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# A Study on Replacement of Lime by Egg-Shell Powder for Stabilizing Clay

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**Abstract**

This particular research aims to assess the potential of waste Egg-shell powder and lime for stabilizing clayey soil. For increasing soil strength and reducing cost of soil improvement some laboratory tests were performed to judge whether the Egg-shell powder is capable enough to replace the traditional material lime. The acquired results clearly indicated that treated soil mixes give higher strength values than untreated soil mixes. It is decided to introduce Egg-shell powder in quantities of 0.75%, 1.5%, 2.25% and 3% of soil weight. For environment friendly, cost economic and working purposes, it is found that 28% of lime can be replaced completely by Egg-shell powder for gaining much better strength characteristics of soil, though 55% of the lime can be replaced with Egg-shell powder for soil stabilization.

**Keywords:** Lime, Soil stabilization, Egg-shell powder (ESP), Clay, Unconfined Compressive Strength (UCS)

## 1. INTRODUCTION:

The demand of the modern construction industry is the optimum soil properties which is needed for safe and economic execution activities. But unfortunately, this lacks in a huge number and as a result the need of effective soil stabilization is increasing day by day. In present era, it has been observed that construction activities on soft and weak soil especially in clayey soils often results in significant amount of shear failure along with large scale differential settlement which leads to failure of important structures thereby threatening human lives. This makes us realize that it has few effective solutions such as making the soil very suitable for construction activities by enhancing its required physical and index properties or acquire a deep foundation for the expected load to act on the soil. But as the matter-of-fact deep foundation is unsuitable to adopt frequently unless required truly as it is costly and hectic to construct. As an alternate solution soil treatment is the most widely accepted methodology for improving soil properties and curtailing cost so it is gaining focus of all current researchers nowadays.

Recent studies in past few decades clearly indicates the attempts that scientist are trying to made to find out various materials which can be used along with clayey soils to enhance its physical and index properties. (Basha, 2005) successfully performed various experiments to stabilize the untreated soil with Rice husk ash and cement. (Brooks, 2009) carried out soil stabilization studies practically using variety of fly ash and rice husk ash. (Kamon, 1991) conducted theoretical researches on soil stabilization using industrial wastes combined with lime. (Paul, 2014) studied soil stabilization in accordance with Egg-shell powder mixed with quarry dust. (Anoop S P, 2017) conducted many laboratory experiments under

controlled environment to improve soil using elephant dung strips with lime. Lime was declared to be most effective and efficient soil stabilizer for improving clayey soil properties needed to support higher load values for safe construction. Among all the variety of studies and experiments carried out worldwide, it is evident that lime has to be produced as it is not an industrial waste or a by-product. Lime manufacturing involves excessive heating above almost 750° C which clearly indicates that soil stabilization of large areas with lime alone will not only increase the costing but also pollute the environment with excess $CO_2$ emission. In the present study an attempt to partially replace the lime content with Egg-shell powder is made to improve the clayey soil strength and also the extent of lime content is found out which can be introduced to replace the lime content by Egg-shell powder.

Due to almost identical chemical composition, Egg-shell powder is nearly an ideal replacement material for lime in order to stabilize the clayey soil as the main component of Egg-shell powder is eventually calcium carbonate ($CaCO_3$) which is similar to lime. Egg-shell is frequently generated from normal households, small scale hotels and large-scale restaurants due to good number of consumptions by humans. Due to this large amount of uses, disposal problem of egg-shells has also become a problem. Involving egg-shell as stabilizing agent for clayey soil not only solves this disposal problem but also reduces environmental pollution occurred to huge amount of egg-shell disposal. Moreover, generation of Egg-shell powder is very easy as compared to generation of lime and it doesn't involve high amount of heat (up to 800°C) and generation of Carbon Di-oxide ($CO_2$) as it is in case of generation of lime. Thus, use of Egg-shell powder in stabilizing clayey soil is considered as a sustainable and eco-friendly choice.

