

A Feasibility Study on the Compressive Strength of Flyash and Lime Stabilized Laterite Soil Blocks

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ABSTRACT: Soil is one of the nature's most abundant building materials which plays major role in the construction process. Stabilization of the locally available soil is the most effective method for improvement of soil properties. This paper deals with the experimental investigations carried out to study the compressive strength of flyash and lime stabilized laterite soil. In this study, tests were conducted to investigate the properties of laterite soil sample such as moisture content, specific gravity, grain size analysis, consistency limits, optimum moisture content (OMC), maximum dry density (MDD), unconfined compression strength (UCS), compressive strength and water absorption of blocks by replacing the laterite soil with flyash and lime in 5%, 10%, 15%, 20% and 25% by weight. The investigation revealed an increase in UCS up to 15% replacement of lime and thereafter showed a decreasing trend. On further investigation, replacement of soil sample by 5% of flyash and 15% of lime found to produce maximum unconfined compression strength. The average compressive strength of the stabilized blocks casted using the same mix gave a better strength than the conventional soil bricks.

KEYWORDS: Laterite soil, flyash, lime, unconfined compression strength, stabilized blocks.

I. INTRODUCTION

The rapid industrialization in developing countries has increased the need for infrastructure development. In order to meet these demands, alternative building materials has taken over the conventional building materials. Soil has been the most widely known and abundantly available material that can be used as a construction material. The local availability of soil makes it advantageous as it is one of the most energy efficient building materials, cost effective and is a very reliable material for low cost buildings. A variety of inorganic wastes are produced by the industries. Disposal of these wastes is yet another major problem faced by many countries across the globe. Using these industrial wastes in the various engineering applications can solve the problem of disposal of hazardous by-products and related issues. The stabilized blocks are cost effective and energy efficient alternative material to the conventional burnt clay bricks and to other commonly used masonry units in construction. To improve the quality of the stabilised blocks and also to utilise the by-product which is being dumped as a waste causing environmental issues, a detailed investigation was carried out to use lateritic soil as a raw material to make flyash stabilised blocks and lime as a binder. For the purpose of this study, flyash was collected from UPLC, Padubidre, Udupi District, Karnataka and the laterite soil was collected for Saligrama, Udupi District, Karnataka which is shown in Figure 1.1.

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Figure 1.1: Laterite Soil from Saligrama, Udipi District.

Flyash is available in large quantities as a by-product from thermal power plants and industries using coal as a fuel. This by-product because of its inherent physical and chemical properties is responsible for creating environmental problems by polluting air, water and soil. Recycling such wastes as a sustainable construction material is a best solution to solve the disposal problem as well as it is an economical option in design of green buildings. The raw material of lime is calcium carbonate (CaCO_3) which is either in the form of limestone chalk, marble, coal, corals or sea shells. The plenty of limestone in earth's crust and the ease of its transformation to calcium oxide make it a very dependable construction material. The word lime originates with its earliest use as building mortar and has the sense of sticking and adhering. Hence these materials are still used in large quantities as building and engineering materials.

This paper deals with the experimental investigations carried out to study the feasibility of flyash and lime on the stabilized laterite soil blocks. The main objective of the present study is to improve the quality of stabilized blocks by adding flyash and lime as a binding material in 0%, 5%, 10%, 15%, 20% and 25% proportions to get the desired strength and durability.

II. LITERATURE REVIEW

Several studies have been carried out to study the effectiveness of soil stabilization by adding various industrial by-products. Nayak D. et al. [1] studied the usage of granite dust with the locally available red laterite soil to produce stabilized earth blocks. Various laboratory experiments were conducted after mixing the samples in various proportions i.e., 10%, 20%, 30%, 40% and 50% by weight of soil in phase 1 of the study and then lime as a binder up to 15% was added to the optimum mix in phase 2 of the study. Singh et al. [2] used the alkali activated flyash to improve the strength properties of the weak soil. A series of experiments were conducted on flyash with alkali activation which lead to enhanced strength of this waste by-product. Similarly, the laboratory evaluation on the effectiveness of polypropylene fibres on the strength of fibre-reinforced and cement-stabilized soft clay were also studied. The results showed that the fibre additive can significantly improve the strength and ductility of the cement treated soft clay [3]. Consoli et al. [4] studied the effect of strength controlling parameters such as carbide lime content, porosity, curing temperature, curing time, porosity/carbide lime ratio on the environment friendly soil block. The results showed that compressive strength increased with increasing lime content, decreasing porosity, and increasing curing time. Nagaraj et al. [5] used lime as a partial replacement for cement in the preparation of Compressed Stabilized Earth Blocks. It was observed that blocks prepared with optimum quantity of lime along with cement has led to continuous build-up of strength even beyond 2 years, whereas blocks prepared with cement alone and lesser quantity of lime had not gained much strength after 6 months from the time of preparation of the blocks.

