# Effect of Reinforcement on Stress Strain Behavior of Fly Ash: An Experimental Investigation

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***Abstract*— Coal based thermal power plants produce abundant amounts of fly ash which are disposed of on-site impoundments behind engineered earth dam. One of the best applications of fly ash is using it as a construction material as embankments, fills etc. This paper studies properties of fly ash, effect of reinforcement on the stress-strain behaviour of fly ash. A comprehensive set of laboratory uniaxial compression tests were carried out on fly ash with and without reinforcement. The stress strain behaviour was analysed by changing galvanised iron (GI) reinforcement numbers and location. The influence on number & location of GI reinforcement on stress strain behaviour of sample were studied. It was observed that the inclusion of GI reinforcement increases the peak stress; axial strain at failure. In general, inclusion of reinforcement in fly ash layer can greatly increase the strength, stiffness of fly ash layer thereby comparable strength can be obtained even with decrease of thickness of layer.**

***Keywords*— fly ash, stress-strain behaviour, galvanised iron (GI), unconfined compression test.**



## I. INTRODUCTION

Fly ash, residue from coal based thermal power plants, and comprises of fine particles that rise with the flue gases. Safe disposal of fly ash, a waste end product of thermal power plants, is a challenge that the engineers and environmentalist are facing in the modern era of urbanization. One safe method of disposing this waste by-product is to utilize them in the civil engineering construction activity. The reinforced earth is a construction method which is gaining more popularly among the civil engineers because of its inherent characteristics of simplicity, design confidence and the easy method of construction. The reinforced earth is a combination of tensile reinforcements and a frictional back fill soil. Generally a well graded sand or gravel sand is used as a backfill material as they offer adequate friction and provide good drainage. With the usage of fly ash in the backfill not only the method of construction becomes more economical, the disposal problem of fly ash is also taken care to some extent. The research work carried out on the utility of fly ash when subjected to monotonic or static loading have established clearly the effectiveness of fly ash as backfill material. However the studies on the performance of this backfill material when subjected to repeated loads is limited.

Several investigators have studied stress-strain and strength characteristics of reinforced soil using tri axial, direct shear, and plane strain tests. Some of these investigations are given here to provide a reference to existing experimental data on the behaviour of reinforced soils. Broms (1977) researched the mechanical behaviour of geotextile reinforced sand with monotonous grain size using a number of tri axial tests. Holtz et al. (1982) conducted a number of long-term and short-term triaxial tests on dry sand reinforced by woven and nonwoven geotextiles. They also observed the influence of reinforcement on the creep of reinforced samples. Nakai (1992) investigated the stress-strain behaviour of reinforced sand using triaxial tests and finite element analysis, a comprehensive set of laboratory unconfined compression tests was carried out on fly ash with and without reinforcement. The stress strain behaviour was analysed by changing geo grid numbers with different locations. The influences of the number of geogrid layers on sample were studied and concluded that the hyperbolic equation (Kondner, 1963) can be used to represent the stress–strain relationship of both unreinforced and reinforced fly ash.

Here all the above investigations studied the effect of geotextile on the behaviour of sand; the present investigation contributes for the effect of GI reinforcement on stress-strain behaviour on Fly ash. GI reinforcement is used in order to improve the bearing capacity of fly ash for its versatile uses and the stress – strain behaviour of the reinforced fly ash is determined. The optimum position and numbers of GI reinforcement distance between the layers of geo grids are determined.

## II. OBJECTIVE & SCOPE

Construction of steep slopes reduces the usage area, though fly ash alone accomplishes it, for better results fly ash is combined with reinforcement. Economic way of conductions is possible by the inclusion of reinforcement since it reduces the thickness. The stress-strain curve of fly ash by varying the location and number of reinforcement can be used to represent the stress–strain relationship of both unreinforced and reinforced fly ash. A series of laboratory unconfined compression test has been carried out to prove the effectiveness of reinforcement in fly ash layer.