## 2. MATERIALS:

The key ingredients for this current experimental analysis are basically combination of clayey soil, lime and Egg-shell powder. Soft clayey soil from the river banks of Ganges in Achhipur area of South 24 PGNS district in Kolkata was taken as sample for the current study. Egg shells were collected from nearby restaurants and lime was purchased from neighborhood market situated in Jadavpur area of Kolkata. The collected egg-shells then cleaned thoroughly to make it free from unwanted dirt and then dried them. Dried egg-shells are crushed finely to make them in fine powder form and then they are sieved through 75 micron IS sieve for making them same as fine-grained soil and it is shown in Fig 1.

**Fig.1: Egg-shell powder (dried**

## 3. EXPERIMENTS:

The used soil mixes mentioned earlier were tested in the laboratory in controlled atmosphere and the obtained results are outlined in Table 2. The UCS (Unconfined Compressive Strength) of the clayey soil

was calculated to be just 0.4 kg/cm$^2$ which specify the desirability of soil stabilization. Optimum lime content was then mixed thoroughly with untreated clayey soil and surprisingly there was a considerable change in the soil strength which appeared as more than double after introducing lime content.

The materials involved in the experiment were mixed in different proportions to study its effect on the stabilization process of soft clayey soil. Firstly, the virgin untreated soil was tested properly and the soil strength was determined to assess if there is any need for soil stabilization. The optimum lime content, which was found to be 5% of the weight of the clayey soil, was calculated as per ASTM D 6276 standards and was added into the untreated virgin clayey soil mix. After this, as a replacement material to lime, Egg-shell powder was used in the stabilization process of clayey soil. Keeping the total lime replacement amount as a constant, the proportions of Egg-shell powder and lime were moderately varied and the used soil mixes are mentioned in Table 1.

**Table.1: Used Soil Mixes**

| Mix Designation | Details |
|---|---|
| C | Untreated soil |
| C + 5 L | Clay + 5% weight of soil replaced by lime |
| C + 4.25 L + 0.75 ESP | Clay + 4.75% lime replacement and 0.75% soil weight replaced by Egg-shell powder |
| C + 3.5 L + 1.5 ESP | Clay + 3.5% lime replacement and 1.5% soil weight replaced by Egg-shell powder |
| C + 2.75 L + 2.25 ESP | Clay + 2.75% lime replacement and 2.25% soil weight replaced by Egg-shell powder |
| C + 2 L + 3 ESP | Clay + 2% lime replacement and 3% soil weight replaced by Egg-shell powder |

Experiments were performed in laboratory on untreated virgin clayey soil and also on modified soil mixes; which were prepared using lime and Egg-shell powder to study the influence of introducing Egg-shell powder. Various experiments which were performed during this study were Atterberg's limit test, Unconfined Compressive Strength (UCS) test and Compaction test; all as per IS 2720 standards.

**Table.2: Test results of untreated and treated soil mixes**

| Sample | Liquid limit (%) | Plastic limit (%) | OMC (%) | γd (g/cc) | Mean UCS (kg/cm$^2$) |
|---|---|---|---|---|---|
| C | 23 | 11.15 | 17 | 1.74 | 0.40 |
| C + 5 L | 29 | 12.56 | 21 | 1.79 | 0.82 |
| C + 4.25 L + 0.75 ESP | 32 | 12.69 | 21 | 1.81 | 0.79 |
| C + 3.5 L + 1.5 ESP | 33 | 13.06 | 23 | 1.85 | 0.90 |
| C + 2.75 L + 2.25 ESP | 34 | 13.13 | 23 | 1.76 | 0.77 |
| C + 2 L + 3 ESP | 34 | 13.04 | 23 | 1.74 | 0.65 |

## 4. RESULTS AND DISCUSSIONS:

Addition of Egg-shell powder didn't influence the Atterberg's limits of clayey soil sample much after

adding Egg-shell powder. Consistency characteristics and flow property of the clayey soil sample was not at all allowed to change by the prepared Egg-shell powder. The variation of Atterberg's limits with the introduction of Egg-shell powder is shown in Fig 2.

