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Effects of Moisture Content Variation on Shear Strength Properties of Flyash Samples

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Abstract: In a country where there is scarcity of land, it's difficult to think free space for the disposal of wastes like Flyash. In many countries where coal burning power stations are the sources of power generation, fly ash produced in bulk and its production exceeds several folds of its usage. However, in geotechnical engineering, the usage of fly ash for backfill materials and admixture in ground improvements is relatively increasing. In this paper, an attempt was made to determine the appropriate water content for usage of Flyash in retaining walls as backfill material. The shear strength properties of fly ash were determined at various moisture contents. The main purpose of this experimental program was scheduled and performed to optimize the moisture content of fly ash, so that its angle of internal friction will be the maximum value and its apparent cohesion values will be the minimum. The standard proctor compaction test was performed on flyash samples and the optimum moisture content and maximum dry density values were calculated accordingly. The different moisture contents selected were 10%, 13% and 15% dry side of OMC, 20 % OMC and 25% wet side of OMC. The direct shear test experimentation was conducted at three different normal stresses; these were 50kpa, 100kpa and 150 kpa. The experimental results have shown decreasing of the angle of internal friction and increasing of apparent cohesion up to OMC value. However, on wet side of the OMC, both the apparent cohesion and angle of internal friction have been shown to be decreasing. As a result the moisture content at 10% dry side of optimum fulfilled the requirement and selected to be used for the ongoing retaining wall experimental work. In this study, the shear stress and horizontal displacements of the experiment, the angle of internal friction and apparent cohesion are discussed at various moisture contents.

***Keywords:** Flyash, Waste Material, Optimum Moisture Content, Maximum Dry Density and Direct shear*

1. Introduction

The sources of power and its generation highly affect the development and prosperity of any country. The main focus of the developing nations in the entire world is to generate power and utilizing it for their development. Studies have shown that, India had generated 1362 MW in 1947 and its power generating capacity was increased to 120,000 MW in 2004-05. In addition to that, the capacity was forecasted to be increased to 200,000 MW by 2012 and 300,000 MW by 2017 (6) and (16).

Fly ash is a fine powder produced as waste material in bulk from thermal power stations where coal is the major source. In a country where there is scarcity of land, it's difficult to think free space for the disposal of wastes like Flyash. Its disposal poses lots of problems on the environment such as the air, the water and the soil as well. Therefore, the proper solution for the problems mentioned is utilizing it in bulk in the field of civil engineering, such as Construction material for embankments, as base and sub-base materials in road construction, for abutments and most importantly as a backfill material for retaining walls. Because of its less expensiveness and availability, India strongly depends on a natural fuel for power generation called coal. However, it has high amount of ash which is about 35-50%. As a result, from India's thermal power plants, the annual fly ash production was expected to be about 170 million tons by 2012 and 225 million tons by 2017 (1).

Several types of geotechnical engineering problems such as lateral earth pressure of retaining walls, slope stability of natural or artificial slopes and bearing capacity of foundations and abutments etc. are directly or indirectly related to the shear strength parameters of the soil. The current study deals with bulk utilization of flyash in the field of geotechnical engineering as a substitute of conventional backfill materials. Therefore, studying shear strength properties of flyash can play a vital role towards its bulk utilization as backfill material behind retaining walls.

Several researchers conducted direct shear tests on cohesive and cohesionless soils, to determine: the effects of moisture content variation on shear strength parameters and the interface friction angle between the soil and reinforcements for various applications (11), (12), (13), and (10). However, the effect of moisture variation on compacted flyash is not studied very well. As a result, to have a good moisture density relationship for reinforced compacted flyash, it's required to select different moisture contents to study the Nashik flyash by direct shear testing method. According to (2), the development of the apparent cohesion of flyash was reported to be the surface tension developed between the flyash grains that pull each other. However, this phenomenon will not go beyond the optimum moisture content value of the flyash under consideration. The current study on the Nashik flyash exhibits maximum value of apparent cohesion at the optimum moisture content and suddenly fallen down beyond the optimum moisture content.