This paper having the following objectives:

- To find the effective reinforcement position (which increases the peak stress and strain)
- To study the effect of density on reinforced fly ash sample

## III. METHODOLOGY

To investigate the effect of test parameters on the mechanical behaviour of unreinforced fly ash, uni axial compression tests were performed on number of samples both reinforced and unreinforced condition. The test conducted to study the various parameters on stress strain behaviour includes number of steel reinforcement, positions, density and moisture content. The sample size in all the tests performed was kept constant L/D ratio of 2 i.e. 75 mm diameter and 150 mm height. A summary of these test parameters is given as under:

### *A. Test materials:*

**Fly ash:** The fly ash used in investigation was collected from NTPC kanihe. Samples are oven dried at $105^0$ c and are preserved for future use. Tests like standard proctor test, modified proctor test, direct shear, and Specific gravity are conducted and results of which are shown in Table 2.1.

**Galvanised iron (GI)**: commercially available GI has been used in the present investigation as a reinforcement which having a grid size of 1cm x 1cm and properties shown in table 2.2.



### *B. Experimental Program*

As per IS-2720, Standard Proctor test (part-7) and Modified Proctor test (part- 8) was conducted and the relation between Optimum moisture content and dry density was determined. As per IS-2720(part-10) uni-axial compression test (75 mm diameter and 150 mm height) was performed under the strain controlled loading conditions to obtain maximum vertical stress for respective densities, for both unreinforced and reinforced fly ash samples. The stress-strain curves for different layers and position of GI reinforcement are plotted and the peak stress was figured out

Table 2.1 Properties of fly ash

| Sl.no | Properties | Magnitude |
|---|---|---|
| 1 | Density standard proctor test | 1.193g/cc |
| | Modified proctor test) | 1.349g/cc |
| 2 | OMC standard proctor test | 39.06% |
| | Modified proctor test | 27.45% |
| 3 | Specific gravity | 2.43 |
| 4 | Cohesion | 18 kN/m$^2$ |
| 5 | $\phi$ | $28.8^0$ |

Table 2.2 Properties of GI

| Sl.no | Sample ID | values |
|---|---|---|
| 1 | Displacement at Peak (mm) | 6.284 |
| 2 | Load at Peak (kN) | 0.4195 |
| 3 | Strain at Peak (%) | 12.57 |
| 4 | Stress at Peak (MPa) | 23.9 |
| 5 | Strain at Break (%) | 18.43 |
| 6 | Load at 0.2% Yield (kN) | 0.379 |
| 7 | Stress at 0.2% Yield (MPa) | 21.62 |
| 8 | Young's Modulus | 2882 |
| 9 | Strain At Break (%) | 18.43 |

## IV. RESULTS AND DISCUSSION:

The parameters dry density $\gamma_d$ and OMC obtained from standard proctor test. Unconfined compression test, was conducted using the obtained OMC and $\gamma_d$ values, and stress-strain curves obtained. The typical stress-strain curves for unreinforced and reinforced sample with different number of reinforcement and different locations under 80% and 90% 100% OMC have been shown in Figs. 1-3.

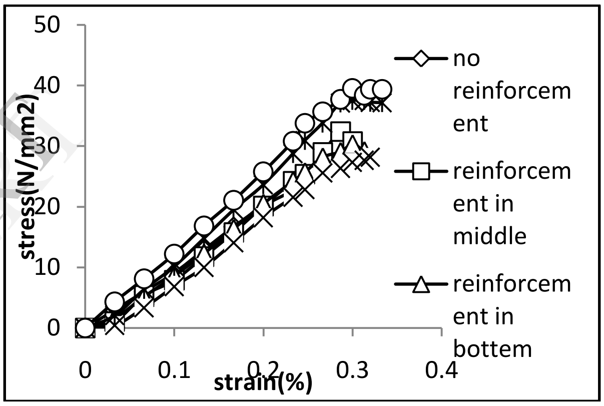


Fig 1: Stress-Strain Curve (100% OMC)

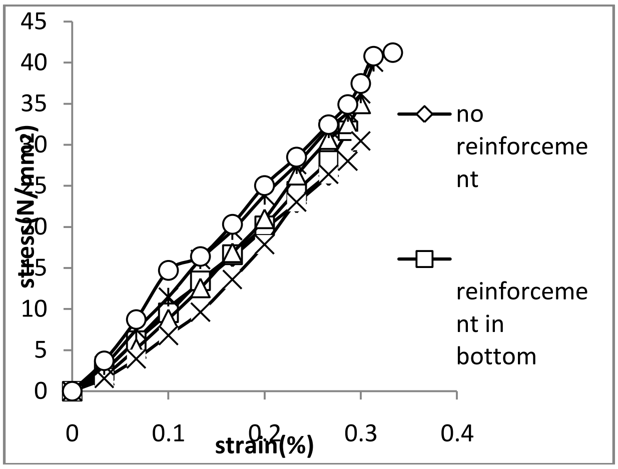


Fig 2: Stress-Strain Curve (90% OMC)

