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STUDY OF GEOTECHNICAL BEHAVIOUR OF POND ASH MIXED WITH MARBLE DUST

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ABSTRACT

There are numerous substances that cause air, water and soil pollution, disrupt ecological cycles and set off environmental hazards and one of them is fly ash. Fly ash is the ash produced by burning of pulverized coal in thermal power plants that gets collected at the bottom of furnace as well as in electrostatic precipitators. The high temperature of burning coal turns the clay minerals present in the coal powder into fused fine particles mainly comprising aluminium silicate. Fly ash produced thus possesses both ceramic and pozzolanic properties. It exhibits engineering behavior similar to fine grained soils. It is possible to use fly ash as an alternative to geomaterials. This paper deals with geotechnical characteristics of the pond ashes collected from Badarpur, Dadri and Rajghat Power Plant located in the National Capital Region, Delhi. Since the proposed study is based on the characteristics of pond ashes mixed with another waste - marble dust, another waste, which is generated as a by-product during cutting of marble, hence its properties has also been investigated. The purpose of mixing this admixture with pond ash is to check the strength, deformability, volume stability (shrinking and swelling), permeability, erodibility, durability etc. This paper presents the details of the pond ashes, the experiments carried out to characterize them when mixed with marble dust and the results and discussions.

Keywords

Pond Ash, Marble Dust, Geotechnical Characterization, Physical* Properties, *Triaxial Tests

1. INTRODUCTION

In India, thermal power is the chief source of energy and produces nearly 70 percent for total energy production. The coal ash generated from all the existing thermal power plants is over 100 million tonnes per year (Gulhati & Datta, 2005). Since the production of high ash content and low percentage utilization, most of the fly ash has to be suitably disposed off on land by creating an engineered ash pond to take care of environmental concerns. The fly ash as well as bottom ash produced by the plant is generally disposed of in an ash pond in a form of slurry in a ratio varying from 1 part ash and 6 to 10 parts of water which are located within few kilometers distance from the power plant. This ash is called pond ash. This study deals with geotechnical characteristics of the pond ashes obtained from Badarpur, Dadri plant sites of National Thermal Power Corporation and Rajghat plant sites of Indraprastha Thermal Power Corporation. The characteristics of pond ashes when mixed with another waste Marble Dust in the percentage of 2, 5, 8 and 10 by weight are also checked in the current study.

The purpose of mixing marble dust with pond ash is to check the strength, deformability, volume stability (shrinking and swelling), permeability, erodibility, durability etc. Improving the engineering properties of pond ash by admixture is often simply compared with soil stabilization, particularly in road construction.

2. MATERIAL USED

2.1 Pond Ash

Bulk quantities of pond ashes in wet state were collected from the sites of the Badarpur, Dadri and the Rajghat thermal power stations in and around New Delhi. All pond ashes were collected personally and procured freshly at the beginning of the study and stored properly.

The chemical, geotechnical and mineralogical features of ash depend on various factors like:
a) Type of coal used for fuel.
b) Degree of combustion.
c) Disposal system used.

The coal obtained from mines can be categorized according to carbon content as:

a) Grade A (maximum carbon content)
b) Grade B
c) Grade C
d) Grade D (minimum carbon content)

The quantity of ash produced varies according to the grade of coal used for combustion. A coal having maximum carbon content will produce minimum ash and vice versa.

Table 1 and 2 presents the detailed physical and chemical analysis of the pond ashes.

Table 1 Chemical properties of Badarpur, Dadri and Rajghat pond ashes

Constituents in Percentage	Source of pond ash		
	Badarpur	Dadri	Rajghat
SiO_2	49.5	52.82	54.98
Al_2O_3	25.01	20.07	20.75
MgO	1.21	1.24	1.32
Fe_2O_3	9.81	8.58	8.29
CaO	4.48	5.87	5.92
Loss of Ignition	9.79	10.53	8.22
Others	0.08	0.29	0.25

Table 2 Geotechnical properties of Badarpur, Dadri and Rajghat pond ashes

Properties	Source of pond ash		
	Badarpur	Dadri	Rajghat
Fine sand size, 0.475-0.075 mm, %	72	56	66
Silt size, 0.075-0.002 mm, %	22	34	31
Uniformity coefficient, C_u	4.8	5.96	5.11
Coefficient of curvature, C_c	1.05	1.06	1.06
Effective size D_{10}, mm	0.049	0.026	0.043
D_{30} size, mm	0.11	0.065	0.1
D_{60} size, mm	0.235	0.155	0.22
Specific gravity	2.2	1.96	2.1
Plastic Limit	Non-plastic	Non-plastic	Non-plastic
Maximum dry unit weight, kN/m^3	12	11	11.9
Optimum moisture content, %	32	33	30.9
CBR value (%)	12.2	10.4	11.2
Triaxial (CU) Test			
Cohesion intercept (c), kPa	0	0	0
Angle of shearing resistance Φ,(°)	30.4	32.0	28.9

2.2 Marble Dust

Marble dust is generated as a by-product during cutting of marble. The waste is approximately in the range of 20% of the total marble handled. The amount of marble dust generated in Rajasthan (from where the sample collected) every year is very substantial being in the range of 5-6 million tonnes.

