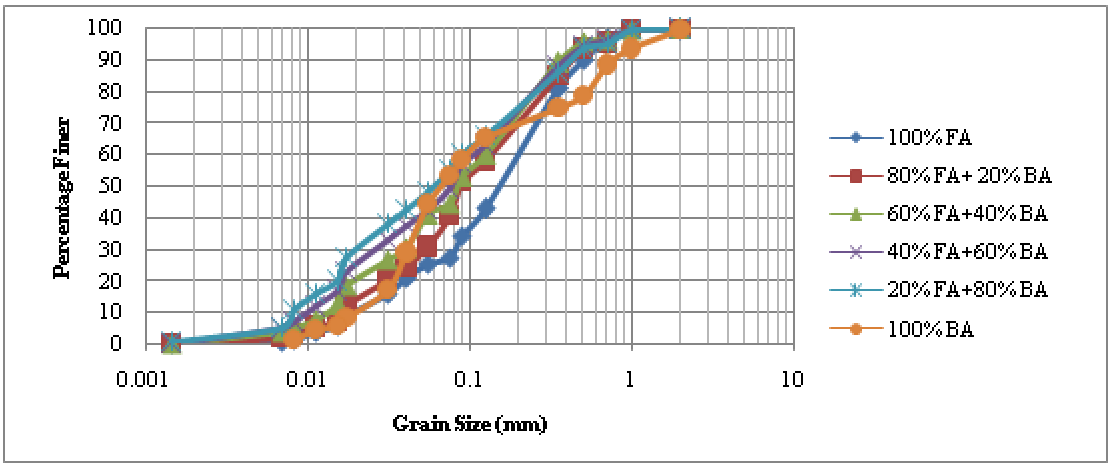

Figure 1: Grain Size distribution curve of Fly Ash and Bottom Ash mixtures in different proportions

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 for various mixtures of Fly Ash and Bottom 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

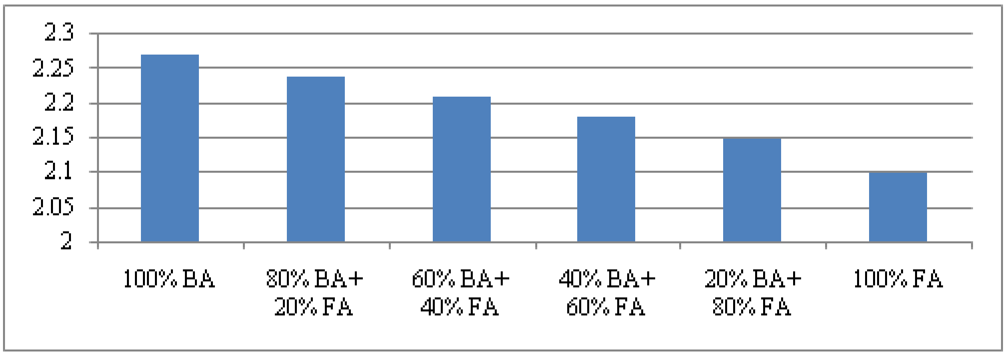

Figure 2: Specific gravity of fly ash and bottom ash mixtures in different proportions

8.3 Characteristics of Mix Proportion

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

Mix designation	MDD (g / cc)	OMC (%)	Coefficient of Permeability (cm/sec)	Cohesion (c) Kg/cm^2		Angle of shearing resistance (ϕ)		CBR Value (Unsoaked Condition) %	CBR Value (Soaked Condition) %
				Dry	Wet	Dry	Wet		
100% FA	1.370	18.60	5.580×10^{-4}	0.205	0.01	25.8^0	23.0^0	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

