Geotechnical Properties of Fly Ash and Bottom Ash Mixtures in Different Proportions

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Abstract: Fly ash is very effectively used in various civil engineering projects. Fly ash is a by-product recovered from the flue gases of coal combustion plant. The quantity of ash produced depends upon the quality of coal and the method of burning. In India less than 20% of ash is used in the manufacture of brick, cement, concrete and other product. Bottom ash is a by-product of burning coal at thermal power plants. Bottom ash particles are much coarser than the fly ash. Here we are using different proportion as 100% BA, 80%BA+20%FA, 60%BA+40%FA, 40%BA+60%FA, 20%BA+80%FA, 100% FA. Different test like Grain size analysis Specific gravity, Standard proctor test, Permeability test, direct shear test, California Bearing Ratio test were done on different proportions. MDD increases while dry density decreases as bottom ash increases. Permeability decreases as fly ash content increases. CBR value decreases for both soaked and unsoaked condition as fly ash content increases.

Keyword: Fly ash, bottom ash, grain size, CBR value, permeability.

1. Introduction

Fly ash and bottom ash are very effectively used in various civil engineering projects. Fly ash and bottom ash is a byproduct recovered from the flue gases of coal combustion plant. The quantity of ash produced depends upon the quality of coal and the method of burning. In India less than 5% of ash is used in the manufacture of brick, cement and other products. Coal fire power plants produce millions of tones of fly ash and bottom ash annually but only a fraction is productively employed. Consequently power plant ash is "negative cost" material, i.e., it is made to other users to avoid disposal costs. Coal ash has many uses in civil engineering project. Bottom ashes often angular sand and gravel size particles, are employed as aggregate in highway construction and icing control. The main disposal problem is with fly ash, the finer silt size fraction recovered from stack emissions. Fly ash is often a component in concrete mixtures, but it is also used in stabilized road bases, landfill linear and waste stabilizations. These latter uses involve as blended with lime, Portland cement or waste by-products such as kiln dust, which induced pozzolanic cementing.

Fly ash and Bottom ash was collected from Anpara Thermal Power Project (U.P.) and has been used in present investigation. The fly ash and Bottom ash were mixed in different proportions and their physical, chemical and geotechnical characteristics were investigated. Fly ash and Bottom ash fulfill the technical properties required for various use. However experimental inadequate awareness among the user at various levels has resulted in limited use of fly ash and bottom ash material as fill.

Environmentally safe disposal of large quantities of fly ash and bottom ash is not only tedious but also expensive. To reduce the problem of disposal of fly ash and bottom ash great efforts are being made to utilize fly ash and bottom ash. The properties of fly ash and bottom ash that are important for use in geotechnical engineering applications are its low unit weight and compressibility and pozzolanic reactivity. The strength behaviour of fly ash assumes importance in its use for geotechnical application. It is known that strength behaviour of fly ash varies with density. In almost all geotechnical applications, pozzolanic property of fly ash and bottom ash play an important role, which induces cementation between particles. Ash is the inorganic portion of the source coal in the form of spherical, often hollow, spheres of silicon, aluminum and iron oxides and unoxidised carbon.

2. Fly Ash

Fly ash obtained from thermal power station is a by-product available in abundant quantity and ought to be converted into meaningful and useful products. Fly ash is nothing but the finely divided residue resulting from the combustion of powdered coal, which is transported from firebox to the boiler by flue gas. Fly ash is the by-product of coal combustion thermal power plant. Due to its pozzolonic nature it can be used effectively for variety of purpose.

Fly ash obtained as the by-product from pulverized coal consists of predominantly small spherical particle, which differs in shape and size due to its difference in degree of pulverization of coal and efficiency of collecting system. One of the major factors hindering the utilization of fly ash has been an economic system for collection, handling and transportation of fly ash at thermal power station and facilitate for handling and storage at the user end and its economics.

Fly ash is mostly used in dry state, whereas system of disposal at most of the thermal power stations is wet, which has been established keeping in view the requirement of existing system and relatively easy mode of disposal. There is however a distinct possibility of dry collection of fly-ash by modification in the existing operating system. Fly ash obtained from Indian coal contains less glass contents and

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has a lesser pozzolonic value, when compared to the imported coal.