The physical, chemical and mechanical properties such as workability, setting times, permeability etc. of controlled low-strength material (CLSM) with the addition of waste foundry sand, coal bottom ash, cement kiln dust and wood ash have been studied [6]. Ramirez et al. [7] conducted an investigation on the application of alumina filler waste and coal ash waste for the production of unfired bricks. The laboratory results demonstrate that the compressive strength resistance of the unfired bricks reduced as the clay replacement level is increased. Kinuthia et al. [8] investigated the stabilized unfired clay bricks for environmental and sustainable use. Lime or Portland cement was used as an activator to an industrial by-product (GGBFS) to stabilize clay for unfired clay brick production. From the environmental and sustainability analysis results, the unfired clay material had shown energy-efficiency and suggested a formidable economical alternative to the firing of clay building components. Sinha et al. [9] conducted a series of laboratory tests to investigate the fatigue behaviour of interlocking grouted stabilized mud flyash brick masonry. For the range of tests considered, it was found that the effect of repeated compressive loading can cause reduction in the compressive

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strength of brick masonry as high as 25%. Building construction using stabilized soil has been a trend in different parts of the world for nearly six decades. The process of making bricks starting from collection of soil to curing, the testing methods of the bricks and the operation of machines has been discussed [10]. Kumar [11] conducted a feasibility study on the production of flyash-lime-gypsum bricks and hollow blocks to solve the problems of housing shortage and at the same time to build houses economically by utilizing industrial wastes. In the present study a feasibility study has been carried out on the compressive strength of flyash and lime stabilized laterite soil blocks.

III. EXPERIMENTAL INVESTIGATION

The laterite soil used in the present study was mixed with flyash and hydrated lime in various proportions i.e. 5%, 10%, 15%, 20% and 25% by weight of oven dry soil mix. The various laboratory tests were conducted as per the IS standards to determine the physical and engineering properties of both laterite soil and flyash. The optimum moisture content (OMC), maximum dry density, specific gravity, sieve analysis, consistency limits, plastic properties of fine soils, unconfined compression strength (UCS), compressive strength and water absorption of the stabilized blocks were determined. The determination of the moisture content of the soil sample by oven drying method was conducted as per IS: 2720 (Part-2) 1973. The moisture content (w) of the soil is determined using the relation,

$$w = \frac{W_2 - W_1}{W_3 - W_1} \times 100 \quad (1)$$

Where, W_1 - Weight of empty container
 W_2 - Weight of container + Wet soil
 W_3 - Weight of container + Dry soil

The specific gravity of a soil was determined by using pycnometer, as per IS: 2720 (Part-3) 1964. The specific gravity (G_s) of the soil is determined using the relation,

$$G_s = \frac{W_O}{W_O + (W_A - W_B)} \quad (2)$$

Where, W_O - Weight of sample of oven-dry soil
 W_A - Weight of pycnometer filled with water
 W_B - Weight of pycnometer filled with water and soil

The grain size analysis, also known as particle size distribution or gradation analysis was conducted, as per IS: 2720 (Part-6) 1995. This is conducted in two stages:

- The dry analysis, which involves shaking the representative set of sieves of varying aperture.
- The wet analysis, for fraction passing through 75μ carried out with use of hydrometer.

The unconfined compression test is a tri-axial shear test in which the minor principal stress is equal to zero i.e. the specimen is sheared under a vertical or axial stress. The samples for UCS test were prepared with OMC and MDD obtained from the compaction test. Proper care was taken to maintain the homogeneity of the mix. The Figure 2.1 shows test sample for soil with various percentages of lime and flyash.