(14) Have done experiments on the properties of pulverized coal ashes especially on flyash for suitable structural filling materials.in their discussion, they emphasized how flyash production and delivery processes going on in thermal power plants. In this study their main objective was identifying the particle shapes of flyash material as well as its cyclic properties. The very important parameter related to our study is the flyash particle shape. The authors reported the details of the particle shapes which were studied under the electron microscope. As a result different shapes of flyash particles were reported; these were large irregular grains, small irregular agglutinated forms and small to medium sized spheres. In addition to this, when flyash is selected as a construction material in the field of geotechnical engineering, determining its shear strength parameters are very important. Some researchers have studied unconsolidated undrained triaxial tests (2), (15), (7), consolidated direct shear tests (3) on flyash samples compacted at OMC. However, depending on its purpose, the Nashik flyash was mixed homogeneously with different moisture contents and the shear strength parameters were determined by conducting direct shear testing. (5) Studied the geotechnical engineering properties of the mixture of bottom ash and class F flyash under consolidated drained triaxial testing at 50 kpa, 100 kpa and 200 kpa confining stresses. The overall result of their experiment was reported to be very distinct and it was found to be different from conventional soils in general, this was due to the shape of the particles of both the bottom ash as well as the flyash. According to the reviewed literatures, previously flyash was mainly one of the components in concrete structures and its limited utilization made disposal problems. Because of the reason that, it required disposal costs in large, flyash was reported to be “a negative cost material”. However, its use was reported as in waste stabilization, landfill liners and it is also a component to stabilize road bases as well (9).

2. Methodology

1.1 The Flyash under Experimentation

The current flyash for experimentation was collected from Nashik (an ancient city of India located in the north-west region of Maharashtra), procured through “RPS Infrastructure Limited, Mumbai” in a dry state. The standard proctor compaction test was conducted on flyash samples as per ASTM C 698 to determine the maximum dry density and the optimum moisture content. As a result MDD was found to be 12.535 KN/M3 and the corresponding OMC was found to be 20%. The standard proctor compaction test curve is presented in Fig. 1.

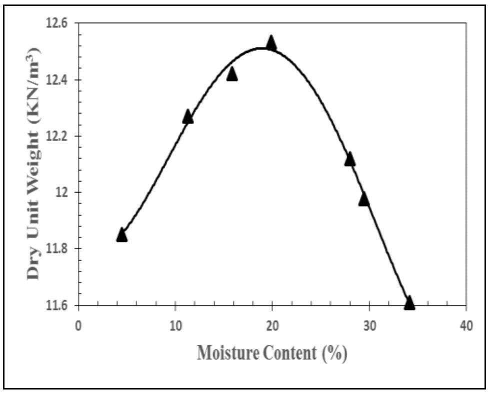

Figure1 *Standard proctor compaction curve of flyash*

2.1 Experimental Program, Test Equipment and Procedure

The experimental program was planned to perform series of direct shear tests in order to investigate the effects of various moisture contents on the shear strength parameters of compacted flyash. The experimental program covered a total of 15 tests and 3 trial tests were performed prior to the main experiment. In this study, five moisture content values were selected such as; 10%, 13%, 15% dry side of OMC, 20% OMC and 25% wet side of OMC. Correspondingly three vertical stresses were also selected these were 50 kpa, 100 kpa and 150 kpa. The final target for the experimental plan in this study was to find out the moisture content where the angle of internal friction is maximum and the apparent cohesion value is minimum.

The dry weight of flyash and the amount of water required were prepared and mixed together by hand. In a shear box of dimensions 60mm*60mm*20mm, the wet flyash was compacted by tamping by adjusting the number of layers and tamps per layer to accommodate the total sample in the shear box. Therefore, the specimens were compacted to attain 90% compaction density.

3. Results and Discussion

3.1 Effects of Moisture Content on Angle of Friction and on apparent Cohesion of Flyash

Flyash is a very light weight material when it’s compared with conventional backfill materials. And in a dry state it is cohesionless and by any means its non-plastic material. Therefore, it can be confirmed that, its shear strength is due to the angle of internal friction at a given loading condition. Hence, the shear strength of flyash in a dry state develops by the angle of internal friction only. However, when flyash is in unsaturated and compacted state, it develops apparent cohesion that pulls the flyash grains together. Fig. 2 shows the plots of apparent cohesion and moisture content. As the moisture content value increases the apparent cohesion keeps on increasing and attains its maximum value at OMC and gradually it falls again beyond the optimum moisture content. This is due to the loose contact force of the flyash grains by the developed pore water pressure.