When dry, fly ash is cohesion less and considered by many as the dusty nuisance. When saturated, fly ash becomes a pasty material but as with most fine grained soil, it can be easily handled and compacted at more intermediate moisture content, exhibiting some amount of cohesion property. Coal fly ash has been successfully used as highway road embankment fill material for highway construction projects in a number of different locations throughout the world. When compared with the conventional soil used as embankment.

3. Bottom Ash

Bottom ash is a by-product of burning coal at thermal power plants. Bottom ash particles are much coarser than the fly ash. It is a coarse, angular material of porous surface texture predominantly sand-sized. This material is composed of silica, alumina, and iron with small amounts of calcium, magnesium, and sulfate Grain size typically ranges from fine sand to gravel in size. Chemical composition of bottom ash is similar to the fly ash but typically contain greater quantity of carbon.

Bottom ash exhibits high shear strength and low compressibility. These engineering properties make bottom ash an ideal material in design construction of dam and for other civil engineering applications. Bottom ash also exhibits a relatively high permeability and grain size distribution that allows the design engineer to use it in direct contact with impervious material. Bottom ash has proved to be an economical material because it has demonstrated to have not only good engineering property but also to have constructability benefits. Bottom ash can be used as concrete aggregate or for several other civil engineering applications where sand, gravel and crushed stone are used.

Government should encourage the use of fly ash related products so that fly ash and bottom ash can be used in huge quantities.

Table 1: Estimation of Coal ash generation and utilization	n in
different countries in 12-13	

	unitere	$2 \text{ Int countries In } 12^{\circ}$	-15
Sr. No.	Country	Production (M.T.)	Utilization (M.T.)
1.	Australia	20	< 5
2.	China	> 135	24
3.	Germany	60	30
4.	India	> 140	28
5.	Japan	15	5
6.	Russia	84	14
7.	South Africa	40	05
8.	Spain	33	2.5
9.	Europe	75	32
10.	U.S.A.	65	15
11.	North America	86	10
12.	East Europe	58	16
13.	Others	54	10

4. Utilization of Fly Ash and Bottom Ash in India

Fly ash and bottom Ash generated at Thermal Power Plants stations is ideal for use in cement, concrete, bricks, blocks, tiles, lightweight aggregate etc. The ash usage in the years in 1991-92 was 0.3 million tons and covered to the level of utilization 16.70 million tons during 2004-05.

The various channel of coal as utilization currently include use by a numbers of cement asbestos, cement products, concrete manufacturing industries, land development, roads, embankments, mining filling, ash dyke rising and building products. The area wise break-up of utilization of fly ash and bottom ash for the year 2005-06 is as under.

Table 2: Area wise u	ıtilization	of fly ash	and	bottom	ash in
]	India in 2	012-13			

Area of utilization	Quantity(in million tonnes)
Land Development	7.56
Cement and Concrete	7.67
Roads/Embankments	1.30
Ash Dyke Raising	3.20
Mine Filling	1.15
Bricks	0.75
Others	0.49
Total	22.12

5. Material Used

5.1 Fly Ash

For the present study the source of fly ash is Anpara Thermal Power Project, Anapara (U.P.). The total production of fly ash at Anpara Thermal Power Project is about 2.5 million tons per year.

5.1.1 Physical Characteristics

Table 3: Physical Characteristics of Anpara fly ash

Color	Grey
Physical State	Powder with traces of unburnt carbon
Sp. Gravity	2.15
Particles size	-
Clay size particles	2.50%
Silt size particles	59.5%
Sand size particles	38.0%

5.1.2 Chemical Characteristics

Table 4:	Chemical	characteristics	of A	npara	fly	ash
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Constituents	Percentage (by weight)	
SiO_2	68.0	
Al_2O_3	24.0	
$Fe_2O_3 + Fe_3O_4$	2.18	
TiO ₂	2.64	
CaO	1.49	
MgO	0.06	
SO_4^-	Nil	
Loss on ignition	1.63	

Data as supplied by Anpara Thermal Power Project Authority.