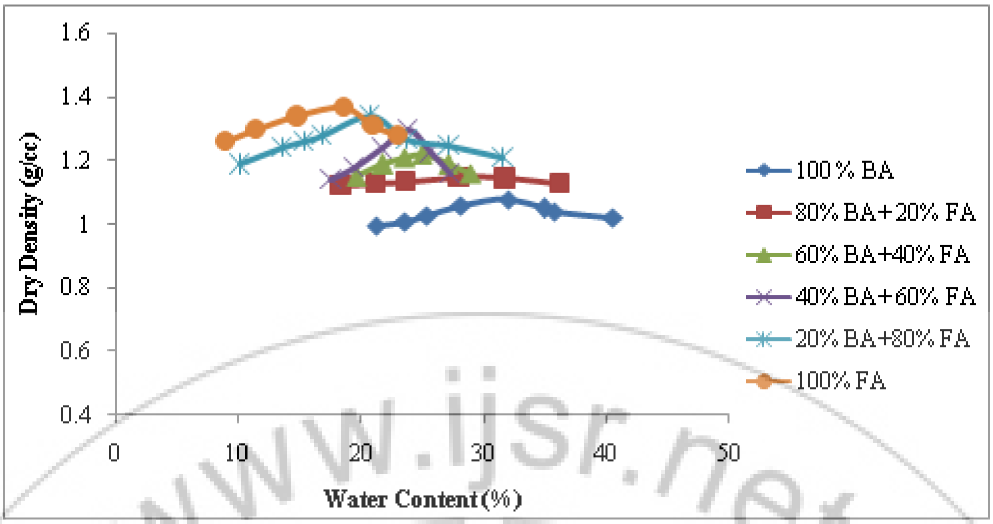

Figure 3: Compaction Curve of Fly Ash and Bottom Ash in different proportions

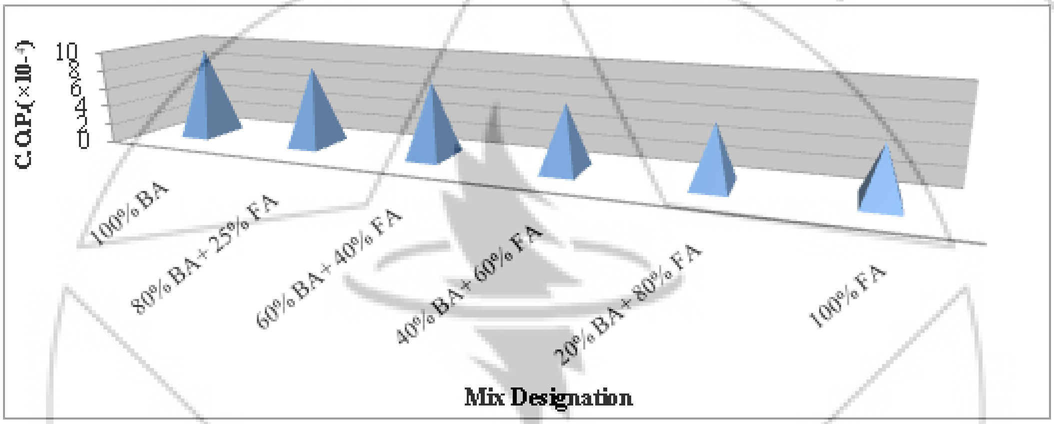

Figure 4: Coefficient of permeability of Fly Ash and Bottom Ash mixtures in different proportions

