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Effects of Curing Conditions on Strength of Lime Stabilized Flyash

Aparupa Pani[1], S. P. Singh[2]
[1](Department of Civil Engineering, National Institute of Technology, Rourkela India)
[1]aparupapani@gmail.com)
[2](Department of Civil Engineering, National Institute of Technology, Rourkela India.
[2]s.p.singh@nitrkl.ac.in)

ABSTRACT: Stabilization of fly ash is one of the promising methods to transform the waste material into a safe construction material. For increasing use of flyash as a construction material, it is required to enhance some properties by stabilizing raw flyash with suitable stabilizer like lime content. The present work aims at evaluating the effectiveness of lime in stabilizing the waste products flyash and its suitability to be used as a structural fills and embankment materials. The flyash which is collected from the captive power plant of NSPCL-RSP stabilized with different percentages of lime and tested after different curing periods. Proctor compaction test, unconfined compressive strength (UCS) test and California bearing ratio (CBR) test were conducted on compacted flyash stabilized with different amounts of lime. The test result shows that an increase of either lime content or curing period, results an increase of strength. For a given flyash a suitable amount of lime can be arrived at to ensure adequate strength that can make it suitable for embankment, base or sub-base course of highway embankments.

Key words: California Bearing Ratio, Compaction Characteristics, Flyash, Lime Stabilization, Unconfined Compressive Strength.

I. INTRODUCTION

The greatest challenge before the processing and manufacturing industries is the disposal of the residual waste products. Waste products that are generally toxic, ignitable, corrosive, or reactive have detrimental environmental consequences. Thus disposal of industrial wastes is a major issue for the present generation. One of the common and feasible ways to utilize these waste products is to go for bulk utilization in construction of roads, highways, and embankments. If these materials can be suitably utilized in construction of roads, highways and embankments, the pollution problem caused by the industrial wastes can greatly be reduced. So effective usages of these industrial wastes which are substitute for natural soil in the construction not only solve the problems of disposal and environmental pollution but also help to preserve the natural soil. In recent years, environmental and economical issues have stimulated interest in the reuse of industrial waste/by-products subject to fulfilment of required specifications. Flyash is a waste material collected from thermal power plants in the form of fine residue from the burnt coal is carried in the flue gas, separated by electrostatic precipitators, and collected in a field of hoppers. flyash is a non-plastic and lightweight material having a specific gravity relatively lower than that of a similar graded conventional earth material. Several researches on application of flyash as bulk fill materials are available [2] [3]. Huge utilization of coal ash in construction of road embankments dates back to the late 1950s and early 1960s. Applications of fly ash alone or soil stabilized with flyash and admixtures for road construction have been reported by a number of researchers [8]. In [5], authors reported the unconfined compressive strength of fly ashes as a function of free lime present in them. In [1], authors reported that the fraction of lime, present as free lime in the form of calcium oxide or calcium hydroxide, controls self-hardening characteristics of fly ashes. In [1] [7] [8], have investigated the suitability of flyash as road sub-base material. Flyash containing adequate reactive silica and insufficient free lime develop considerable strength only upon addition of certain cementing agents such as cement and lime [3].

The strength increases with the increase in the lime content up to about optimum lime content. With further increase in the lime content the strength remains constant and at times decreases, causing deleterious effect. The optimum lime content up to which a given fly ash demonstrates increased strength depends on its reactive silica and varies considerably for different fly ashes. Flyashes with insufficient reactive silica show increased strength only with cement and do not generally respond well to lime [6]. The strength gained is found to depend on curing period, compactive energy, and water content [8].

This paper reports the development of unconfined compressive strength and California bearing ratio of fly ashes [14] [15] with varying lime content and curing periods.

II. Material Used

2.1 Flyash and lime

The materials used for this study are flyash and lime. The flyash collected directly from the electrostatic precipitators of captive power plant (CPP-II) of Rourkela Steel Plant (RSP). The collected samples were mixed thoroughly to get the homogeneity and oven dried at the temperature of 105-110 C. Similarly lime procured from the local market was powered, sieved through 150 micron sieve, and stored in airtight container for subsequent use. The particle-size distribution curve of the fly ashes is presented in Fig 1. The physical properties and chemical composition of the flyash are presented in Tables 1 and Table 2 respectively.

