

## CHARACTERISTICS OF LOW LIME FLY ASH STABILISED WITH LIME AND GYPSUM

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**Abstract.** This paper presents the effect of fly ash stabilized with lime alone and in combination with gypsum on environment in effective utilization of fly ash, a solid waste generated by thermal power plants during generating thermal power where coal used as a fuel. An extensive series of test were conducted on low lime stabilized fly ash with lime (5 – 8%) alone and in combination of gypsum (0.4 – 0.8%) which were cured for 1, 7 and 28 days. All the samples are tested for hydraulic conductivity, strength and durability characteristics. From the test result it is observed that with increase in the percentage of lime, results in increases liquid limit, up to 8%. The similar pattern was observed with the sample stabilized by gypsum. Hydraulic conductivity characteristic of stabilized fly ash improved by addition of lime alone and in combination with gypsum. This paper discusses the effect, reasons and advantages for improvement in properties of fly ash stabilized with different percentages of lime and gypsum for reduction of solid waste and effective utilization of fly ash.

### 1. Introduction

Solid waste disposal has become more problem in many countries due to fast growth urban infrastructure and industrialization. Millions of tones of fly ash is being produced by number of thermal power plants, out of which a vast majority is of fly ash having low lime content (class F). Fly ash is a solid waste generated by thermal power plants where coal is used as fuel. As the need of power is increasing with a very fast rate for development purpose, the production of fly ash is increasing rapidly while generating electrical energy by thermal power plant. Disposal of this enormous amount of fly ash (solid waste) faces problem of huge land requirement, transportation, ash pond construction and maintenance, which can be reduced by utilizing fly ash as construction material for civil engineering structures and indirectly can be reduce the environmental problems like dusting, leaching etc.

As the amount of solid waste (fly ash) increasing day by day from different thermal power plants, utilization of fly ash as a construction material is not meeting with the production may be due to low strength properties, as it is required to enhance certain engineering properties by stabilizing it with suitable stabilizers like lime and gypsum. Recent days fly ash becomes an attractive construction material because of it's self hardening characteristics for which available free lime. The variation of it's properties depends up on the nature of coal, fineness of pulverization, type of furnaces and firing temperature.

This paper presents the effects and improvement in index, engineering and hydraulic properties like optimum moisture content, dry density, and hydraulic conductivity of Class F fly ash stabilized with lime (5-8%) alone and in combination with gypsum (0.4-0.8%) through compaction and hydraulic conductivity tests.

### 2. Materials and Sample Preparation

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For this study, low lime fly ash (class F) was collected in the form of dry state electrostatic precipitator from Kota Thermal Power Plant, Kota, Rajasthan, India. Class F fly ash contain low percentage of lime (1.40%). Particle size distribution curve (Fig.1) shows that a major particle consists of silt size (84%) with some sand size particles (9%) and clay sized (7%) particles. The specific gravity of the sample (fly ash) is 2.26 and the chemical composition (% by dry weight) of the fly ash as follows: SiO<sub>2</sub>=52.6%, Al<sub>2</sub>O<sub>3</sub>=30.70%, Fe<sub>2</sub>O<sub>3</sub>=5.72%, CaO=1.40%, MgO=0.12%, LOI=5.84%, and other are 3.59%. In accordance with ASTM classifications this fly ash categorized to Class F type. This fly ash was stabilized with hydrated lime of 0%, 5%, and 8% of dry weight of fly ash. To accelerate the bonding between particles, anhydrous gypsum with 0%, 0.4% and 0.8% was also used to reduce the stabilized matrix by producing more ettringite. In this entire paper, all mixes are designated with common coding process as mentioned: FA stands for fly ash, L stands for lime, G stands for gypsum and the sample mix of fly ash, 0% lime and 0% gypsum is designated as FA+0L+0G. Total nine samples are used in this study: FA+0L+0G, FA+5L+0G, FA+8L+0G, FA+0L+0.4G, FA+0L+0.8G, FA+5L+0.4G, FA+8L+0.4G, FA+5L+0.8G, FA+8L+0.8G.

### 2.1. Water Content Density Relationship of Stabilized Fly Ash

All nine mixes, Standard Proctor compaction tests were performed according to IS: 2720(part VII) 1974. Moisture content dry density relationships obtained from standard Proctor tests of all samples are presented in Fig 2. The optimum moisture content (OMC) varied from 8.16 to 29.19%, where as maximum dry density (MDD) ranged from 1.16 to 1.44 g/cm<sup>3</sup>. Such low density of compacted fly ash was matched with results reported by previous researchers. this type of fly ash is useful for many filed applications as little change in moisture content may not rapidly change in density of field compacted layer.

