PIPING AND SEEPAGE RESISTANCE OF FLY ASH MIXED WITH PLASTIC WASTE

J Raja, Research Associate, IISc, Bangalore, E-mail: iiscraja@yahoo.in
G L Siva Kumar Babu, Professor, IISc, Bangalore, E-mail: glsivakumar@gmail.com, gls@civil.iisc.ernet.in

ABSTRACT: Fly ash is a waste product produced from thermal power stations which contribute to environmental pollution and common plastic bottles that are widely used today is another waste which is a global concern for the eco-friendly environment. Here an attempt has been made to utilize fly ash by adding plastic waste and geogrid waste products for an effective utilization in geotechnical engineering. Fly ash is a material which is highly vulnerable to surface runoff and internal piping. This can be improved by adding plastic waste and geogrid waste which improves the shear resistance of the composite. The experiment results conducted on fly ash composite shows that piping resistance of the composite is increased and the permeability is decreased due to the addition of plastic waste and geogrid waste.

INTRODUCTION
Increased use and cost of backfill materials and filters have made engineers to look for alternative materials like fly ash which have the similar properties as that of soil. Fly ash is a waste product in the power plants and is disposed in both dry and wet states. This is proved to be disadvantageous because it pollutes the atmosphere, ground water, causes health disorders and also affects the topsoil characteristics drastically. Around 110 million tons of fly ash gets accumulated every year at the thermal power stations in India. The disposal of fly ash is a growing concern for many countries worldwide. In India alone, fly ash landfills cover an area of 40,000 acres (160 km²). Due to this reason fly ash is used beneficially to some extend and more than 65% of fly ash produced from coal power stations is still disposed of. This article is an attempt to find a suitable utilization of fly ash and plastic waste which reduces the need for the disposal into landfills and other areas. From the last two decades there is an increased use of fly ash in dykes, embankments, as a sub-base material in flexible and rigid pavements. Fly ash dykes and levees are important flood prevention structures. They are some times damaged by seepage flow due to the rainfall and flood. When the seepage velocity exceeds the critical velocity, the piping occurs and the soil in the levee flows out and the levee structure may be weakened. In this research, the seepage of piping tests is conducted to study the piping resistance of the plastic and geogrid waste reinforced fly ash. This article delineates the experimental setup used for finding the piping resistance of the fly ash mixed with various percentages of plastic waste and geogrid waste by simulating the field conditions that causes piping in soils. It follows with the discussion of the critical hydraulic gradient and upward seepage rate from the experimental results of fly ash composites obtained from the seepage of piping tests and an application to sheet pile wall constructed with fly ash mixed with plastic and geogrid waste is presented.

LITERATURE REVIEW
Furumoto et al. conducted permeability tests on short fibre reinforced soil, large scale model tests were conducted and concluded that piping resistance of soil increases when mixing short fibre to effectively restrict soil particles movement and the resistance to the piping is improved. Seepage induced failures in the form of piping are generally observed in irrigation and drainage projects such as river levees, contour bunds, temporary canal diversion works, temporary check dams and geotechnical structures [1,2] reported the use of fiber–soil mixtures for the construction of river levees and indicated that fibers contributed to increased piping resistance. They studied the effectiveness of coir fiber-reinforced soil in controlling seepage and improving the piping resistance of soil. [3] studied the effect of randomly distributed geofibers on the piping behaviour of embankments constructed with fly ash as a fill material and concluded that the reinforcing fly ash specimens with polyester fibers reduced seepage velocity and improves piping resistance.

EXPERIMENTAL PROCEDURE
This section gives the details of the experiment procedure of the test to find critical hydraulic gradient and upward seepage rate of fly ash blended with plastic waste and geogrid waste. Before the test sample is prepared the basic characteristics of fly ash like particle size distribution, specific gravity of fly ash, maximum dry density, optimum moisture content of the fly ash using standard proctor test and gradation properties are determined. The basic characteristics of fly ash are given in Table 1.

Experimental Setup
The apparatus used in the test are specimen mould(Acrylic material), water tank, stand pipe, graduated measuring jar and scale as shown in Fig. 1.

Materials used
In the present study Raichur pond ash with chemical composition SiO₂ (63.23), Al₂O₃ (26.25), TiO₂ (1.10), Fe₂O₃ (3.51), MgO (0.50), CaO (0.20), K₂O (0.64), Na₂O (0.26), LOI (4.01) is used. From the grain size distribution curve (shown in Fig. 2), it is observed that fly ash is uniform graded with 95% of particle size between 75.0μ to 2.0mm.
The coefficient of uniformity, $C_u$, of fly ash is 2.36 (<4) indicates that fly ash is a uniformly graded.

Plastic waste from used water bottle is cut in the form of strips of length between 10-20mm and aspect ratio (L/D) between 20-40 is used.

Table 1 Characteristics of Fly ash

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid limit (%)</td>
<td>32</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.01</td>
</tr>
<tr>
<td>Maximum dry density (g/cc)</td>
<td>1.27</td>
</tr>
<tr>
<td>Optimum moisture content (%)</td>
<td>22.0</td>
</tr>
<tr>
<td>Coefficient of uniformity, $C_u$</td>
<td>2.36</td>
</tr>
<tr>
<td>Coefficient of curvature, $C_c$</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Test Setup and Sample Preparation

Before the sample is prepared, calculations like weight of soil to be added, fibers and amount of water to be added are calculated. The sample is prepared at (96% of MDD) on dry side of optimum water content. Plastic waste and geogrid waste are randomly distributed over the sample and mixed with fly ash as shown in Figs. 3-4 and is kept in a mould of size 10.0cm diameter and 11.0cm height as shown in Fig. 1 and compacted in three layers by uniformly dropping a weight of 500.0g plate from a height of approximately 50.0cm with 10 drops per layer.