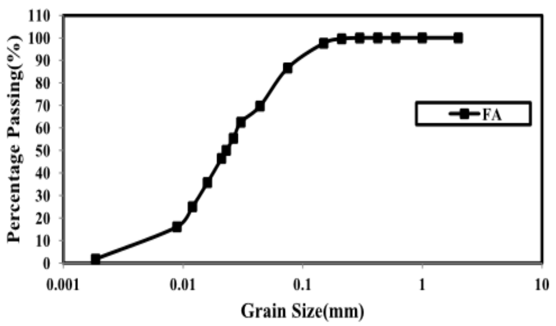

Fig 1: Particle size distribution curve of flyash

For determination of grain size distribution, the flyash was passed through test sieve having an opening size 75µ. Sieve analysis was conducted for coarser particles and hydrometer analysis was conducted for finer particles as per IS: 2720 (part IV)-1975 [4] [11] [12]. The percentage of flyash passing through 75µ sieve was found to be 86.62%. The particle size of fly ash ranges from fine sand to silt size. Coefficient of uniformity (Cu) and coefficient of curvature (Cc) for fly ash was found to be 5.88 & 1.55 respectively, indicating uniform gradation of samples.

Table 1: Physical properties of flyash

Physical parameters	Values	Physical parameters	Values
Colour	Light gray	Shape	Rounded/sub-rounded
Silt & clay (%)	87	uniformity Co-efficient (Cu)	5.88
Fine sand (%)	13	Co-efficient of curvature (Cc)	1.55
Medium sand (%)	0	Specific gravity (G)	2.38
Coarse sand (%)	0	Plasticity index (I_p)	Non-plastic

2.2 SEM and XRD studies

The surface morphology of flyash was studied by using Scanning Electron Microscope. This analysis show that flyash mainly contain spherical size particle and have uniform gradation. Micrographs were taken at accelerating voltages of 20 kV for the best possible resolution. Fig.2 shows the surface morphology of flyash. The chemical composition of fly ash was determined by XRD analysis and it shows that the flyash merely consists of aluminium oxide and silicon oxide as shown in Fig.3. Apart from these two major particles it contains magnesium (MgO), potassium (K_2O), calcium oxide (CaO).

Table 2: Chemical composition of flyash

Constituent Composition (%)	Percentage (%)
MgO	1.7
Al_2O_3	28.1
SiO_2	53.6
K_2O	1.97
P_2O_5	1.72
CaO	2.65
Fe_2O_3	1.8
Na_2O	0.5
MnO	0.3
TiO_2	0.85
SO_3	-
Loss on Ignition	6.5

