm diameter and 76 mm height) in three layers and at optimum moisture content. Figure 1 shows the preparation of compacted specimens in rubber membranes. Three different compaction efforts (such as 8 blows, 16 blows and 32 blows per layer) were applied for preparing compacted soil specimens at three relative densities: loose, medium and dense-to-very dense, respectively. The compacted specimens were kept in desiccators (water-cool and close-fitting lids) for different periods of time (1, 9 and 17 days) before conducting tests. The unconfined compressive strengths of all three types of compacted specimens were determined at the age of 1, 9 and 17 days. Figure 2 presents the photographs of unconfined compressive strength test (in-progress) and a failed specimen. The water content of the failed specimen was also determined to check that the moisture content did not decrease more than 0.5% during ageing.

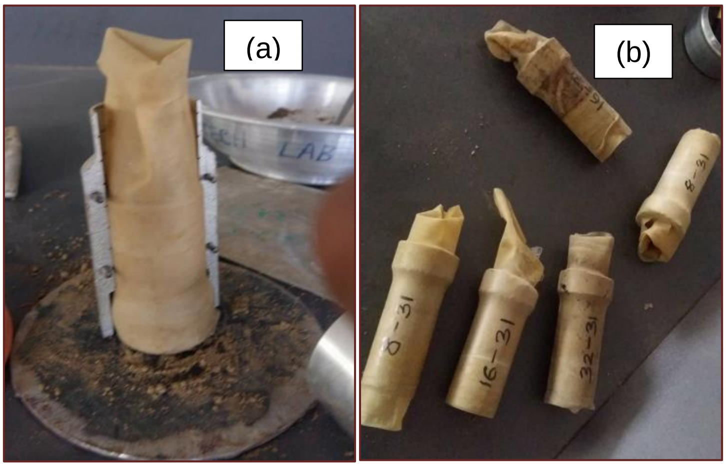


**Figure 1.** (a) Preparation of compacted specimen, (b) Marked specimens.

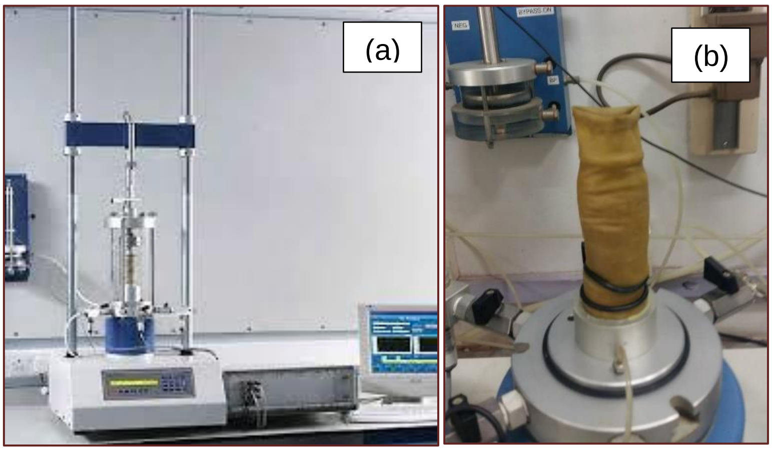


**Figure 2.** (a) Unconfined compressive strength test setup, (b) Failed specimen.

*2.2. Soil*

The soil used in this study was collected from Mirpur Cantonment, Dhaka. Different soil properties were determined by conducting different tests: Cassagrande's liquid limit, plastic limit (by thread-roll), specific gravity and standard Proctor compaction test. The soil parameters determined are given in Table 1. According to unified soil classification system, the soil was classified low plastic silt (ML). Figure 3 presents the compaction curve (standard Proctor test) of the silt soil used in this study. It was determined that the samples prepared for unconfined compressive strength tests were loose, medium and dense-to-very densely compacted when the blows per layer were 8, 16 and 32, respectively. The relative densities of loose, medium and dense-to-very densely compacted soils were determined 35%, 70% and 85%, respectively.