5.2 Bottom Ash

5.2.1 Physical Characteristics

Color	Black grey
Physical State	Sand size particles with
T Hysical State	traces of unburnt carbon
Sp. Gravity	2.27
Particle size	-
Clay size particle % (< 0.002mm)	0.0%
Silt size particle % (0.002-0.075	27.5%
mm)	21.370
Sand size particle % (0.075-4.75	72 5%
mm)	12.370

Table 5: Physical Characteristics of Anpara Bottom as	sh
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5.2.2 Chemical Characteristics

 Table 6: Chemical characteristics of Anpara bottom ash

Constituents	Percentage (by weight)
SiO ₂	68.0
Al_2O_3	25.0
$Fe_2O_3 + Fe_3O_4$	2.18
TiO ₂	1.45
CaO	1.66
MgO	0.02
$SO_4^{}$	Nil
Loss on ignition	1.69

Data as supplied by Anpara Thermal Power Project Authority.

Here the sum of three oxides SiO_2 , Al_2O_3 and Fe_2O_3 is more than 70% so it is classify as F class ash.

6. Preparation of Fly Ash and Bottom Ash Mixture

The following procedure was adopted for preparation of fly ash and bottom ash mixtures in all tests. The materials were first dried for 24 hrs and brought to room temperature. Fly ash and bottom ash were then mixed together in the required proportions (by dry weight) in dry form. Different proportions of Anpara fly ash and bottom ash and their mixed designation are given in table: 7

Table 7: Fly	y Ash and	Bottom	Ash Mix	Designation
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Mix Designation	% of Fly Ash + % of Bottom Ash
100% BA	100% Bottom Ash
20% FA + 80% BA	20% Fly Ash + 80% Bottom Ash
40% FA + 60% BA	40% Fly Ash + 60% Bottom Ash
60% FA + 40% BA	60% Fly Ash + 40% Bottom Ash
80% FA + 20% BA	80% Fly Ash + 20% Bottom Ash
100% FA	100% Fly Ash

7. Testing Programme

Since fly ash generate in huge quantity from thermal power plants in comparison to bottom ash so mainly work has been done on fly ash not on bottom ash so in the project we want to investigate that what is the effect of engineering property on mixing of fly ash and bottom ash in different proportions and how bottom ash can be safely used with fly ash in geotechnical applications and other civil engineering projects. So following testing is done on fly ash and bottom ash and its mixtures in different proportions.

- Grain size analysis
- Specific gravity
- Standard proctor test
- Permeability test
- Direct shear test
- California Bearing Ratio test

8. Results and Discussion

This investigation has been carried out to find the effect of fly ash and bottom ash mixture on optimum moisture content, maximum dry density, permeability, shear strength, particle size analysis and CBR values. In the present investigation fly ash and bottom ash has been taken from Anpara Thermal Power Project, Anpara (U. P.). The results of these investigations have been presented in the form of tables and graphs in this chapter. Brief discussions on the laboratory test results are given below.

8.1 Particle Size Analysis

	Clay									Classification
	Size	Silt Size	Sand Size				Void	Uniformity	Coefficient	
	Particles	Particles	Particles	D ₁₀			Ratio (at	Coefficient	of Curvature	
Mix Designation	(%)	(%)	(%)	(mm)	D _{30(mm)}	D _{60(mm)}	OMC)	(Cu)	(Cc)	
100% FA	2.5	59.5	38	0.012	0.022	0.056	0.569	4.66	0.72	ML
80% FA+20% BA	1.8	55	43	0.01	0.023	0.072	0.612	7.15	0.69	ML
60% FA+ 40% BA	1.35	51.5	49.5	0.011	0.029	0.092	0.705	9.62	0.73	ML
40% FA+ 60% BA	0.9	43.5	55.5	0.015	0.045	0.13	0.792	11.02	0.81	SM
20% FA+80% BA	0.4	37.8	61.9	0.018	0.06	0.2	0.89	11.19	0.91	SM
100% BA	0	27.5	72.5	0.019	0.078	0.22	1.1	11.58	1.45	SM

Table 8: Particle Size Analysis

ML= (Inorganic silts with fine sands),

SM= (Silty sands, poorly graded sand silt mixtures)

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Figure 1: Grain Size distribution curve of Fly Ash and Bottom Ash mixtures in different proportions

8.2 Specific Gravity

The specific gravity was found out for fly ash, bottom ash, and fly ash and bottom ash mixtures in different proportions and is presented in Table 10. The specific gravity of fly ash is 2.15 and for bottom ash it is 2.27.

