Visakhapatnam Chapter

Proceedings of Indian Geotechnical Conference 2020
December 17-19, 2020, Andhra University, Visakhapatnam

An Experimental Study on Fly Ash Behaviour as Land Fill

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Abstract. Fly ash is an industrial waste generating in thermal power station and disposal of it is a serious issues without affecting surrounding environment. To overcome this problem the major quantity of ash produced is used in geotechnical engineering application such as construction of embankments, land filling etc. Using fly ash for construction of embankments saves expenditure on excavation of soil from another place and reduces demand of land to dispose of ash as well. Sometimes road or highways running through low lying areas, ponds, shallow water bodies are required land filling to bring the road profile to the required level. The present study is aimed at investigating the use of fly ash as land fills in shallow water bodies. Here experimental study is conducted where series of experiments are carried out with fly ash and fly ash mixing with various percentages of sand in thin layers. Settlement behaviour of fly ash in water due to self-weight, dry density and water content profile with depth are investigated using different compaction pressures on deposit.

Keywords: Fly ash, Land Fill, Sand mix, Dry density, Compaction pressure.

1 Introduction

Fly ash, the finer fraction of coal ash, can be used as alternative material for construction of embankments for roads and highways or used as land fill material in shallow water. A good number of literatures have been reported to investigate suitability of using fly ash as land fill or embankment material [1], [2], [3]. The effective use of fly ash as construction material can be observed in the second Nizamuddin bridge, Visvesvaraya Setu (Okhla fly over project) [4] etc. From grain size distribution it can be said that fly ash is mainly clayey silt type with low specific gravity which has same settling behavior as fine grained soil. Sridharan and Prakash [5], Imai [6] classified settling of fine grained soil into three categories as homogeneous settling, transitional settling, segregational settling depending upon water content and grain size distribution. Literature also establishes the fact that fine grained soil can be employed effectively as fill material and addition of sand may improve strength of soil [7]. As most of the works are limited to clayey or silty soil as fill material, present study aims at investigating fly ash behaviour as landfill in water conducting series of experiments.

2 Test Programme and Procedure

Two series of experiments were carried out where three types of cylinders with diameter of 71.4 mm, 200 mm and 298.5 mm were used. Fly ash was poured in layers and weight of each layer was 250 gm, 2 kg and 4 kg for cylinder 1, 2 and 3 respectively. The initial heights of water were 125 mm, 127 mm and 200 mm for those three cylinders. For series 'A' programme was as follows (Table 1). Different sizes of cylinder with various heights of water were taken to study variation of density and water content profile.

Table 1. Series 'A' tests

Cylinder Type	Soil Type	No of Tests
Cylinder – 1	Fly ash, Fly ash with 10% sand and Fly ash with 20% sand	4 (including one on fly ash after shaking)
Cylinder - 2	Fly ash, Fly ash with 10% sand and Fly ash with 20% sand	4 (including one on fly ash after shaking)
Cylinder – 3	Fly ash, Fly ash with 10% sand and Fly ash with 20% sand	3

When tested with sand, first fly ash was poured and allowed to settle for a minimum period of four hours and then sand was poured uniformly on sedimented fly ash and reading was taken after one hour. Subsequent layers were prepared in the same way. Here four layers were formed for cylinders 1 and 2 while in case of cylinder 3 seven layers were produced to observe settlement behaviour.

The dry density and water content for each layer was determined from final settlement reading. After fourth layer was poured the fly ash was kept for 24 hours. After that, fly ash or fly ash with sand was removed in layers. For each layer total weight was measured and water content was considered at mid height of layer.

Additional tests were carried out in cylinder 1 and cylinder 2 as mentioned in table 1 where after allowing each layer of fly ash to settle for four hours cylinder was shaken well. This caused further settling of fly ash and then next layer was poured. Here also four layers were formed.

For series B, similar tests were conducted but only cylinder 2 and 3 were used and compaction pressure of 0.2 kg/ sqcm and 0.5 kg/ sqcm were applied on cylinder 2 while 0.2 kg/ sqcm compaction pressure was applied on cylinder 3. The pressure were applied at the top of sedimented fly ash or fly ash with sand layers by dead weights which were kept for a period of 24 hours.