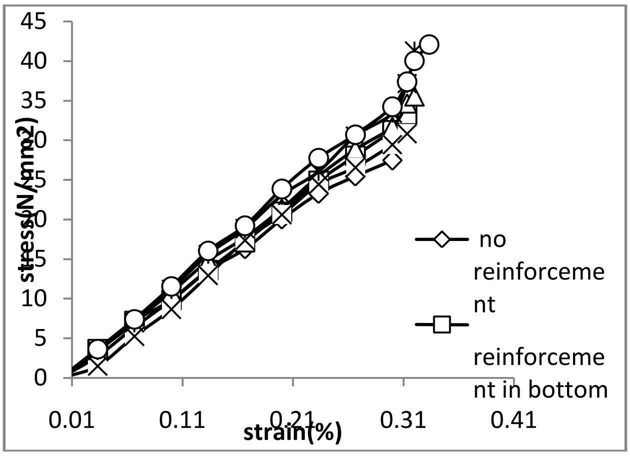


Fig 3: Stress-Strain Curve (80% OMC)

The above experimental procedure is repeated using the parameters dry density $\gamma_d$ and optimum moisture content (OMC) obtained from Modified proctor test. The results are shown in Fig 4-6.

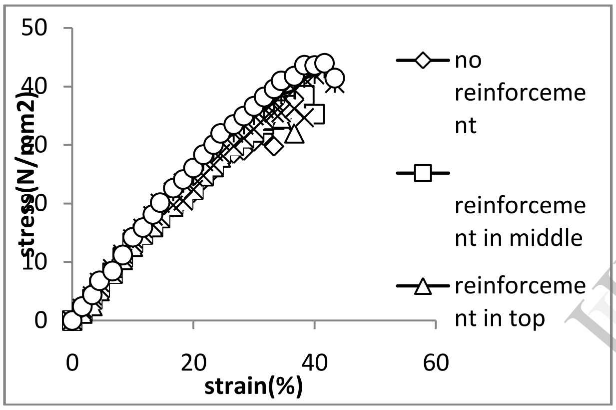


Fig 4: Stress-Strain Curve (100% OMC)

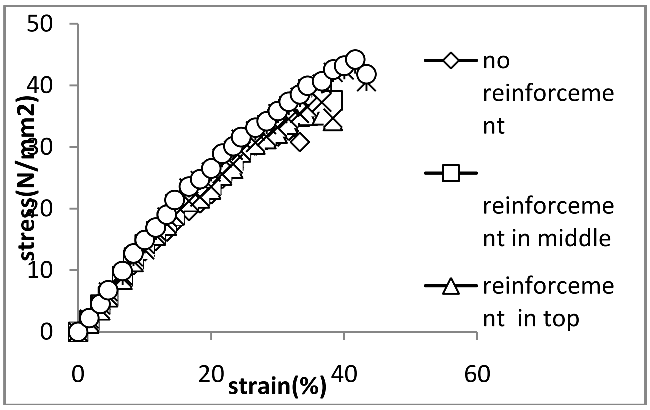


Fig 5: Stress-Strain Curve (90% OMC)

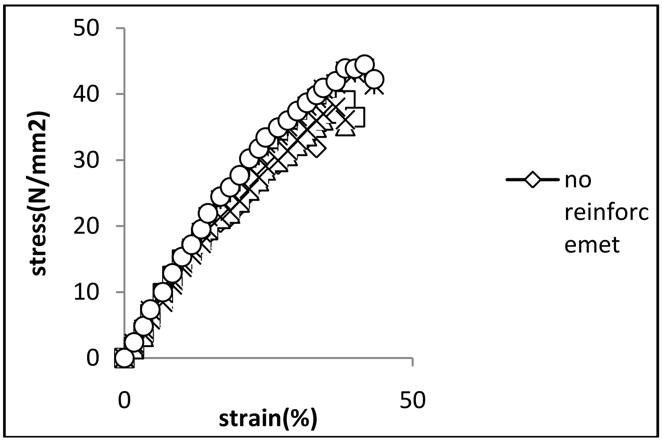


Fig 6: Stress-Strain Curve (80% OMC)