Test Procedure

The water tank shown in Fig. 1 is filled to sufficient head with water before connecting the stand pipe to the bottom of the sample. After preparing the sample in the mould the stand pipe is connected to the mould to the bottom of the sample. Before allowing the water to flow through the sample initial head is noted. Value is opened at the bottom and allow the sample to saturate with sufficient head (preferably for 24hrs). After the specimen is saturated, the water level of the tank is gradually raised to apply the hydraulic gradient to the specimen. The head is increased in steps of 0.5cm or less to determine the precise head of failure at which piping occurs with time of observation (30min). Discharge is measured using graduated cylinder. The above procedure is repeated at different heads until detachment of particles due to upward flow is observed.
Seepage flow velocity and hydraulic gradient

Seepage velocity is a parameter which combines the effects of porosity and tortuosity of the actual flow path among and around the mineral grains. Actual seepage flow velocity is the seepage flow divided by the pore area. The relationship between actual seepage flow velocity and hydraulic gradient is shown in Figs. 5-6 for plastic and geogrid waste. In all cases, the relation between actual seepage flow velocity and hydraulic gradient is nonlinear expect in the initial stages. Plastic waste and geogrid waste appeared to effectively restrict soil particles movement and the resistance to the piping is improved. There is an increase in critical hydraulic gradient from 0.45 for 0% plastic waste to 0.56 for 1% is observed for plastic waste which shows an increase of about 24% compared to plain fly ash. For geogrid waste as the fiber content increases the critical hydraulic gradient increases from 0.45 for 0% geogrid waste to 0.58 for 1% geogrid waste where there is an increase of about 29% which is higher than that of plastic waste due to increased shear resistance offered by geogrid waste.

Fig. 5 Variation of seepage velocity vs. hydraulic gradient with plastic Waste

Fig. 6 Variation of seepage velocity vs. hydraulic gradient with geogrid Waste

Upward seepage rate of fly ash mixed with plastic and geogrid waste

The slope of the plotted lines in Figs. 5-6 indicates the upward seepage rate. From Fig. 7 it is observed that the fly ash mixed with 0% fiber content, the upward seepage rate is 2.30x10^{-4} cm/s and decreased to a value of 2.00x10^{-4} cm/s, 1.90x10^{-4} cm/s for plastic waste and geogrid waste of 1.0%. In all cases, the upward seepage rate have marginal decrease with the increase in the fibre content.

Fig. 7 Variation of hydraulic conductivity for plastic waste and geogrid waste

Particle Application

The excessive seepage and piping at the tail end are the two important considerations one should take into account in the design of sheet pile walls. Optimum combination of plastic waste and geogrid waste mixed with fly ash can be used efficiently in reducing the seepage and can be a cost-effective solution with reduced maintenance.

Fig. 8 Sheet pile wall

A sheet pile as shown in Fig. 8 is driven into the fly ash composite to a depth of 7.0m and the upstream water level is at a height of 6.0m. upward seepage rate of the fly ash composite for plastic waste and geogrid waste for different percentage are taken according to Fig. 7. An impervious
layer exists at a depth of 8.0m below ground level. A flow net is drawn for the above case and the no. of flow lines and equipotential lines of the flow net are determined and the discharge through the medium is calculated in cumecs/m.

The exit gradient obtained from the seepage of piping tests shown in Figs. 5-6 is used for calculating the safety factor against piping for different percentage of both plastic waste and geo grid waste. From Fig. 9 it is observed that factor of safety against piping is increased from 0.98 to 1.4 for 1.0% geogrid waste. Geogrids mixed fly ash exhibits an improved piping resistance at 1.0% of fiber inclusions due to high shear strength offered by the geogrid waste.

![Fig. 9 Variation of factor of safety against piping with different percentage of fibres](image)

From Fig. 10 it is observed that amount of seepage decreases with increase in the percentage of fibers. The percentage decrease in seepage is more for geogrids in the order of 21% compared to decrease for fly ash blended with plastic waste.

![Fig. 10 Variation of discharge with fiber content](image)

**SUMMARY AND CONCLUSIONS**

Experimental investigations have been carried out on flyash mixed with plastic waste and geogrid waste and their effect on the seepage potential and piping resistance is studied. The following are important findings of the present research:
The present study reveals that the addition of discrete and randomly distributed fiber inclusions in fly ash is an effective method in improving the piping resistance of the fly ash and is cost effective. Flyash blended with geogrid waste shows an improved resistance to the piping phenomenon compared to the plastic waste blended with flyash due to the higher shear resistance offered by the geogrid waste compared to the plastic fiber.

The upward seepage rate is decreased for fly ash composites due to decrease in void ratio and the blocking of pore spaces of fly ash by fibers replacing fly ash solids. The upward seepage rate has a marginal decrease with increase of the fibre content.

For the steady state seepage case performed on the sheet pile wall constructed with a fly ash mixed with plastic and geogrid waste can effectively restrict soil particles movement and the resistance to the piping is improved.

**ACKNOWLEDGEMENTS**

The results presented in the paper are part of research project on the engineering behavior of fly ash composites sponsored by the Department of Science and Technology (DST), Government of India, New Delhi. The authors thank the authorities for the financial support.

**REFERENCES**