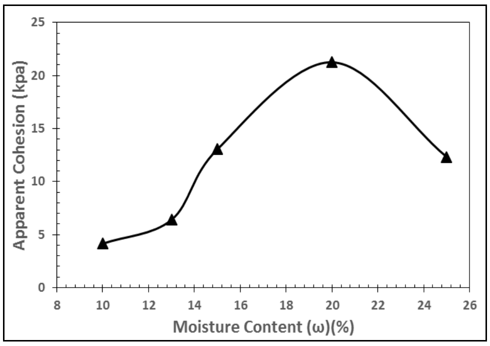

Figure 2 *Variation of apparent cohesion of fly ash with moisture content*

However, as the moisture content increases, the angle of internal friction reduces unlikely to the apparent cohesion, Ruther it reduces marginally. The range of variations of the angle of internal friction as per Fig. 3 and Table 1, were found to be 26.50 to 33.20. The flyash samples compacted at dry side of OMC gave relatively high shear strength values. In this experiment, the moisture content that gave maximum angle of internal friction and minimum apparent cohesion was selected to be 10% of moisture content. As a result, this value will be used for the ongoing reinforced compacted flyash backfilled retaining wall.

Table 1 *Different values of apparent cohesion and angle of internal friction at different moisture contents*

Moisture content, ω (%)	Apparent cohesion, Ca (kpa)	Angle of internal friction, ϕ (^{0})
10 (dry side of OMC)	4.2	33.2
13 (dry side of OMC)	6.4	29.4
15 (dry side of OMC)	13	28.3
20 (at OMC)	21.3	27.7
25 (wet side of OMC)	12.3	26.5

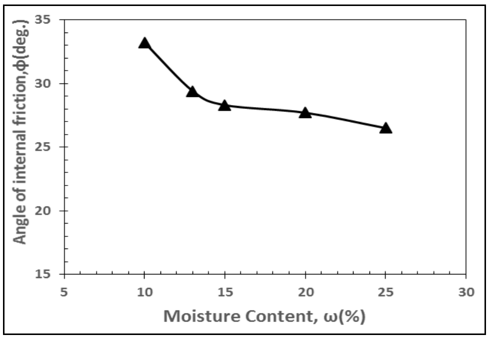

Figure 3 *Variation of angle of internal friction of fly ash with moisture content*

3.2 Shear Stresses versus horizontal displacements

The shear stresses and the corresponding horizontal displacements of the flyash samples compacted at different moisture contents and each similar samples were tested under 50kpa, 100kpa and 150kpa of vertical stresses. Fig.4 shows the various shear stresses versus graphs of horizontal displacements of flyash samples compacted and tested at different moisture contents. As it can be observed on the graphs, the increase in shear stresses in all the graphs increases the horizontal displacements up to failure, i.e., the increasing of shear force mobilises the shear stress of the soil sample in the shear box and hence horizontal deformation came to exist. It is also noted that, as the vertical stress increases the corresponding shear force value at the same displacement spot also increases. Here the relationship between the graphs of shear stress and horizontal displacement shows, a peak stress value which reduces gradually to residual shear stresses at maximum horizontal displacement. The values of the shear stresses and horizontal displacements in each graph clearly shows, how the shearing resistance in kg/cm^2 increases when the normal stress increases from 0.5 kg/cm^2 to 1.5 kg/cm^2. This implies, the shearing resistance of a soil or in our case flyash is highly dependent on the magnitude of the contact force between soil/flyash grains. This was in fact due to the vertical normal stresses.

4. Conclusion

The main purpose of conducting direct shear test on Nashik flyash was to investigate the suitable moisture content for the ongoing flyash backfilled retaining wall at which the angle of internal friction of flyash is required to be maximum and the apparent cohesion is required to be minimum. Based on the experimentation, the following conclusions can be drawn.

1. In a dry state, flyash is cohesionless material and its strength is due to its angle of internal friction. However, when flyash is in unsaturated and compacted state it develops apparent cohesion that pulls the flyash grains together. Therefore, in this experiment it was observed that when moisture content is increasing, the apparent cohesion becomes developing and attains its maximum value at OMC. However, it becomes decreasing beyond OMC value. On the other direction, the angle of internal friction was constantly observed to be decreasing marginally as the moisture content increases. The reason behind the reduction of friction angle when moisture content is increasing was due to lack of contact of soil grains among each other, because the pores were field by some moisture.
2. The flyash collected from Nashik has apparent cohesion values ranging from 4.2 kpa to 21.3 kpa and angle of internal friction values ranging from 26.5o to 33.2o when the flyash was mixed with

different moisture contents from dry side of optimum to wet side of optimum moisture content and tested against direct shear method.