The effect of variation of moisture content on unconfined compressive strength of varies samples tested are (both standard & modified proctor tests) shown in Fig7. From the Fig.7 it is observed that the reinforcement inclusion increases the peak stress and shear strength of the samples considerably, compared with unreinforced samples and Significant variations are observed on changing the location and numbers of GI reinforcement, where as effective results are observed when a single reinforcement is placed on the middle compared to other locations, whereas, as the numbers of reinforcement are increasing at different places, the strength acquired also increasing, and achieved the constant state. In Fig 8, stress comparisons are made between unreinforced and reinforced fly ash samples compacted at various percentage of OMC (both Standard & Modified proctor tests).

In general, it is observed that the inclusion of GI reinforcement in middle gives better result compared to others and also with increase in numbers of GI reinforcement.



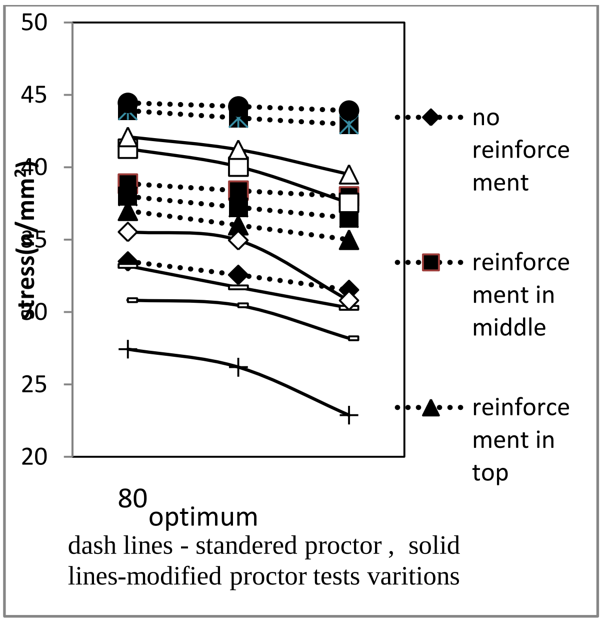


Fig 7: Comparison of different peak stress at OMC

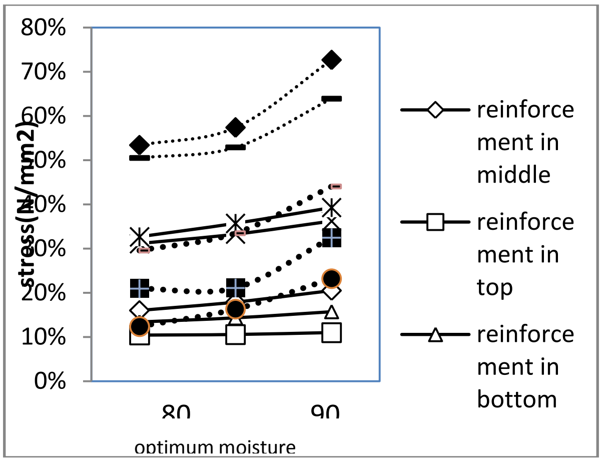


Fig 8: Comparison stress between unreinforced & reinforced fly ash

The optimum number of GI reinforcement is 3 for the parameters dry density $\gamma_d$ and OMC 80%obtained from the Modified proctor test. It can be observed that, there were no pronounced failure points in stress-strain. The figures also shows that the beneficial effect of GI reinforcement to enhance the strength of reinforced samples appear in high strain. It means that, the high strain levels should be imposed to appear the effect of GI reinforcement layers to increase the strength of samples.

## V. CONCLUSION:

A series of uniaxial compression tests were performed on number of samples both reinforced and unreinforced condition. From the experimental results the following conclusions can be drawn as follows,

1) It is noted that GI reinforcement inclusion considerably increases the peak strength, axial strain at failure and reduces post-peak loss of strength.

2) The increase in peak stress in case of samples prepared at standard proctor density is found to be lower than the modified density. A similar pattern also observed for peak strain.

3) It is also noted that the percent deviation of OMC in all the tested cases found to vary significantly.

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