The marble cutting industries are dumping the Marble dust in any nearby pit or vacant spaces near their unit, although notified areas have been marked for dumping. This leads to serious environmental problems like dust pollution and occupation of vast areas of land, especially after the slurry dries up. This also contaminates the underground water reservoirs (Singh et al., 1999).
Minor impurities in the Marble dust include quartz, chert, flint, hematite, limonite, graphic, mica etc. The chemical analysis of the dust shows that it is a mixture of calcium and magnesium carbonates with 90% of the particles below 200 microns.

Table 3 and 4 presents the detailed physical and chemical analysis of the Marble dust.

3. EXPERIMENTAL INVESTIGATIONS

The pond ash samples used in the present research work was obtained from Badarpur and Dadri plant sites of National Thermal Power Corporation and Rajghat plant site of Indraprastha Thermal Power Corporation located in National Capital Region. The collected pond ash from Badarpur, Dadri and Rajghat power plant were characterized in the geotechnical laboratory. Tests were conducted to determine the physical properties, and geotechnical properties of all pond ashes. The specific gravity test was performed for all three of them. Standard and modified proctor tests were performed for pond ash samples alone and when mixed with marble dust and OMC and MDD were calculated. The grain size analysis was also done for all pond ash samples. The consolidated undrained triaxial tests and California Bearing Ratio tests were performed for various compositions of pond ashes and marble dust at an increasing percentage of 2%, 5%, 8% and 10%. The details of the experimental program are summarized in Table 5. The tests were performed conforming to standard specifications listed in Table 6.

Table 3 Chemical properties of Marble dust

Properties	Test value (%)
Calcium Carbonate ($CaCO_3$)	90.06
Magnesia (MgO)	5.85
Silica (SiO_2)	2.32
Alumina ($A1_2O_3$)	1.36
Iron Oxide (Fe_2O_3)	0.39
Soda	Less than 0.01
Potash	Less than 0.01

Table 4 Physical properties of Marble dust

Properties	Value
Standard Proctors Test	
MDD (gm/cc)	1.65-1.85
OMC (%)	15.8
Specific gravity	2.82-2.86

Table 5 Experimental program

Details of experiments	Material
Specific gravity	Pond ashes
Grain size distribution	Pond ashes
Atterberg limit tests	Pond ashes
Compaction tests: Light compaction (standard Proctor) test and heavy compaction (modified Proctor) test	Pond ashes and mixes
Consolidated undrained triaxial tests under confining pressures of 100, 200, and 300 kPa	Pond ashes and mixes
California Bearing Ratio test	Pond ashes and mixes

Note: (a) Pond ashes refer to Badarpur, Dadri and Rajghat pond ashes
(b) Pond ashes and mixes refer to all three above pond ashes and the mixes of these pond ashes with marble dust

Table 6 Standard codes used to perform laboratory tests

Laboratory tests	Standard/Procedures
Specific gravity	RILEM recommendations (1989)
Grain size analysis	IS: 2720 (Part 4) – 1985
Atterberg limit test	IS: 2720 (Part 5) – 1985
Standard Proctor compaction test	IS: 2720 (Part 7) – 1980
Modified Proctor compaction test	IS: 2720 (Part 8) – 1983
Unconsolidated undrained triaxial shear test	IS: 2720 (Part 11) – 1981
California Bearing Ratio test	IS: 2720 (Part 16) – 1987

3.1 Details of Tests Conducted

3.1.1 Specific gravity

The specific gravity G of the fly ash was tested in a non-aqueous medium (kerosene) as per International Union of Laboratories and Experts in Construction Materials, Systems, and Structures (RILEM) (1989) recommendations.

3.1.2 Grain size distribution

The grain size distribution was carried out as per the Indian Standard IS: 2720 (Part 4) – 1985.

3.1.3 Atterberg limit test

The tests for Atterberg limits were conducted as per Indian Standards IS: 2720 (Part 5) – 1985. Liquid limit tests were carried out using Casagrande's equipment.

3.1.4 Compaction characteristics

Light (standard Proctor), and heavy (modified Proctor) compaction tests were carried out to determine the maximum dry density (MDD) and optimum moisture content (OMC) of Badarpur, Dadri and Rajghat pond ashes and their mixes as per IS: 2720 (Part 7) – 1980 and IS: 2720 (Part 8) – 1983.