Figure 2.1: UCS samples with various percentages of flyash and lime

IV. RESULTS AND DISCUSSION

RESULTS

The study involves correlating the unconfined compression strength (UCS), optimum moisture content (OMC) and dry density by partially replacing locally available laterite soil by various percentages of flyash and lime. The results

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obtained from experiments conducted on the laterite soil sample are as follows. The properties of the laterite soil are as shown in Table 1. The consistency limits and the soil classification of the laterite soil are shown in Table 2 and Table 3.

Table 1: Properties of laterite soil

Properties	Specific Gravity	OMC (%)	MDD (kN/m ³)	UCS (kN/m ²)
Results	2.5	17.573	17.962	167.34

Table 2: Consistency Limits

Properties	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Shrinkage Limit (%)
Results	34	25.49	8.51	8.2

Table 3: Soil Classification of laterite soil

Properties	Gravel Size (%)	Sand Size (%)	Silt and Clay Size (%)	Cu	Cc	Soil Classification
Results	39.6	58.3	2.1	11.33	1	SW

GRAIN SIZE ANALYSIS

The grain size analysis is carried out on laterite soil as per IS: 2720 (Part-6) 1995. The Figure 3.1 and Figure 3.2 shows the grain size analysis carried out by set of sieves and hydrometer for the laterite soil sample with various flyash proportions respectively.

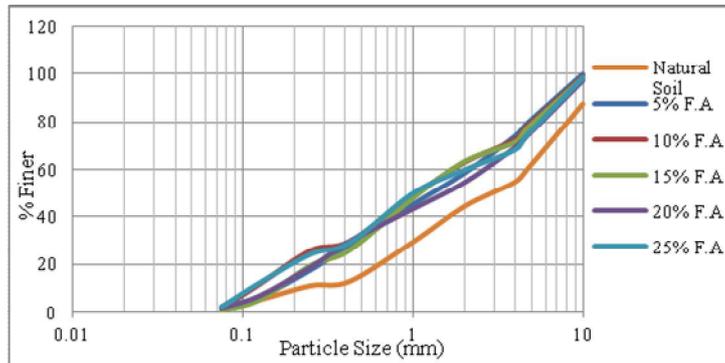


Figure 3.1: Grain size analysis

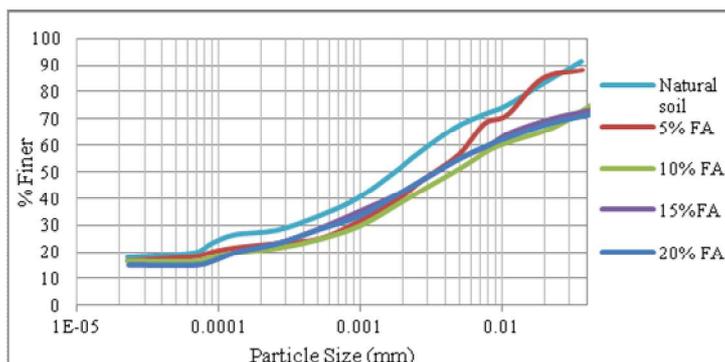


Figure 3.2: Hydrometer analysis

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CONSISTENCY LIMITS

The oven dried lateritic soil blended with flyash was tested for consistency limits as per IS: 2720 (Part-5) 1985. The liquid limit, plastic limit, and shrinkage limit of the soil sample is determined to get the flow index (I_f) and the plasticity index. The Table 4 shows the consistency limits of the laterite soil sample with various percentages of flyash.

Table 4: Consistency limits of the laterite soil sample with various percentages of flyash.

Consistency Limits	0% F.A.	5% F.A.	10% F.A.	15% F.A.	20% F.A.	25% F.A.
Liquid Limit, W _L (%)	34	32.5	30.8	29.5	28.8	28
Plastic Limit, W _P (%)	25.49	24.33	23.06	21.8	20.98	20.77
Shrinkage Limit, W _S (%)	8.2	7.96	7.33	7.67	7.02	6.88
Flow Index, I _f	7.4	7.22	7.02	7.18	6.98	6.77
Plasticity Index, I _p (%)	8.51	8.17	7.74	7.7	7.82	7.23

The plasticity index decreases as the replacement of flyash increases. Drying shrinkage is primarily governed by the plasticity index. Water-loss also contributes to the shrink of the clay fraction. From the above table, the plasticity index and shrinkage limit for the optimum mix is found to be 8.17% and 7.96% respectively.