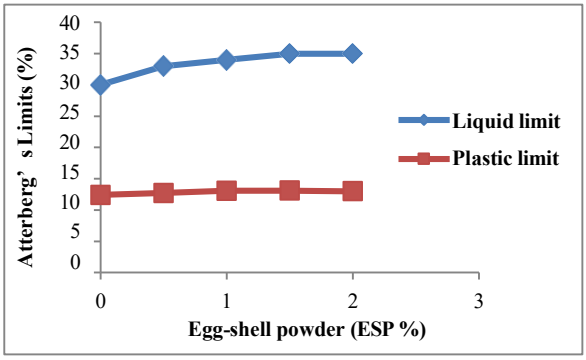


**Fig.2: Atterberg's limits vs ESP**

Soil compaction tests clearly indicated an increase in the maximum dry density of clayey soil when 25% of lime is replaced by Egg-shell powder but above this limit the dry density gradually started to decrease. Egg-shell powder is not at all a fully compatible material which can be widely used as a replacement for lime and thus the properties of soil could not be enhanced much when Egg-shell powder is introduced in considerable amount to replace the lime content. After the addition of different amount of Egg-shell powder to lime modified mix, the variations in maximum dry density are shown in Fig 3.

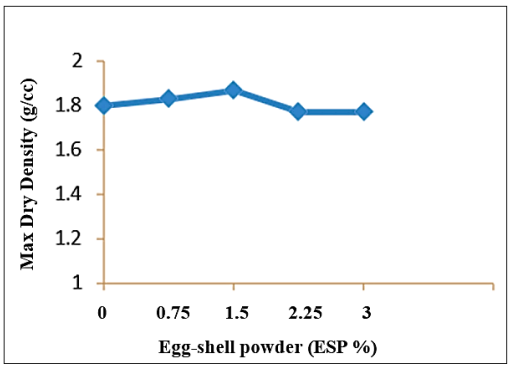


**Fig.3: Maximum Dry Density vs ESP**

It can be stated from experimental results that the modified clayey soil mixes evidently gave much higher strength value than the untreated virgin clayey soil. After testing all the soil mixes in the laboratory for determining its unconfined compressive strength, the results clearly showed that there is a considerable increase in unconfined compressive strength up to 25% of lime content replacement by using Egg-shell powder as an alternate material. Above the specified replacement level of 25%, the soil strength was revealed to be declined. Adding specified small dosages of Egg-shell powder significantly accelerated the strength value of lime modified soil mix but increasing the replacement percentage beyond specified limit made the soil strength started to fall noticeably as shown in Fig 4. This is from the fact that, addition of small dosages of Egg-shell powder appreciably increased the pozzolanic reaction rate occurring in the soil mix and thereby offered higher soil strength.

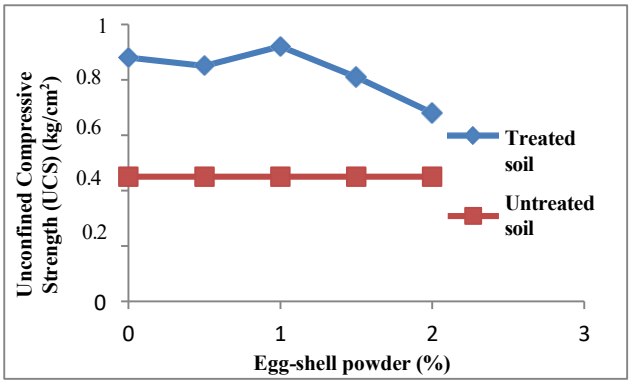


**Fig.4: UCS vs ESP**

## 5. CONCLUSIONS:

It is evident from the current study that use of Egg-shell powder can increase the strength of clayey soil mix and it can be used as an excellent replacement material of lime which very costly to produce. Using Egg-shell powder not only solved the disposal problem of widely used egg shells but also ensures economical and sustainable stabilization process for improving clayey soil properties needed to support larger loads for safe construction process.

From present the study, it was also observed that 25% of the lime content used for clayey soil stabilization process can be successfully replaced by Egg-shell powder. The replacement of lime content by Egg-shell powder considerably increased the treated soil strength. Thus, it can be concluded from the current study, that Egg-shell powder is nearly perfect replacement material for lime in the stabilization process of soft clayey soils as it bears almost similar chemical compositions.

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