3.1.5 Shear strength characteristics

Consolidated undrained (CU) triaxial tests were carried out under confining pressures of 100 kPa, 200 kPa and 300 kPa on all three pond ashes alone as well as on their mixes. The tests were performed as per IS: 2720 (Part 11) – 1981 to determine the total shear strength characteristics of the pond ashes and its mixes with marble dust in terms of Mohr-Coulomb total strength parameters, namely, cohesion (c) and angle of shearing resistance (Φ).

3.1.6. California Bearing Ratio tests

California Bearing Ratio (CBR) tests were carried out to determine CBR value of all pond ashes and their mixes as per IS: 2720 (Part 16) – 1987.

3.2 Tests results and discussion

3.2.1 Specific gravity

The specific gravity of the Badarpur, Dadri and the Rajghat pond ashes is summarized in Table 2. The specific gravity of the Badarpur, Dadri and the Rajghat pond ashes were found to be 2.20, 1.96 and 2.10 respectively. The range of specific gravity of Indian coal ashes as reported by Sridharan (2001) is 1.46 to 2.66. Specific gravity of the above three pond ashes falls within the range.

3.2.2 Grain size distribution

Fig. 1 shows the grain size distribution curves of Badarpur, Dadri and Rajghat pond ashes. The details of the grain size characteristics are presented in Table 2. McLaren and DiGioia (1987) have reported the mean value of uniformity coefficient of ninety eight class F fly ashes collected from different parts of U.S.A. as 5.49 ±3.6. The uniformity coefficient of Badarpur, Dadri and Rajghat pond ashes falls within this range.

3.2.4 Atterberg limit test

The liquid limit of Badarpur, Dadri and Rajghat pond ash was 38.5%, 46.6% and 43.8% respectively. The plastic limit test showed that all pond ashes exhibited non-plastic behavior. Havangi (1999) has obtained the liquid limit of Rajghat fly ash as lying between 48% to 51%. As per the Unified Soil Classification System, Badarpur, Dadri and Rajghat pond ashes may be classified as equivalent to silty sand or SM type soil.

3.2.5 Compaction characteristics

Pond Ash alone

Light compaction (or standard Proctor) and heavy compaction (or modified Proctor) tests were carried out to determine the corresponding maximum dry density (MDD) and optimum moisture content (OMC) of Badarpur, Dadri and Rajghat pond ashes and their mixes. Fig. 2 shows the comparison of compaction curves for the Badarpur, Dadri and Rajghat pond ashes. Badarpur pond ash had maximum dry density than the other two pond ashes.

Because the specific gravity G of the pond ashes is smaller than that of normal soils and the particles are porous in nature, pond ashes have a lower MDD and higher OMC than normal soils.

Based on the analysis of fifty seven fly ashes from different countries, Kaniraj and Havanagi (2001) have suggested an empirical correlation between MDD, OMC and specific gravity G as

$$MDD = 25.234\, G^{0.488}\, OMC^{-0.336} \qquad (3.1)$$

The values of OMC are substituted in percent in the above correlation. The coefficient of correlation (R^2) and standard error of MDD estimate are 0.95 and 1.04 kN/m^3, respectively. For Badarpur, Dadri and Rajghat pond ashes with G = 2.2 and OMC = 32.0%, G = 1.96 and OMC = 33.0% and G = 2.1 and OMC = 30.9%, respectively, Eq. (3.1) gives the value of MDD as 11.57 kN/m^3, 10.82 kN/m^3 and 11.44 kN/m^3 which are quite close to the experimental value of 12.0 kN/m^3, 11.0 kN/m^3 and 11.9 kN/m^3 respectively. Eq. (3.1) indicates that as the specific gravity of a fly ash increases, its MDD also increases. However, the MDD and OMC are inversely correlated.

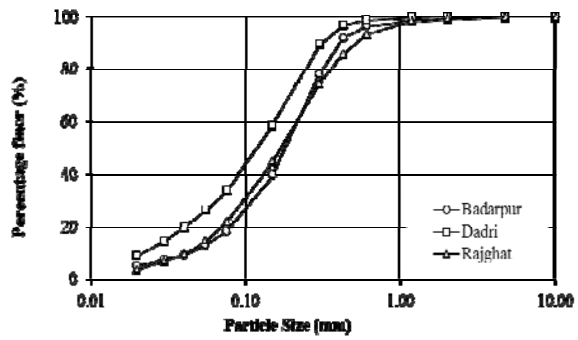


Fig. 1 Grain size distribution curves of Badarpur, Dadri and Rajghat Pond Ash

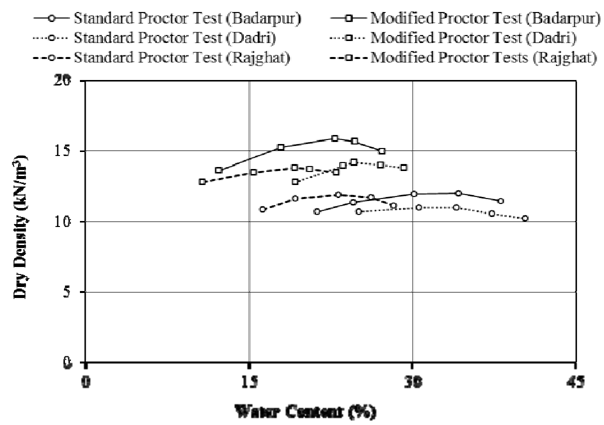


Fig. 2 Proctors compaction test results of Badarpur, Dadri and Rajghat Pond Ashes