3. Using different moisture contents in the direct shear testing helps us to get the suitable water content for the laboratory tank testing of reinforced flyash wall. According to the experimentation, at 10% of moisture content, the apparent cohesion was found to be 4.2 kpa and angle of internal friction was 33.2o. Therefore, the shear strength parameters in here will be used in the reinforced flyash wall experimentation.

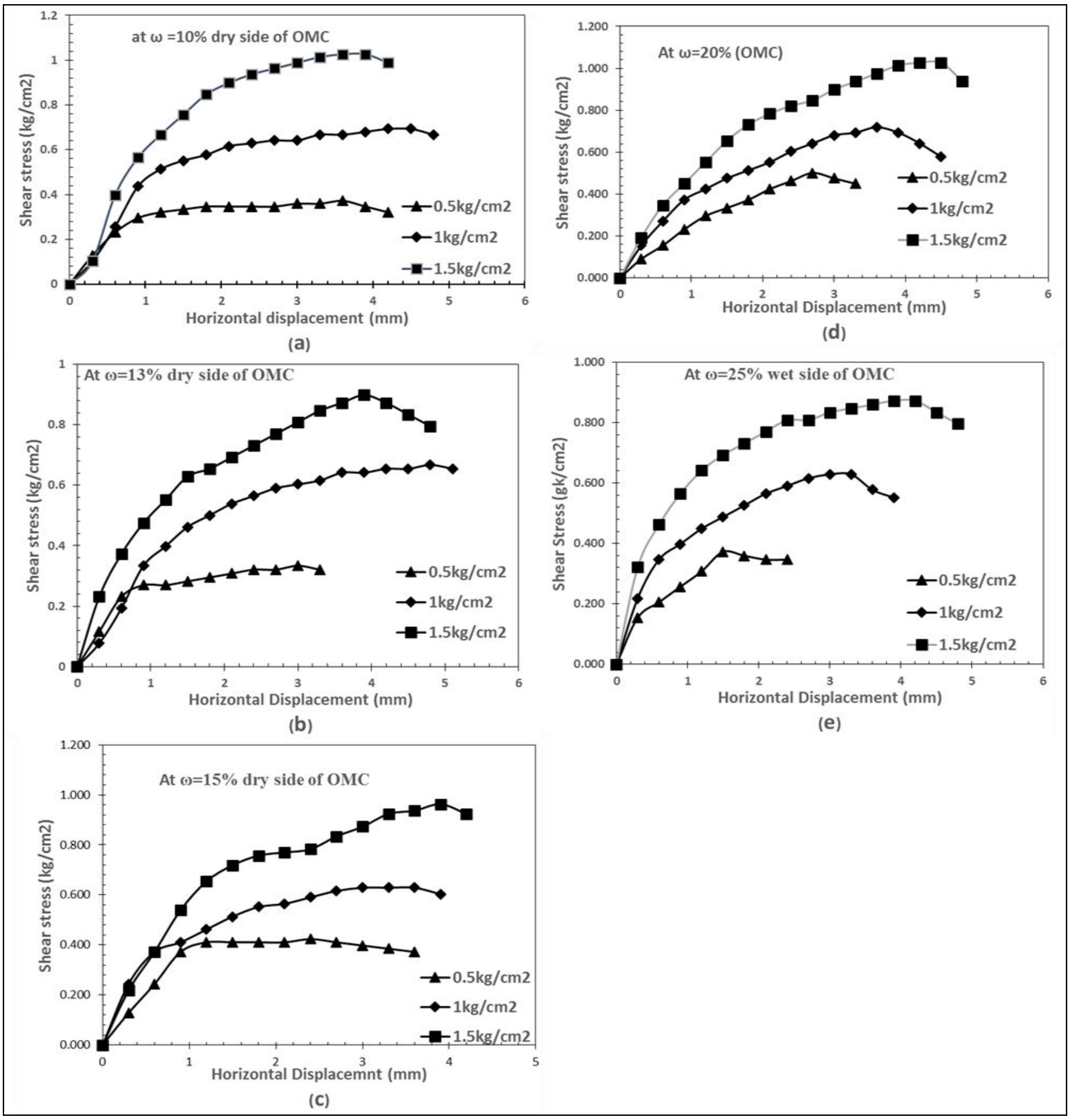

Figure 4 *Relationships between Shear stresses and horizontal displacements for a) at ω=10%, b) at ω=13%, c) at ω=15%, d) at ω=20 %(OMC) and) at ω =25 % (wet side of OMC*

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