# Effect of Fly-ash on Strength Behavior of Clayey Soil

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**Abstract -** *Stabilization includes various methods for improving the engineering properties of soil. Stabilization is used to increase the strength or stability of soil. With addition of fly-ash in the soil, the index properties of soil are found to be improved. It is found that the optimum moisture content decreases while maximum dry density increases with addition of fly ash. The unconfined compressive strength of the soils increases with the addition of fly ash content. This paper presents the effective use of fly ash in improving the engineering properties of clayey soil. A series of tests were conducted on clayey soil treated with fly-ash alone (i.e. 2%, 4%, 6%, 8% and 10%). From the test results, it was observed that with the increase in fly ash content the Maximum Dry Density (MDD) increased up to 5.81% at 6% fly ash content. The optimum fly ash content was determined based on Standard Proctor test and Unconfined Compressive Strength (UCS) test results. The maximum UCS value was observed at 6% of fly-ash content. The increase in UCS at 6% fly ash content was 10.9%.The use of fly ash as the stabilizer with soil is a cost-effective and environment-friendly technique to make the soil mixes strong.*

***Key Words***: Maximum dry density, Optimum moisture content, Unconfined compressive strength, Fly ash, Cost effective.

## 1. INTRODUCTION

Clayey soil generally possesses volumetric changes when subjected to changes in moisture content because of the seasonal water fluctuations. Also, low strength and high compressibility behavior of most clays can cause severe damage to civil engineering structures. Therefore, these type of soil must be treated before commencing the construction operation. Various methods are available to improve the engineering properties of these soils such as densification, reinforcement, chemical stabilization and techniques of pore water pressure reduction. The chemical stabilization of clays using fly ash is one of the best alternatives as it improves various engineering properties of soil such as maximum dry density and unconfined compressive strength.

## 2. LITRETURE REVIEW

Soil stabilization technique is done on relatively weak soil to improve its shear strength, load bearing capacity, filter, drainage system etc. The improvement behavior of soil by geo-textile technique conducted by Krishnaswamy et al (1988) concluded with the increase in reinforcement aspect the soil strength ratio increases. Ramanatha Ayyar et al. (1989) performed tests on coir fiber reinforced clay and it was observed that the discrete fibre of small diameter offer greater resistance to swelling than the larger diameter fibre placed similarly. Kolay et al. (2010) explained the soil stabilization of locally available peat soil from Sarawak, using fly ash and gypsum. The unconfined compressive strength test results showed that the peat soil got strengthened due to the addition of different proportions of gypsum and fly ash and it was also observed that the strength of peat soil increases with the increase in curing period. Ramlakhan et al. (2013) observed that with the increase in lime and fly ash content in the soil the optimum moisture content and California bearing ratio of soil increases. R. Chavali and R. K. Sharma (2014) carried out a study on influence of sand and fly ash on clayey soil stabilization. The results show significant improvement in California bearing ratio of composite containing clay, sand and fly ash as (70: 30: 10). Gyanen et al. (2013) considered the effect of both coarse and fine fly ash in unconfined compressive strength of black cotton soil. It was observed that the peak strength is attained by fine fly ash composite was 1.25 times the strength obtained with coarse fly ash composite. Cokca Erdal (2001) added Soma fly ash and Tuncbilek fly ash to the expansive soil at 0-25%. The optimum content of fly ash to reduce the swell potential was found to be 20%. Jirathanathworn and Chantawarangul (2003) found that by using fly ash mixed with small amount of lime, the engineering properties of clayey soil such as strength and hydraulic conductivity improved. Bose (2012) found that the maximum dry density of soil increases till 20% fly ash content and then its gradually decreases, however the optimum moisture decreases with increase in fly ash content. Kaushik and Ramasamy (2006) investigate the different properties of coal ash to be used as construction material. It was found that the fly ash exhibits high strength at optimum moisture content but poor shear strength at saturated conditions.

## 3. MATERIAL USED

Clayey soil samples were collected from six different sites of Guwahati city, Assam, from a depth of 1m below the ground surface. The soil was pulverized to break lumps and then air and oven dried before conducting the test. The physical properties of various soil samples are as given in Table 1. The fly-ash was collected from Hindustan Paper Corporation Limited (HPCL), Jagiroad, Assam. The specific gravity of fly ash is 1.91.

**Table -1:** Physical properties of soil

| SL no | Sample | SL 1 | SL 2 | SL 3 | SL 4 | SL 5 | SL 6 |
|---|---|---|---|---|---|---|---|
| 1 | Liquid Limit (%) | 46 | 44 | 37 | 39 | 41 | 43 |
| 2 | Plastic Limit (%) | 21 | 20 | 19 | 21 | 18 | 22 |
| 3 | Plasticity Index (%) | 25 | 22 | 18 | 18 | 23 | 21 |
| 4 | Specific Gravity (G) | 2.63 | 2.65 | 2.63 | 2.60 | 2.59 | 2.58 |
| 5 | OMC (%) | 14.6 | 14.1 | 15.2 | 15.6 | 18.7 | 18.4 |
| 6 | MDD (g/cc) | 1.87 | 1.91 | 1.86 | 1.72 | 1.67 | 1.64 |

## 4. COMPACTION AND UNCONFINED COMPRESSIVE STRENGTH TEST

The Standard Proctor Test were done as per IS 2720 (Part 7) - 1980 to determine the OMC and MDD for all the six samples. The value of OMC and MDD are given in Table 2. For unconfined compressive strength test, samples of 3.8 cm diameter and 7.6 cm height were prepared by the compaction of the samples at their optimum moisture contents and maximum dry density. All the samples were tested at an axial strain rate of 1.2 mm /min as per IS: 2720 (Part-X). The Unconfined compressive strength of all the six samples are given in Table 2.