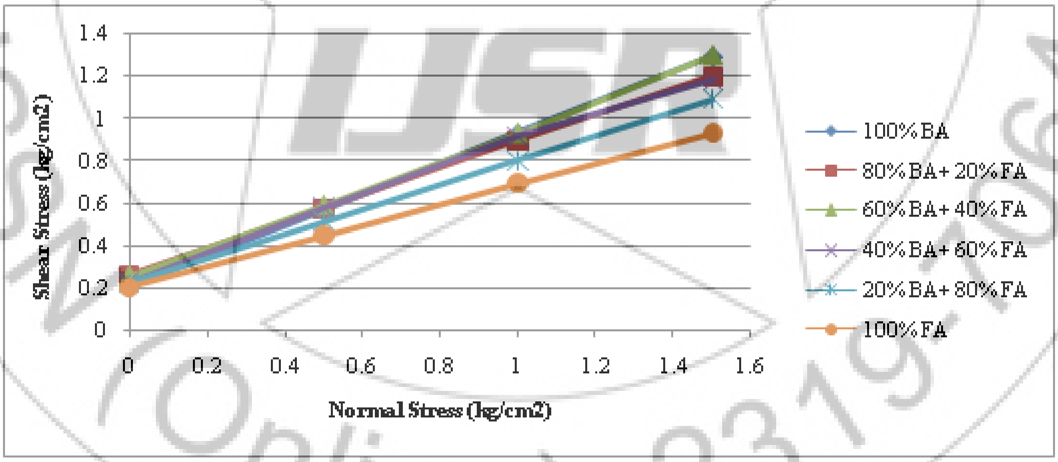

Figure 5: Direct shear test of Fly Ash and Bottom Ash Mixtures in different proportions in Dry Condition

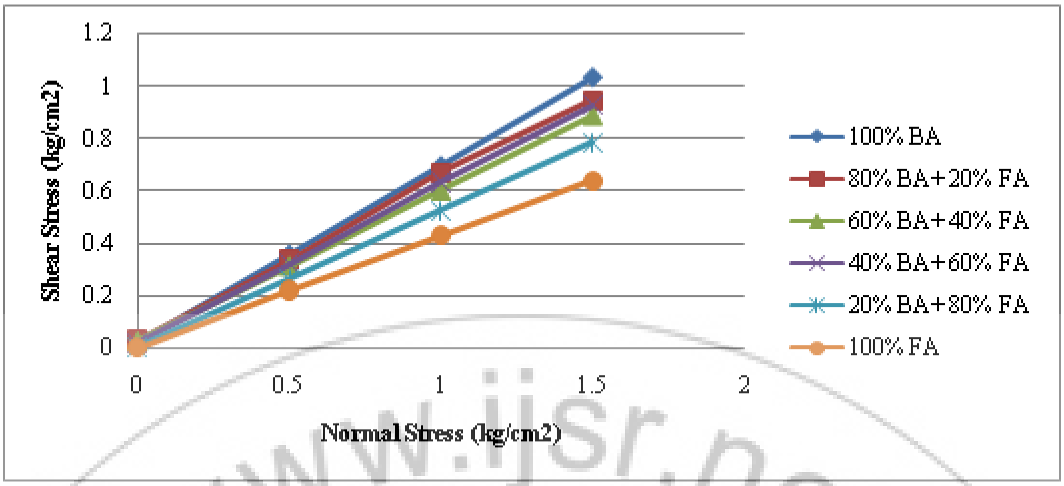

Figure 6: Direct shear test of Fly Ash and Bottom Ash Mixtures in different proportions in Wet Condition