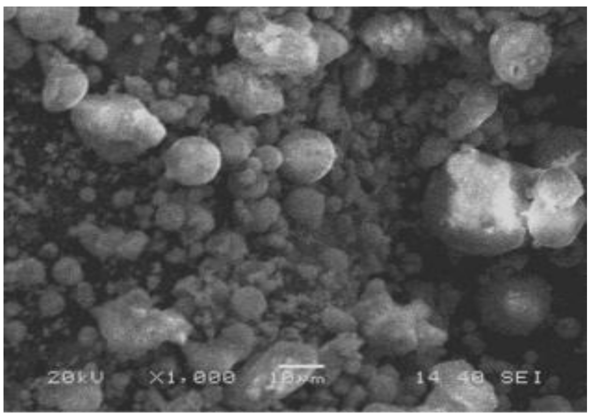

Fig 2: Scanning Electron Micrograph (SEM) of flyash

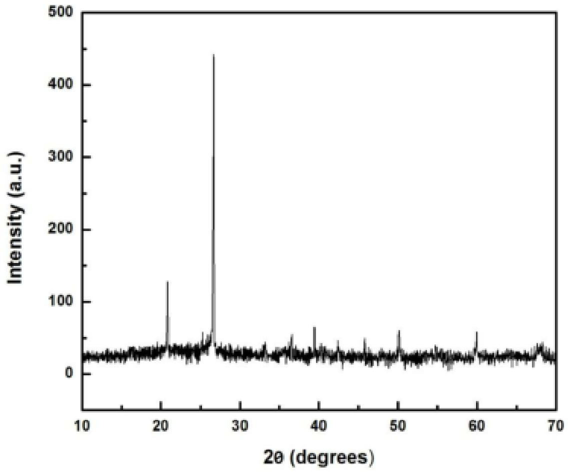

Fig 3: XRD analysis of flyash

III. Methodology

3.1 Unconfined compression test

The maximum dry density values and corresponding moisture contents of fly ashes stabilized with varying percentages of lime are reported in Table 3. Initially the addition of lime imparts plasticity to the flyash resulting in marginal decrease in dry density and increase in moisture content values but later on due to further addition of lime resulting increase in dry density and reduction in moisture content. Unconfined compressive strength tests on flyash specimens compacted to their corresponding MDD and OMC was performed according to IS: 2720 (Part 10) [9] [10]. The cylindrical test specimens were of size 50 mm in diameter and 100 mm in height and were sheared at an axial strain rate of 1.25 mm/min. The effects of curing period on strength were studied by testing the specimens after curing periods of 0, 7, 15 and 30 days. For each lime content and curing period three identical specimens were tested and the average value was reported.

Table 3.Compaction characteristics of flyash amended with lime.

Lime content (%)	Maximum dry density, MDD (g/cc)	Optimum moisture content, OMC (%)
0	1.12	40.5
2	1.085	43
4	1.089	42
8	1.097	41.5
12	1.108	41.3

3.2 California bearing ratio test

CBR tests were conducted in accordance with IS: 2720 (Part 16) [13]. For this test specimens were prepared corresponding to their MDD at OMC in a rigid metallic cylindrical mould with an inside diameter of 150 mm and a height of 175 mm. These tests were done using 50 mm diameter plunger and a surcharge load of 2.5 kg. A mechanical loading machine equipped with a movable base that moves at a uniform rate of 1.25 mm/min and a calibrated proving ring was used to record the load. The soaked and unsoaked CBR value of specimens was determined after 7 days of curing which is shown in Fig 8.

IV. Results and Discussions

The fly ash consists of grains mostly of fine sand to silt size with uniform gradation of particles as shown in Fig 1, with lower specific gravity than the conventional earth materials. Fig 4, Fig 5 and Fig 6 shows with the addition of lime results in filling the voids of the compacted fly ash thus increases the maximum dry density and decrease optimum moisture content. Moreover the specific gravity of lime is higher than that of flyash which is also responsible for higher compacted density. Increase in curing period of lime treated fly ash specimen shows improvement in the UCS and CBR value. But with smaller amount of lime that is 1%-2% the strength improvement is practically negligible, even if cured for long time. This is similar to the colloidal reaction with lime, which is mainly responsible in modifying the physical properties not the mechanical strength. With increased lime content the pozzolanic reaction peaks up producing adequate amount of cementitious compounds leading to visible increase in strength. As the lime percentage increases this facilitates the pozzolanic reaction that form cementiceous gel that binds the particles. The process of pozzolanic reaction is improved with curing period. Increase in curing period results in more pozzolanic reaction and results higher strength shown in Fig 7 and Fig 8. The CBR values of the lime stabilized specimens are found to be much higher than the untreated flyash. Moreover, the loss in CBR value on soaking is very marginal for stabilized specimens compared to compacted flyash only.