STANDARD PROCTOR TEST

The standard compaction test was carried out as per IS: 2720 (Part-7) 2002. The variation of dry density and moisture content for the laterite soil sample is as shown in the Figure 3.3. The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of the laterite soil tested are determined as 17.962 kN/m³ and 17.573 respectively.

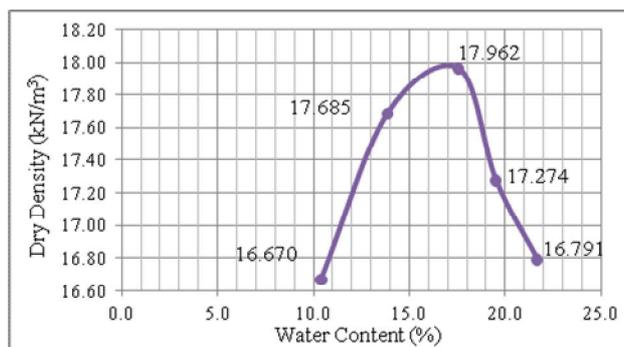


Figure 3.3: Dry Density v/s Moisture Content of laterite soil

UNCONFINED COMPRESSION STRENGTH TEST

The soil specimens are prepared with standard mould of internal diameter of 38mm and height of 76mm. The UCS of soil specimens were tested for various percentage replacements of flyash and lime. The unconfined compression strength of the laterite soil sample was found to be 167.34 kN/m². The UCS values for soil sample with partial replacement with various percentages of flyash and lime are plotted in the graph as shown in the Figure 3.4.

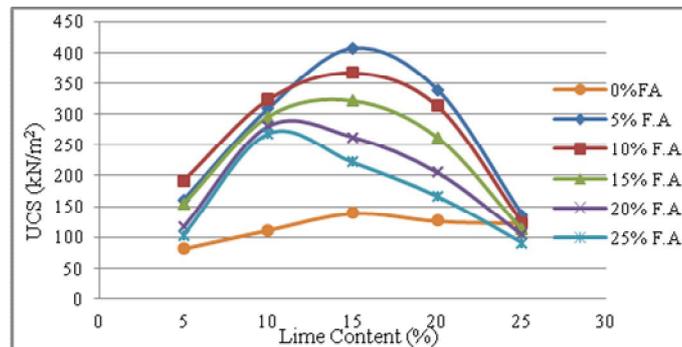


Figure 3.4: Variation of UCS for different percentage of flyash and lime

The soil sample with replacement of 5% flyash and 15% lime showed a high value of UCS compared with other mix proportions. From the graph it is observed that the soil sample replaced by 5% Flyash and 15% Lime showed about 2.5 times more strength than the natural laterite soil sample i.e. the strength was increased from 167.34 kN/m² to 406.85 kN/m². In the initial stage, addition of flyash to the laterite soil increases the frictional resistance to the load applied, which increases the stress. Later, the increase in flyash content reduces the cohesiveness of the soil and due to un-confinement, the strength of the soil sample decreases.

COMPRESSION STRENGTH TEST

The blocks of size 290mm×140mm×140mm were casted for the natural soil and optimum mix of 5% Flyash with 15% Lime and tested for strength and durability. These blocks were air dried for a day and then stacked and cured for 3, 7, 14, 21 and 28 days by covering them with moist gunny bags. After curing, the blocks were dried and tested for dry compressive strength in a compression testing machine, until the blocks failed under compression. The variation of compressive strength of blocks made with natural laterite soil and blocks with 5% flyash and 15% lime are as shown in the Figure 3.5.