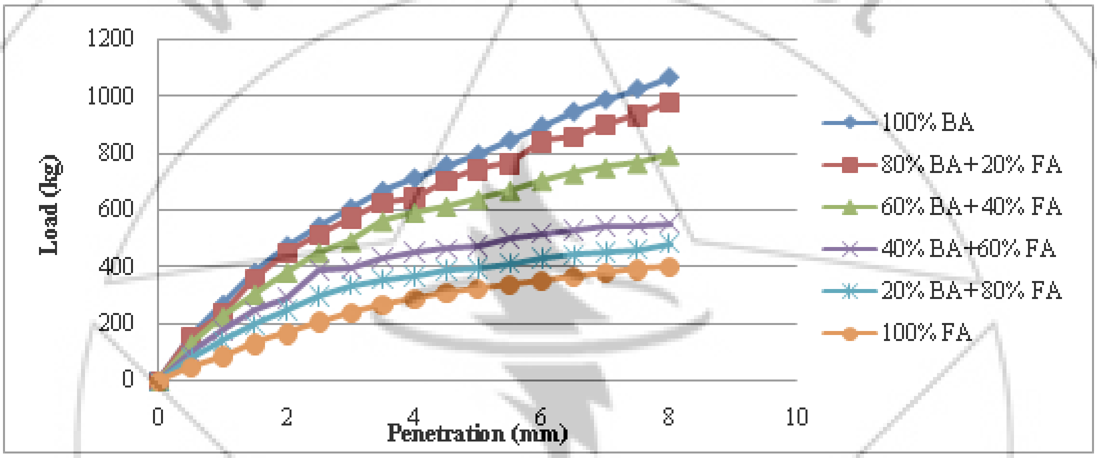

Figure 7: CBR value of Fly Ash and Bottom Ash Mixtures in Unsoaked Condition

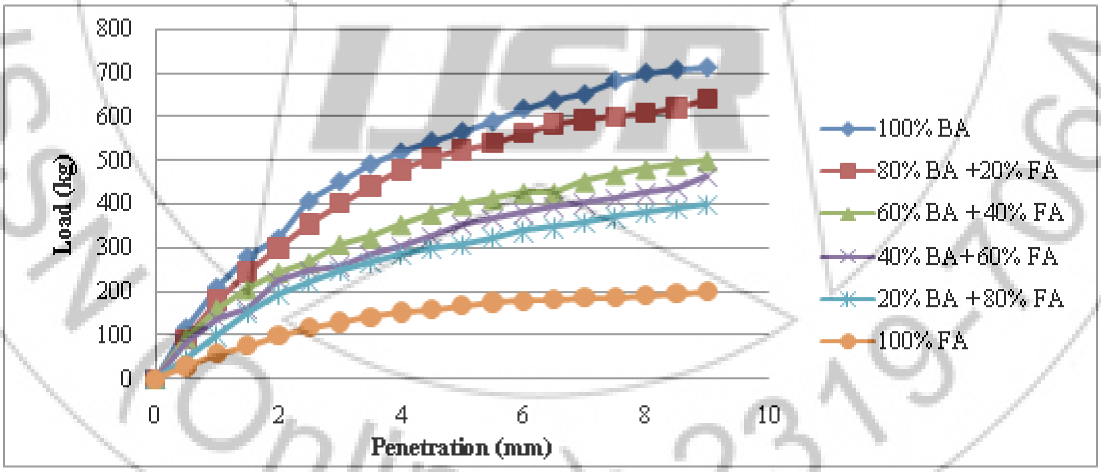

Figure 8: CBR value of Fly Ash and Bottom Ash Mixtures in Soaked Condition

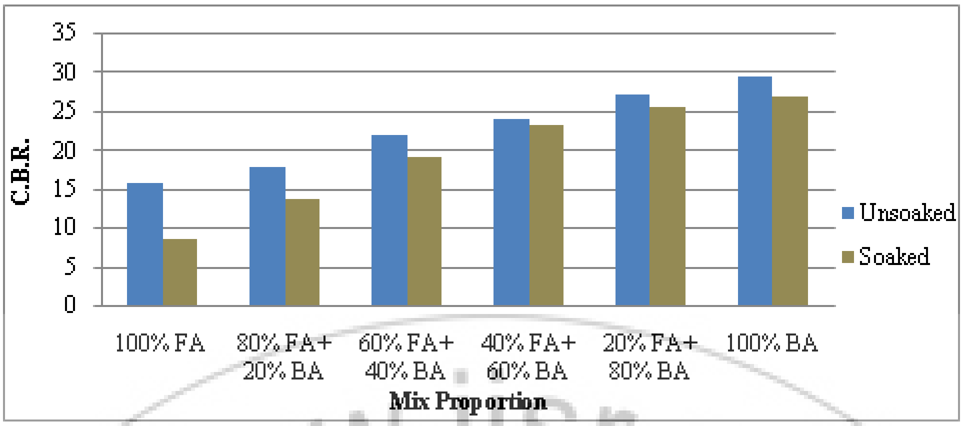

Figure 9: CBR value of mixtures of Fly Ash and Bottom Ash in different proportions in Unsoaked and soaked Condition

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/cm^2 and angle of internal friction from 23^o to 34^0 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.