Physical and strength tests of fly ash were carried out. Dry density, water content and shear strength of fly ash fill (with and without sand) at different layers were measured. Effect of compaction pressure was also investigated. Figure 1 and figure 2 depict the experimental set up used in present study.

Fig. 1. Settling of Fly ash (Cylinder dia 298.5 mm)

Fig. 2. Compaction of sedimented Fly ash (0.2 kg/ sqcm)

3 Test Results

From grain size analysis it is observed that fly ash is mainly silty in nature (75% of particle size in between 2 μ to 75 μ). Grain size distribution of fly ash obtained from wet analysis is shown below:
Sand: 7%, Silt: 75% and Clay: 18%
Specific gravity and liquid limit of fly ash were found to be 1.955 and 48.8% respectively. Liquid limit of fly ash was determined in the laboratory with the help of cone penetrometer as per IS 2720 –V. From proctor compaction test maximum dry density is

found as 1.158 g/cc while optimum moisture content is 32%. Grain size distribution of sand as found out from sieve analysis is presented.
Fine sand: 10%, Medium sand: 73% and Coarse sand: 17%.
Uniformity coefficient and effective diameter (D_{10}) of sand are 2.05 and 0.43 mm respectively. Specific gravity of sand was found to be 2.581.
Settling behaviour of fly ash in cylinder 1 is presented in fig 3 from which it can be observed that rate of settling is uniform initially and then decreased after 15 minutes. Similar kind of settling behaviors are observed for cylinder 2 and 3. Formation of sharp interface and uniform settlement rate reveals that settling is kind of zone settling. The dry density and water content profile of fly ash, fly ash with 10% sand, fly ash with 20% sand and after shaking of fly ash in cylinder 1 are presented in fig. 4 and fig. 5 respectively. Dry density is lesser in upper region and increases with depth. This is due to less over burden pressure in the upper region. Increase in dry density due to addition of sand is more prominent in deeper layer and it is in the range of 5-10%. Water content is reduced when sand layer is placed as it decreases the length of drainage path and facilitates lateral flow of water because a part of thin sand layer penetrates up to a certain depth in the fly ash.

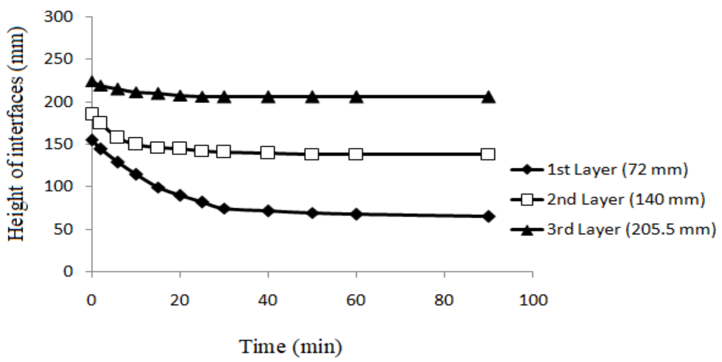

Fig. 3. Settling behaviour of fly ash (Cylinder 1)

Effect of compaction pressure on dry density in cylinder 2 and cylinder 3 are shown in fig 6 and fig. 7. Here dry densities at various depths were measured so that overall density behaviours of compacted fly ash (with or without sand) at different zones are understood. The increases in dry densities are appreciable in the upper region while it is not significant in lower portion of deposit.
A series of direct shear tests were carried out at different dry densities and water contents. Normal stress vs shear stress is presented in fig. 8 for fly ash. These data were utilized for estimation of sedimented/ compacted fly ash or fly ash with sand layers (fly ash with 10% sand and fly ash with 20% sand as mentioned earlier) by interpolation process. Table 2 shows improvement of shear strength (Cylinder 3) for compacted fly ash with sand layers comparing to only fly ash. Similar types of results obtained for cylinder 2.