**Table -2:** Engineering properties of soil

| SL no | Sample | SL 1 | SL 2 | SL 3 | SL 4 | SL 5 | SL 6 |
|---|---|---|---|---|---|---|---|
| 1 | Optimum Moisture Content (%) | 14.6 | 14.1 | 15.2 | 15.6 | 18.7 | 18.4 |
| 2 | Maximum Dry Density (g/cc) | 1.87 | 1.91 | 1.86 | 1.72 | 1.67 | 1.64 |
| 3 | Unconfined Compressive Strength ($kN/m^3$) | 112 | 119 | 120 | 117 | 111 | 107 |

## 5. EXPERIMENTAL OBSERVATION

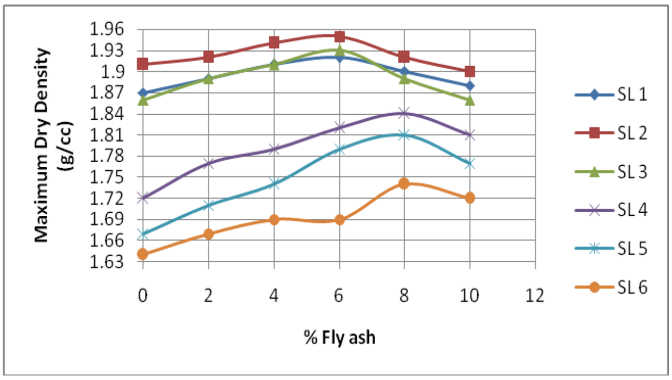


**Figure -1:** Variation of maximum dry density with fly ash content

From the Figure 1, it can be observed that the maximum dry density of the soil increases with the increase in fly ash content and attained a maximum value at 6% of fly ash content and then further addition of fly ash leads to decrease in maximum dry density.

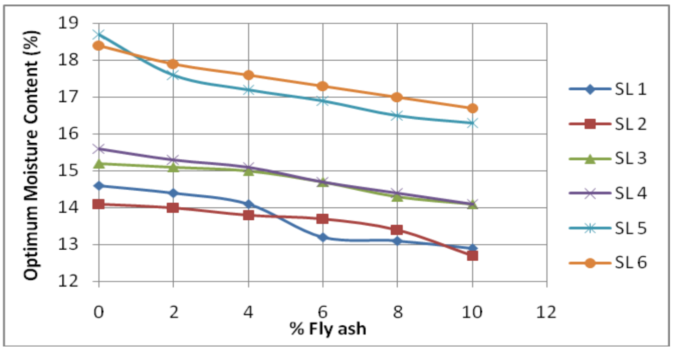


**Figure -2:** Variation of optimum moisture content with fly ash content

From the Figure 2, it can be observed that with the addition of fly ash to the soil, the optimum moisture content start decreasing.

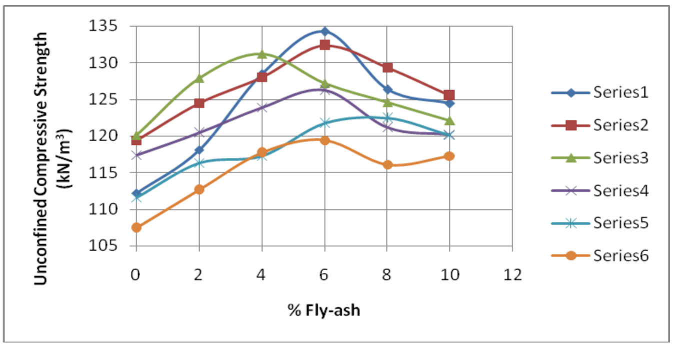


**Figure -3:** Variation of unconfined compressive strength with fly ash content

From the Figure 3, it is observed that with the increase in fly ash content the unconfined compressive strength is increasing and attained a maximum value at 6% of fly ash and then on further increase in fly ash content the unconfined compressive strength decreases.

**Table -3:** Unconfined compressive strength of soil

| | UCS (kN/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| flyash (%) | SL 1 | SL 2 | SL 3 | SL 4 | SL 5 | SL 6 |
| 0 | 112.2 | 119.4 | 120.1 | 117.4 | 111.6 | 107.4 |
| 2 | 118.1 | 124.5 | 127.9 | 120.4 | 116.3 | 112.6 |
| 4 | 128.5 | 128 | 131.2 | 123.9 | 117.3 | 117.7 |
| 6 | 134.2 | 132.3 | 127.2 | 126.2 | 121.7 | 119.4 |
| 8 | 126.3 | 129.3 | 124.6 | 121.1 | 122.4 | 116.1 |
| 10 | 124.4 | 125.5 | 122.1 | 120.2 | 120.1 | 117.3 |

## 6. CONCLUSIONS

The following salient observations are obtained from the study:

1. From figure 1, the maximum dry density is obtained at 6% of fly ash content for the samples (SL 1, SL 2, SL 3) and the maximum dry density is obtained at 8% of fly ash content for the samples (SL 4, SL 5, SL 6).
2. From figure 2, it is observed that with the increase in fly ash content the optimum moisture content decreases.
3. From figure 3, it is observed that the unconfined compressive strength is maximum at 6% of fly ash content for the samples (SL 1, SL 2, SL 4, SL 6).
4. From figure 3, it is found that the unconfined compressive strength is maximum at 4% of fly ash content for the sample (SL 3).
5. From figure 3, it is found that the unconfined compressive strength is maximum at 8% of fly ash content for the sample (SL 5).

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