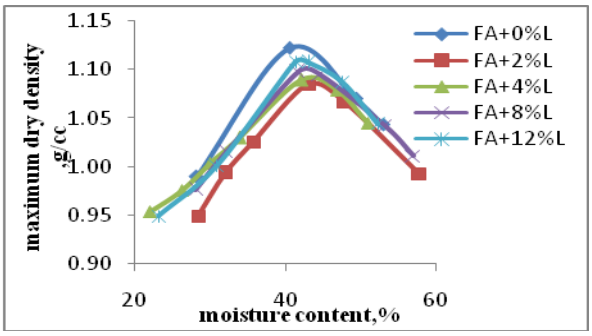

Fig 4: Relationship between dry density and water content at light compaction energy

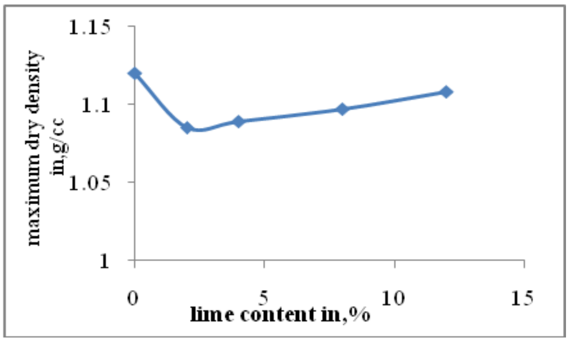

Fig 5: Variation of MDD with lime content

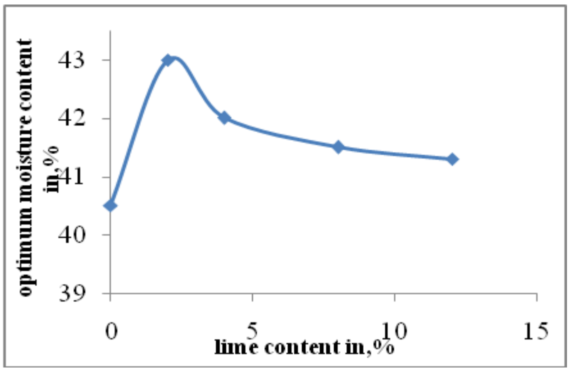

Fig 6: Variation of OMC with lime content

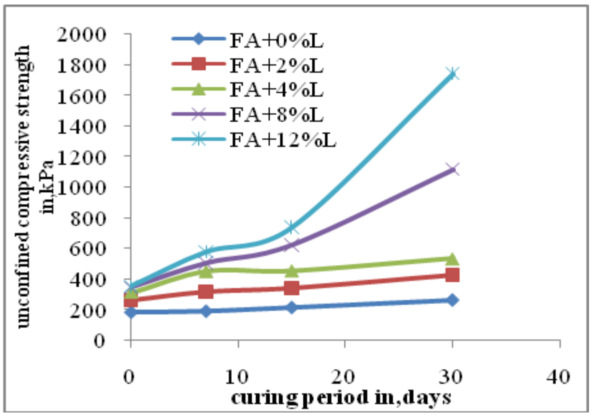

Fig 7: Variation of unconfined compression strength with curing period

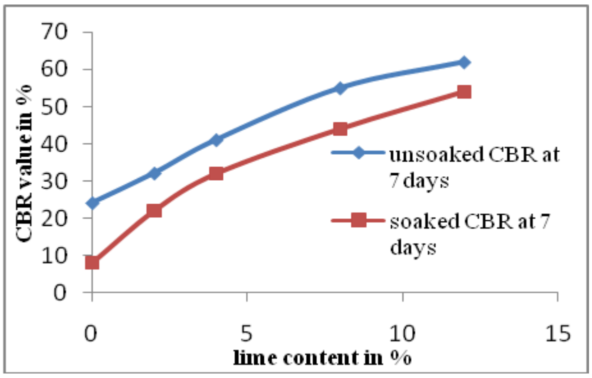

Fig 8: Variation of CBR value with lime content

V. Conclusion

Lime stabilized flyash accelerated gain in strength due to the addition of lime under different curing periods, which results decrease in dry density, increase in moisture content at initial stage but later on with further addition of lime resulting increase in dry density with reduction in moisture content due to flocculation of particles. It also helps in gaining higher unconfined compressive strength (UCS), and California bearing ratio (CBR). Increase in strength is observed at higher lime contents more than 4% after a considerable period of 30 days of curing. The unconfined compressive strength and California bearing ratio of flyash is improved with curing period due to the pozzolanic reactivity. The strength gain with curing period continues even up to 30 days for flyash specimens added with higher doses of lime but at low lime content no appreciable strength gain is observed beyond 15 days curing period.

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