Table 10:	Specific	Gravity f	or various	mixtures	of Fly	Ash

Mix designation	Specific Gravity						
100% FA	2.10						
80% FA + 20% BA	2.15						
60% FA + 40% BA	2.18						
40% FA + 60% BA	2.21						
20% FA + 80% BA	2.24						
100% BA	2.27						



Figure 2: Specific gravity of fly ash and bottom ash mixtures in different proportions

8.3 Characteristics of Mix Proportion

Table 11: Different properties of Fly Ash, Bottom Ash and its Mix Proportions

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Mix designation	MDD	OMC	Coefficient of	Cohesion (c)		Angle of shearing		CBR Value (Unsoaked	CBR Value (Soaked
	(g / cc)	(%)	Permeability	Kg/cm ²		resistance (Condition) %	Condition) %
			(cm/sec)	D	XX 7 4				
			· · · ·	Dry	wet	Dry	wet		
100% FA	1.370	18.60	5.580×10 ⁻⁴	0.205	0.01	25.8°	23.0°	15.75	8.68
80% FA +20% BA	1.340	20.86	6.125×10 ⁻⁴	0.255	0.025	33.5°	32.0°	18.0	13.86
60% FA +40% BA	1.295	23.10	6.80×10 ⁻⁴	0.250	0.03	34.5°	31.5°	22.0	19.3
40% FA +60% BA	1.220	25.98	7.874×10 ⁻⁴	0.230	0.020	30.0°	29°.	24.2	23.4
20% FA +80% BA	1.150	28.98	8.510×10 ⁻⁴	0.220	0.004	31.5°	26.5°	27.1	25.68
100% BA	1.080	32.0	9.613×10 ⁻⁴	0.205	0.02	36.0°	34.00°	29.6	26.9

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Figure 4: Coefficient of permeability of Fly Ash and Bottom Ash mixtures in different proportions



Figure 5: Direct shear test of Fly Ash and Bottom Ash Mixtures in different proportions in Dry Condition

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Figure 7: CBR value of Fly Ash and Bottom Ash Mixtures in Unsoaked Condition



Figure 8: CBR value of Fly Ash and Bottom Ash Mixtures in Soaked Condition

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Figure 9: CBR value of mixtures of Fly Ash and Bottom Ash in different proportions in Unsoaked and soaked Condition

9. Conclusions

- Maximum dry density of fly ash and bottom ash mixture decreases with increasing bottom ash content while optimum moisture content increases.
- Bottom ash exhibits lower density as compared to fly ash but strength characteristics is better than fly ash under as compacted.
- The permeability of compacted ash mixtures was found to decrease slightly with increasing fly ash content. This may be due to the increasing specific surface with increasing fines content, which generates more resistance to water flow through voids between particles. Overall range of the values was similar to that of a fine sands/ silts mixture or silts.
- Permeability of fly ash and bottom ash is 5.580 x 10⁻⁴ cm/sec and 9.613 x 10⁻⁴ cm/sec, as such fly ash can be used as a filling material in core of dyke and mixtures of fly ash and bottom ash in different proportions can be used in highway embankment.
- Shear strength parameter of fly ash and bottom ash shows a variation in cohesion from 0.01 to 0.03 kg/cm² and angle of internal friction from 23° to 34⁰ in wet condition it can be safely used in construction of embankment and also body of dyke for water disposal.
- The CBR value of fly ash and bottom ash in soaked condition is 8.68 % and 26.9%. While in 80%BA+20%FA, 60%BA+40%FA, 40%BA+60%FA, 20%BA+80%FA proportions CBR is 25.68%, 23.4%, 19.3% and 13.86% respectively. The recorded value of CBR for sub-base is 7-20 %. Therefore fly ash and bottom ash mixtures can be used as sub-base of road construction.
- Based on the results obtained in this study, it appears that high volume fly ash mixtures are suitable for use in highway embankment; if proper design and construction procedures are follow. The fly/bottom ash mixtures can provide fill materials of comparable strength to most soils typically used as fill materials, while having the advantage of smaller dry unit weights.
- Bottom ash alone or in combination with fly ash at equal or similar proportion can be used as construction material in most geotechnical application where borrow soil is presently used, thus solving an important environmental problem of disposal of coal ash to great extent. Further, this will help reducing degradation of valuable land

affected by dumping of unutilized coal ash produced and mining of soil for geotechnical construction.

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