**Table 1.** Soil used in this study.

| Soil Parameter | Value |
|---|---|
| Liquid limit (%) | 33 |
| Plastic limit (%) | 27.4 |
| Plasticity index (%) | 5.6 |
| Optimum Moisture Content (%) | 12.6 |
| Maximum dry density (g/cm$^3$) | 1.575 |
| Specific Gravity | 2.61 |
| Soil (USCS) | ML |

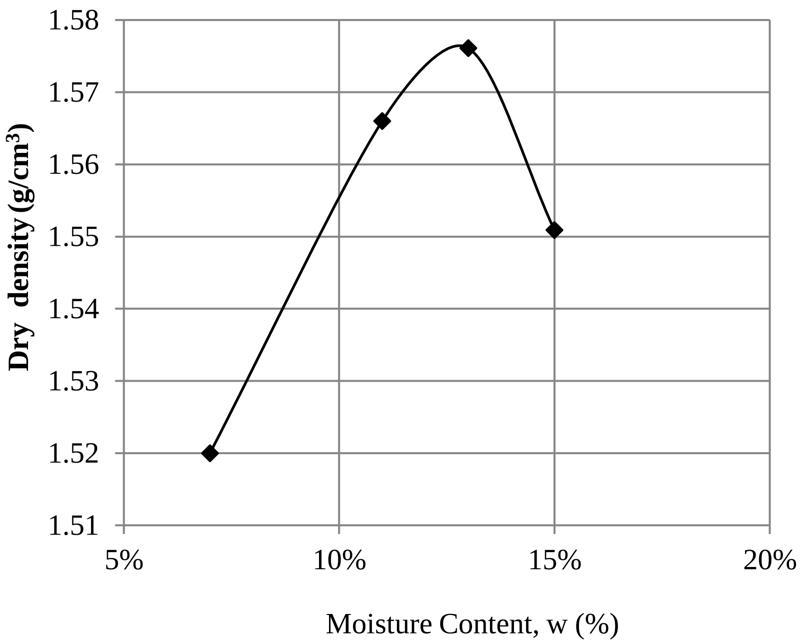


**Figure 3.** Compaction curve from standard Proctor test.

## 3. Results and Discussion

The stress-strain behaviour of the soil in three different degrees of compaction are investigated at the age of 1 day, 9 days and 17 days, as presented in figures 4 – 6, respectively. The stress-strain curve of densely compacted soil is found distinctly different from the specimens compacted at loose and medium relative densities. For loosely compacted condition, the stress-strain curves showed no peak shear stress even after ageing for 17 days. On the other hand, the peak shear stress was always observed for densely compacted soil at any age considered in this study. Further, peak shear stress in the stress-strain curve was observed at the age of 9 days or more, for medium compacted soil.