References

[1] Kalyoncu, R. S. (2005), "Coal Combustion Products Production and Uses", U. S. Geological Survey, Reston, Virginia, 4, 13-17.
[2] Kim, B., Prezzi, M. and Salgado, R. (2005). "Geotechnical Properties of Fly and Bottom Ash Mixtures for Use in Highway Embankments" *J. Geo, Geoenv.*, ASCE, 131(7), 914-924.
[3] Acosta, H.A. Edil, T. B. and Benson, C. H. (2005), "Soil Stabilization And Drying Using Fly Ash", Geo Engg. Report No. 03-03.
[4] Phani, B. R., & Sharma. R. S., (2004), "Effect of Fly Ash on Engg. Property of Expansive Soil," *J. Geo, Geoenv.*, ASCE, 131(7), 764-766.
[5] Usmen, M.A. (1977), "A critical review of the applicability of conventional test methods and materials specifications to the use of coal associated waste in pavement construction." PhD dissertation. West Virginia Univ., Morgantown. W. Va.
[6] Gandhi, S. R., Dey, A.K. & Selvam, S. (1999) "Densification of Pond Ash By Blasting" (J.Geo. Geoenv. Vol. 125 No. 10 1-2.
[7] Consoli, N. C. Prietto, P. D. M. Carroro, J. A. H. and Heineck, K. S. (2001),"Behavior of Compacted Soil-Fly Ash-Carbide Lime Mixtures." *J. Geo. Geoenv.*, ASCE, 127(9), 774-782.
[8] Docky, W. D. and Manigault, D. E. H. (1947), "Lime Stabilization and Low Cost Road Construction", Road and Street, 90 pp.91-95.
[9] Martin, J.P. Collins R.A., Browning J.S. and Biehl F.J. (1990), "Properties and Use of Fly Ash for Embankments", Journal of Energy Engg., ASCE, Vol. 116, No. 2 pp71-86.
[10] Kaniraj, S.R. and Havangi V.G. (1999),"Geotechnical Characteristics of Fly Ash Soil Mixture", Geotechnical Engg. Journal, Vol.30, No.2, August, pp.129-134.
[11] Virendra Singh, Narendra Kumar & Devendra Mohan (1996), "Use of Fly Ash in Soil Stabilization for Road", Proceeding of Indian Geotechnical Conference, 96, Madras, pp.411-414.
[12] Singh (M) & Garg (M.), Cement & Concrete Research, "Cementitious binder from fly ash and other industrial wastes." 29, 3; 1999; 309.

[13] Selvig, W.A., and Gibson, F.H. (1956). "Analysis of ash from United States coals." Bulletin 567, Bureau of Mines.
[14] Seals, R.K., Moulton, L.K., and Ruth, B.E. (1972). "Bottom ash: An engineering material." J. Soil Mech. Found. Div., 98(4), 311-325.
[15] Huang, H.W. (1990), "The use of bottom ash in highway embankments sub grade, and sub base," Joint Highway Research Project, Final Report, FHWA/IN/JHRP-90/4, Purdue Univ., W. Lafayette, Ind.
[16] IS: 2720-Part-3-1980, "Determination of Specific Gravity- Fine-grained soils".
[17] IS:2720-Part-8-1983,"Determination of Water Content-Dry Density Relation using Heavy Compaction".
[18] IS: 2720-Part-37-1975, "Laboratory Determination of Permeability of Granular Soils (Variable Head)".
[19] IS: 2720-Part-39-1977, "Direct Shear Test for Soils containing gravel, Laboratory Test".