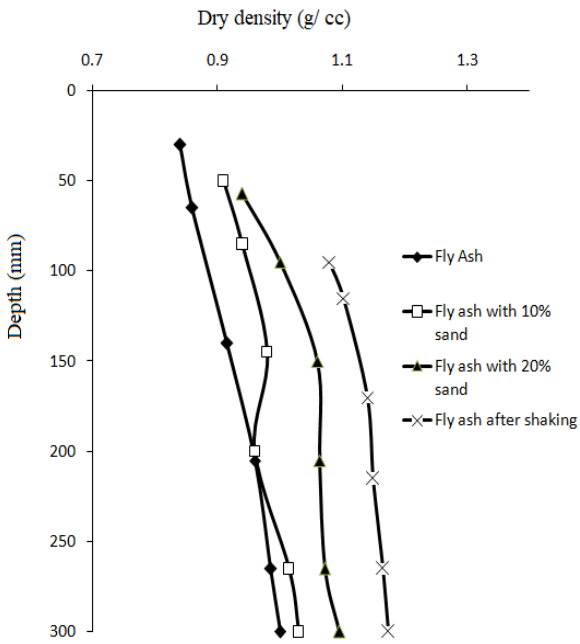

Fig. 4. Dry density profile of fly ash (Cylinder 1)

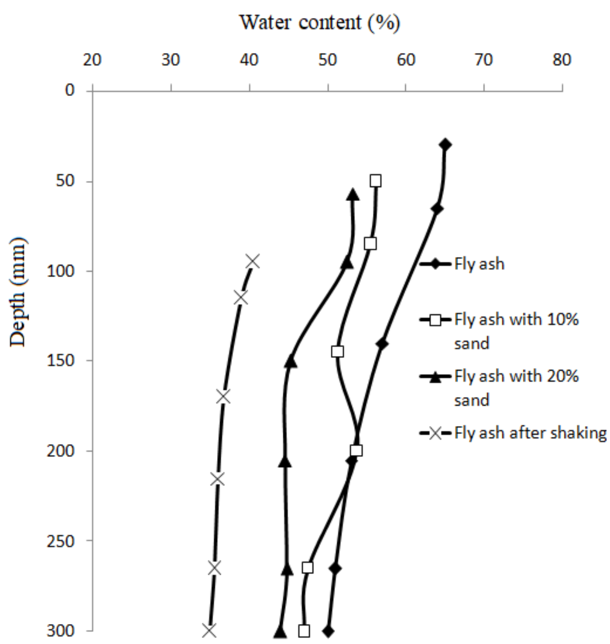

Fig. 5 .Water content profile (Cylinder 1)

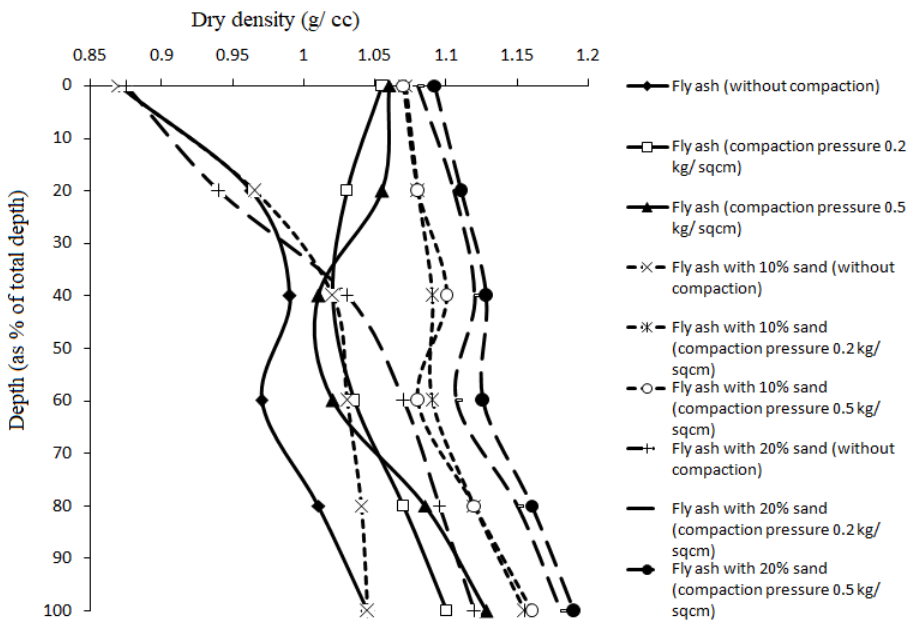

Fig. 6. Dry density profile of sedimented fly ash with and without static compaction (Cylinder 2)