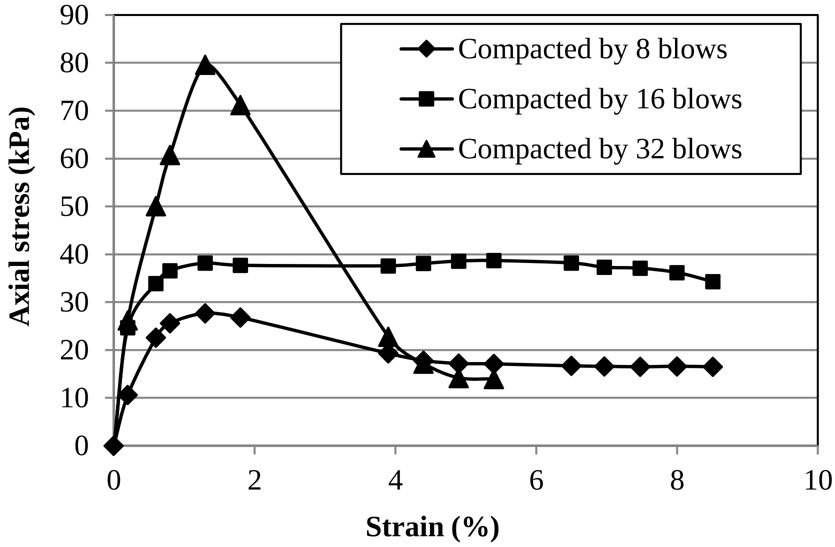


**Figure 4.** Unconfined compressive strength test results: Immediate effect of compaction.

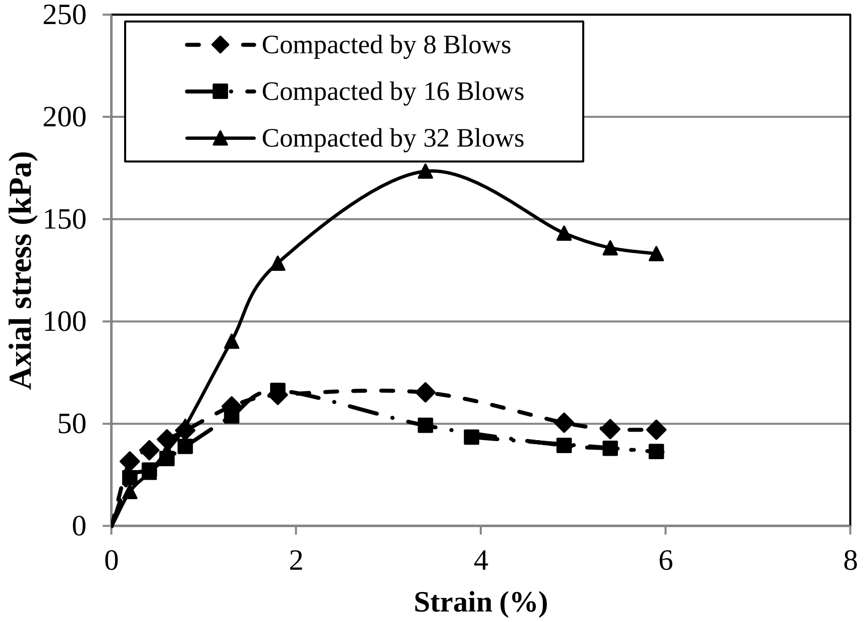


**Figure 5.** Unconfined compressive strength test results: 9$^{th}$ day after compaction.

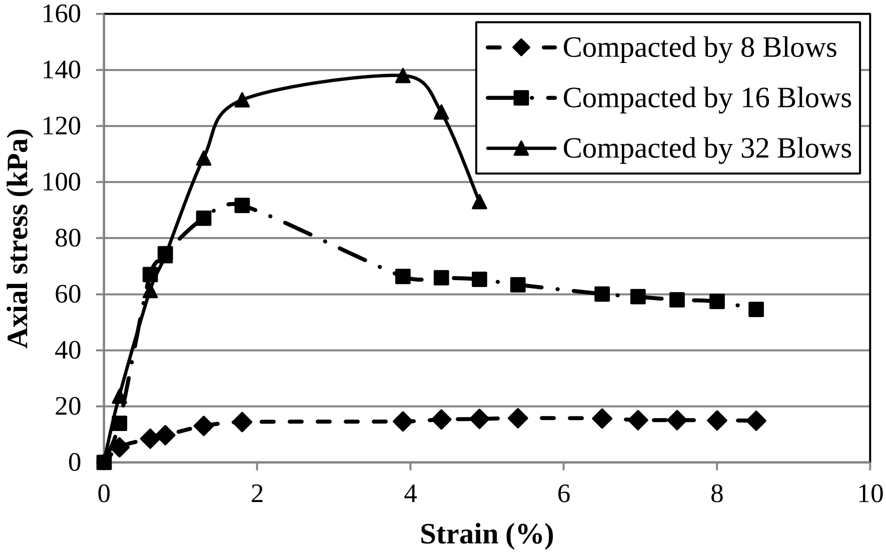


**Figure 6.** Unconfined compressive strength test results: $17^{th}$ day after compaction.

Moreover, the effects of ageing on the strength gain of medium and densely compacted soil are studied in figures 7 and 8, respectively. The medium compacted soil gained strength gradually with time elapsed after compaction, as shown in figure 5. Moreover, it can be noted that the densely compacted soil gained sharply within the first week after compaction, while the rate of gain in strength diminishes slowly (figure 8).