### 2.2. Hydraulic Conductivity

Hydraulic conductivity is defined as the velocity of flow of water through the total cross sectional area of an aquifer under unit hydraulic gradient. This property of media is called permeability. Being such an important engineering property, hydraulic conductivity of fly ash was not studied in detail by previous researchers. In this paper an attempt is made to study in detail the hydraulic conductivity of fly ash, and stabilized fly ash along with the factors affecting the same. This test was performed on the concrete permeability apparatus. Before starting the test, it is very essential to check the seal, which should be water tight. After placing the prepared sample in mould at right position the water is allowed to flow through specimen for 100 hrs. The head loss for known time period is noted and the coefficient of permeability is calculated. The same test was performed for all the nine mixes after curing period of 1 day, 7 days, and 28 days. The hydraulic conductivity results of all the nine mixes are presented in the table 2.

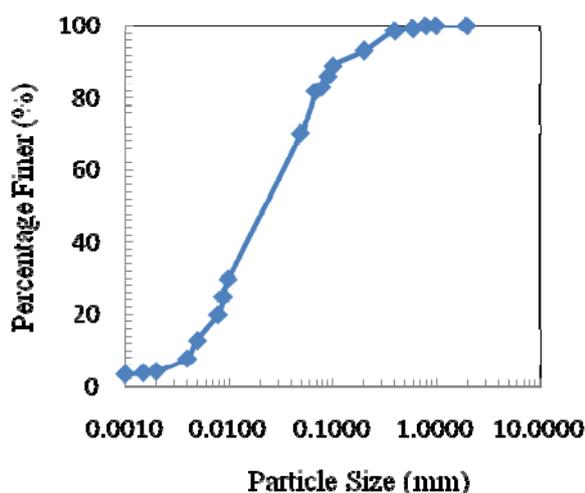


Fig. 1: Grain size distribution curve of fly ash

Table 1: Moisture content dry density of the samples

S.No.	Mix Designation	OMC (%)	MDD (gm/cc)
01	FA+0G+0L	24.45	1.21
02	FA+0G+5L	22.14	1.28
03	FA+0G+8L	20.39	1.42
04	FA+0.4G+0L	26.71	1.17
05	FA+0.8G+0L	21.16	1.23
06	FA+0.4G+5L	26.69	1.18
07	FA+0.4G+8L	25.66	1.44
08	FA+0.8G+5L	26.39	1.16
09	FA+0.8G+8L	17.21	1.31

## 3. Results and Discussion

Fig. 2 and Table 1 illustrate the variation of OMC and MDD with addition of lime and gypsum. It is observed from Fig.2 that with 5% and 8% addition of lime has increased the maximum dry density (MDD) of 33.33% and 100% respectively. From table 1, it can be observed that the percentage of water required for compaction for maximum dry density, reduces for the mixes stabilized by the lime. It is found that with increase in the percentage of lime from 0% to 5% the decrease in moisture content was 10.4% and increase in dry density was 5.5%. While for the further increase in lime percentage from 5 to 8, the decrease in OMC was 8.61% and increase in MDD was 10.73%. For the mixes stabilized by lime and modified by gypsum the OMC first increases and then decreases by 11.80% and 29.19% respectively. And the change in the dry density was found opposite to OMC, it first decreases by 3.74% and then increases by 4.68%. For the mixes stabilized by 5% of fly ash and modifies by 0.4% and 0.8% of gypsum the change in OMC is not found constant, while MDD has constant decrees in value. From table 1 it can be observed that by increasing the percentage of gypsum by 100% the OMC reduces by 1.11% only. Same pattern of change is observed for the stabilized mixed by 8% of lime and modified by gypsum. But for these mixes the decrease in OMC is 49.13% which is drastically different from mixes having 5% of lime. But for the four mixes having 0.4% of gypsum and varying percentage of lime i.e. 5% and 8% , there is decrease in both OMC and MDD, from 26.69% to 25.66% and 1.18 to 1.44. With further increase in moisture content dry unit weight begins to increase as the menisci are broken and the partials are able to move and acquire a closer packing. The MDD results when fly ash is fully saturated, when water content is increased further there happens to be fall in unit weight. For the rest graphs the pattern is not visible because as the percentage of lime - gypsum increases alone or in combination upon raw fly ash the plastic nature is increased, and plasticity reduces he capillary tension.

For all the nine type of mixes prepared which were un-stabilized mix, stabilized mix with lime, stabilized mix with gypsum and lime stabilized mixes modified with gypsum and for all the three curing periods the pattern of hydraulic conductivity is seen as reducing with increase in percentage of stabilizer. From the results tabulated it can be concluded that the hydraulic conductivity is affected by the percentage of lime in the mix, percentage of gypsum in the mix, curing period, and water content.