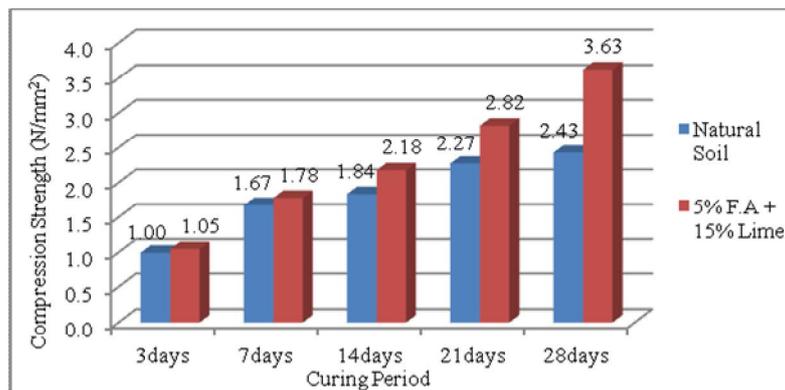


Figure 3.5: Variation of compressive strength with curing period

From the above Figure 3.5 it is clear that blocks casted of soil-flyash blended with 15% lime addition gave an average compressive strength of 3.63 N/mm² after 28 days of curing period. However, the blocks casted with only lateritic soil after natural air drying gave an average compressive strength of 2.43 N/mm² after 28 days of curing period.

In most cases, for given curing conditions, soil will achieve a maximum strength at some optimum lime content beyond which further increase will not produce a significant strength increase. The optimum lime contents will vary depending on soil type, lime type, curing period and curing temperature. Higher density achieved with higher compaction efforts also influences the strength of a lime-soil mixture. Although lime carbonation may contribute slightly to strength increase of the lime-soil mixtures, the pozzolanic reaction mechanism is regarded as the prime contributor of strength.

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WATER ABSORPTION TEST

Water absorption test is conducted over 24 hours to determine the quantity of water absorbed by the block. Initially, the cured specimens are air dried for a day and then it is submerged in water at a temperature of 27°C for 24 hours. It is weighed again on the next day and the quantity of water absorbed by the block is determined as a percentage of its initial mass. The total water absorption of 5% flyash with 15% lime stabilized blocks were tested after 3, 7, 14 and 28 days of curing period which is listed in Table 5.

Table 5: Total water absorption of stabilised soil blocks

Curing Period	3 Days	7 Days	14 Days	21 Days	28 Days
Water Absorption	24.86%	22.74%	19.03%	15.29%	12.44%

The water absorption of blocks is reduced as the curing period is increased. The blocks cured for 28 days shows less water absorption than that of 3 days value. This is due to the filling of the pore or voids by the cementitious or pozzolanic compounds. The average total water absorption value after 28 days curing is less than the water absorption of first class bricks (less than 15%).

V. CONCLUSION

In this study, tests were conducted as per the IS standards to investigate the properties of laterite soil such as moisture content, specific gravity, grain size analysis, consistency limits, optimum moisture content (OMC), dry density, unconfined compression strength (UCS), compressive strength and water absorption of soil blocks by replacing the laterite soil with various percentages of flyash and lime. The following conclusions were drawn based on the above test results:

- From the consistency test, the liquid limit and plastic limit showed a decreasing trend with the addition of flyash. The Flow index and the plasticity index also showed the similar trend.
- In the standard proctor test, the dry density and optimum moisture content showed a decreasing trend as the percentage of flyash content is increased.
- The addition of flyash showed a significant increase in the unconfined compression strength when compared to the normal laterite soil.
- The unconfined compression strength of the laterite soil with 5% flyash and 15% lime was found to be around 2.5 times more when compared to the strength of natural laterite soil sample i.e. from 167.34 kN/m² to 406.85 kN/m².
- The unconfined compression strength increases with the increase in lime content up to 15% and thereafter decreases. The UCS drastically drops down for 25% of lime content for all combinations of flyash. The strength was decreased by about 50% when compared to the natural soil sample.
- The average compressive strength of the blocks tested after 28 days of curing period was found to be more than the minimum compressive strength of fired bricks as per IS: 1077 (1992).
- The average water absorption of blocks reduced with the increase in curing period from 3 days to 28 days. The water absorption value obtained for 28 days curing period was below the minimum value as specified in IS: 1077(1992).

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