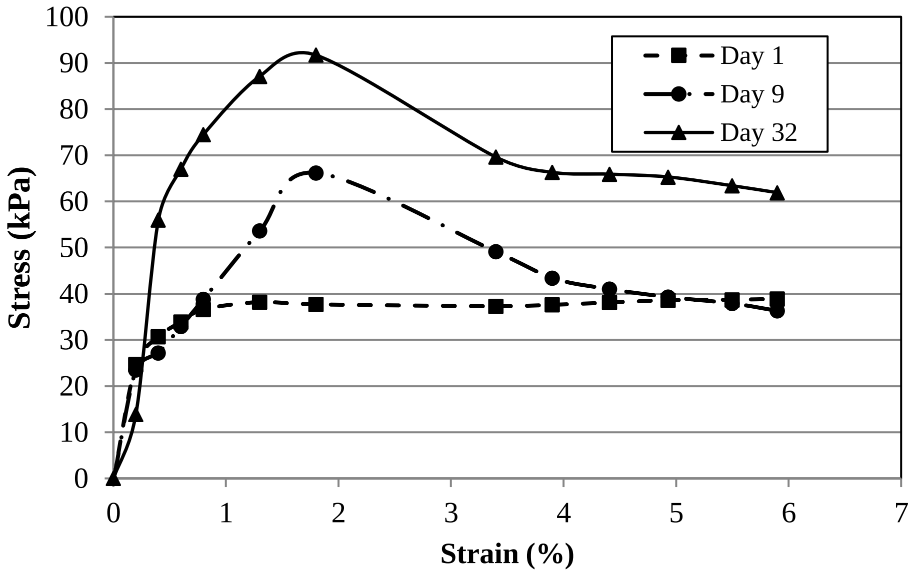


**Figure 7.** Unconfined compressive strength test results: Medium compacted soil.

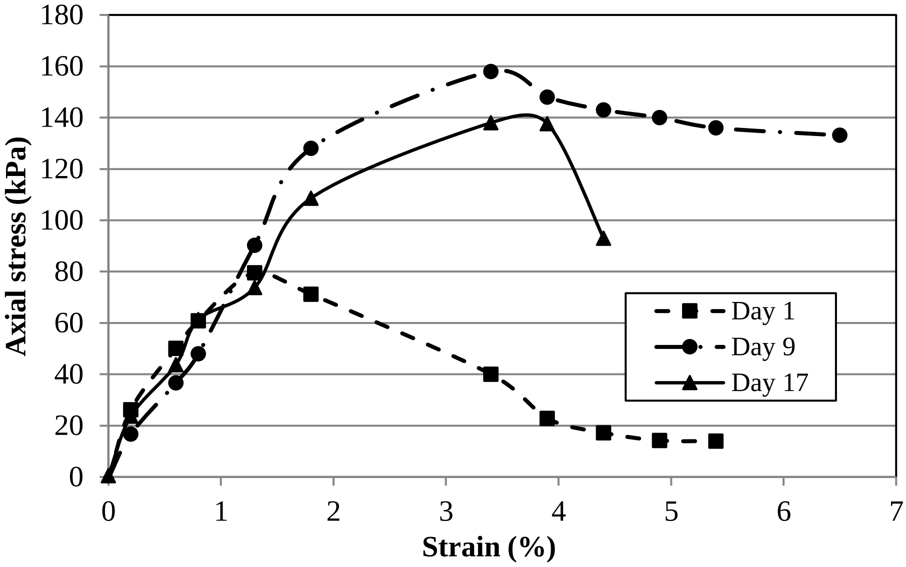


**Figure 8.** Unconfined compressive strength test results: Densely compacted soil.

The gain in strength of aged compacted soil is studied with respect to the strength attained immediately after compaction in terms of a strength magnification factor 'm'. The value of 'm' is obtained as the ratio of unconfined compressive strength obtained at aged sample to that obtained at 1 day aged sample after compaction.

**Table 2.** Ageing and gain in strength.

| Relative Density (%) | m | |
|---|---|---|
| | Day 9 | Day 17 |
| 70 | 1.7 | 2.4 |
| 80-90 | 2.2 | 1.8 |

It can be noted that unconfined compressive strength of compacted soil becomes 1.7 to 2.4 times of that attained in day 1 after compaction.

## 4. Conclusions

The present study explores whether delay in construction after compaction can benefit from soil's strength and stability point of view. Based on the experimental results, the following conclusions can be drawn:

- The soil in densely compacted state showed strength gain due to ageing faster than that in medium compacted state.
- Once the stress-strain curve shows peak shear stress, the compacted soil will not continue to gain in strength for longer period of time. It has been observed for both medium and densely compacted soil.
- Only due to ageing of 9 days or more, unconfined compressive strength of compacted soil is found about 1.7 to 2.4 times of that attained in day 1 after compaction.

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