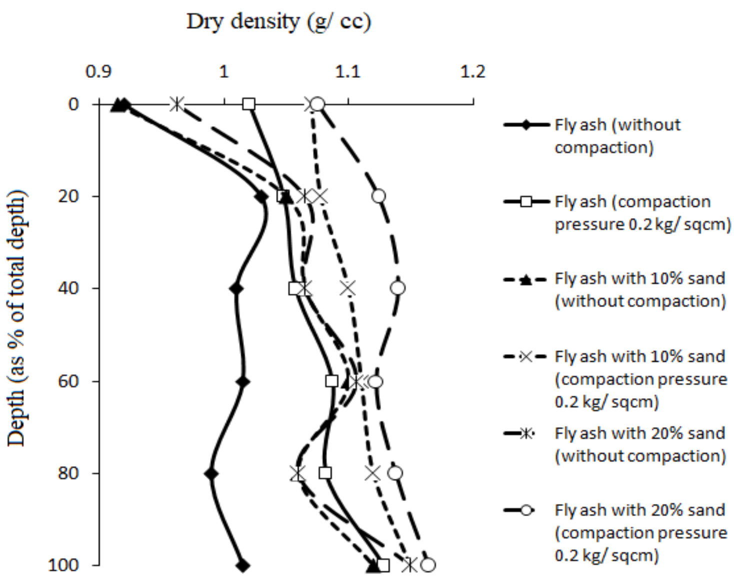

Fig. 7 . Dry density profile of sedimented fly ash with and without static compaction (Cylinder 3)

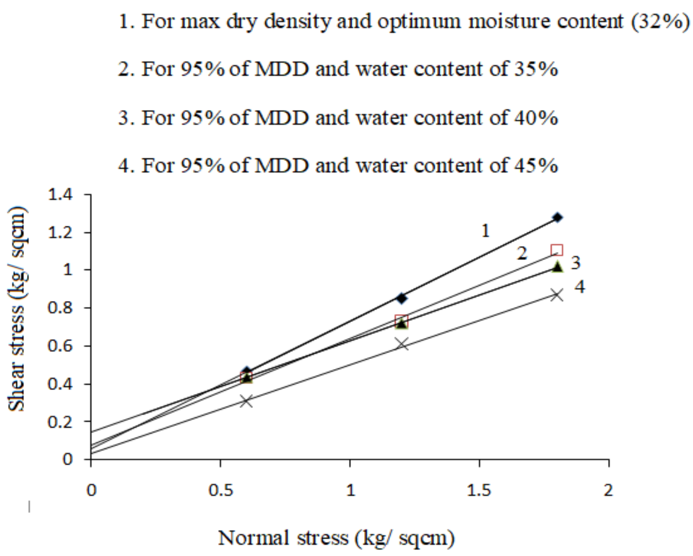

Fig. 8. Direct shear test of fly ash at different water contents

Table 2. Direct shear test results for cylinder 3

Depth (as % of total depth)	Fly ash				Fly ash +10% sand				Fly ash + 20% sand	
	Without compaction		Comp pr 0.2 kg/sqcm		Without compaction		Comp pr 0.2 kg/sqcm		Comp pr 0.2 kg/sqcm	
	c (kg/ cm²)	ϕ (deg)	c (kg /cm²)	ϕ (deg)	c (kg /cm²)	ϕ (deg)	c (kg/ cm²)	ϕ (deg)	c (kg /cm²)	ϕ (deg)
0	-	-	0.10	26.0	-	-	0.10	25.3	0.08	27.5
20	0	23.7	0.09	25.6	0	23.6	0.12	25.5	0.10	31.0
40	0	23.8	0.06	24.4	0.05	24.1	0.07	24.5	0.09	26.0
60	0	23.6	0.05	24.1	0.04	24.3	0.13	25.2	0.11	25.5
80	-	-	0.01	24.0	0.12	25.8	0.06	24.6	0.10	25.8
100	0	23.6	0.05	24.3	0.10	25.0	-	-	-	-

4 Conclusions

Series of experiments were carried out to assess the behaviour of sedimented fly ash deposit in shallow water bodies. On the basis of above experimental study following conclusions maybe drawn

1. Rate of settlement of fly ash in shallow water is uniform initially and then is reduced and becomes almost asymptotic after 30 minutes.

2. With addition of sand layer in between two fly ash layers dry density of deposits increase and this increases are clearly observed in bottom layer
3. When compaction done dry density of upper layer fly ash is increased appreciably
4. Shear strength of compacted fly ash with sand is higher than that of only fly ash

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