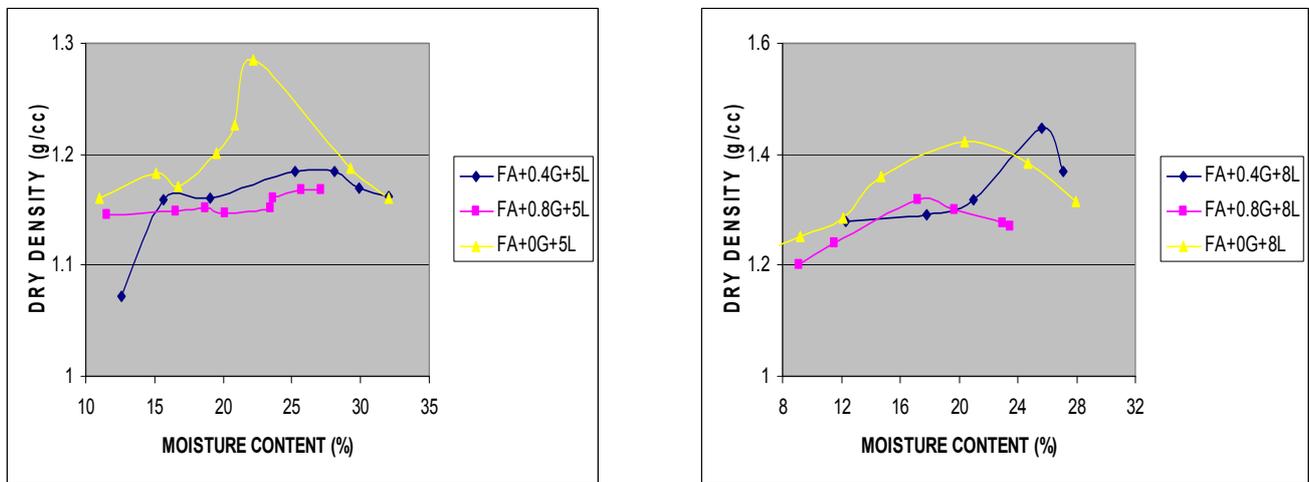


Fig. 3: Standard compaction test results of fly ash with varying percentage of lime and gypsum

Table 2: Hydraulic conductivity of samples

S.No.	Mix Designation	HC x 10 <sup>-7</sup> cm/sec		
		1 DAY	7 DAYS	28 DAYS
01	FA+0G+0L	-	-	-
02	FA+0G+5L	7.11	6.98	6.72
03	FA+0G+8L	6.90	6.87	6.54
04	FA+0.4G+0L	-	-	-
05	FA+0.8G+0L	-	6.71	6.43
06	FA+0.5G+5L	6.89	6.53	6.31

07	FA+0.5G+8L	6.90	6.62	6.21
08	FA+0.8G+5L	6.60	6.49	5.70
09	FA+0.8G+8L	6.17	5.81	5.37

#### 4. Conclusion

This research checks and improves the suitability of stabilized low lime fly ash for and as different civil engineering projects and construction material respectively through extensive laboratory test series. At present the environmental aspect of waste utilization has got special importance. Test for OMC, MDD and hydraulic conductivity is conducted for raw fly ash and stabilized fly ash for lime content 0%, 5% and 8% and lime along with gypsum contents 0.0%, 0.4% and 0.8% of dry weight of fly ash. For hydraulic conductivity test the stabilized compacted sample is cured for 1 day, 7 days and 28days, and after curing water was allowed to pass through sample for 5 days (100 hours).

Based on the experimental results and discussions as presented above, the following conclusion can be drawn:

1. By increasing the lime percentage in the raw fly ash, maximum dry density and optimum moisture content also increases up to 8%.
2. Hydraulic conductivity of fly ash decrease with increase in percentage of lime, percentage of gypsum and curing period. Presence of gypsum with lime reduces the sensitivity of hydraulic conductivity.
3. Raw fly ash stabilized with lime and gypsum can be used waste containment linear due to its property of low hydraulic conductivity.
4. By increasing the period of curing the value of hydraulic conductivity get reduced considerably.
5. The formation of complex structure by pozzolanic reaction in mixes may be the reason for the enhancement of strength due to stabilization. This complex structure may resist the formation of cracks in stabilized specimens. This may be the reason for higher durability of fly ash stabilized for longer period. This also results in considerable reduction in hydraulic conductivity.

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