Kaniraj and Havanagi (2001) have also suggested a procedure to make a preliminary estimate of the MDD and OMC from the specific gravity to facilitate the planning of the compaction test. For G = 2.2, it is estimated from this procedure that for the light compaction, the MDD is likely to be in the range of 10.9-13.0 kN/m^3 and the corresponding range of OMC is likely to be 23.7 – 37.6%.

Pond Ash mixed with Marble Dust

It is observed that in case of standard Proctor test, MDD lies in the range of 11.7-12.4 kN/m^3, 12.3-12.8 kN/m^3, 12.8-13.4 kN/m^3 and 13.2-13.8 kN/m^3 when the pond ashes are mixed with 2%, 5%, 8% and 10% of marble dust. In the case of modified Proctor test, the values of MDD lie in the range of 14.2-15.2 kN/m^3, 14.6-

15.5 kN/m^3, 15.0-16.0 kN/m^3 and 15.5-16.3 kN/m^3, respectively, when the pond ashes are mixed with 2%, 5%, 8% and 10% of marble dust.

3.2.6 Consolidate Undrained Triaxial shear test

Pond Ash alone

In the current study, consolidated undrained (CU) triaxial shear tests were carried out on Badarpur, Dadri and Rajghat Pond ash specimens (at MDD – OMC as initial state) under confining stresses of 100, 200, 300 kPa. The consolidation at all confining pressures took place rapidly and was nearly complete within 4 minutes. The specimens were tested at a deformation rate of 0.20 mm/min. The variations of deviator stress and pore water pressure rise with axial strain are shown in Fig. 3. The effective cohesion and angle of shearing resistance were 0 and 30.4^o for Badarpur pond ash, 0 and 32.0^o for Dadri pond ash and 0 and 28.9^o for Rajghat pond ash. Sridharan (2001) reported the range of values of drained shear strength parameters for some of the compacted and saturated Indian fly ashes lies between 0 kPa and 33^o- 43^o. The above values for Badarpur and Rajghat pond ashes are nearer to the lower value of the range. The effective strength parameter Φ' of the Dadri pond ash specimens is even lower and may be attributed to its finer size and predominantly smooth spherical particles.

It is observed that the axial strain at failure increases with increase in confining pressure for all the pond ash materials alone and mixes with marble dust. Also it has been seen that peak value of pore water pressure rise increases with increase in confining pressure. The deviator stress attained peak value at axial strains in the range of 1.5-3.0% for all the samples and thereafter remained almost constant.

Pond Ash mixed with Marble Dust

From Fig. 3, it is observed that addition of marble dust in pond ash increases Φ' value but did not show any changes in original zero value of c'. It is also been seen that the Φ' value changes quite linearly by addition of lime up to 8% (ranges between 29.7^o-33.1^o, 32.1^o-34.2^o and 33.4^o-35.1), but increases quite significantly at 10% in case of Badarpur and Rajghat pond ashes while in case of Dadri pond ash this changes is not significant.

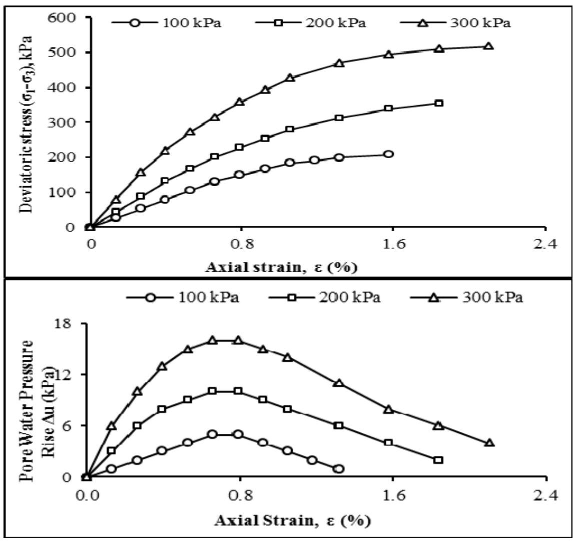
3.2.7 California Bearing Ratio Test

Pond Ash alone

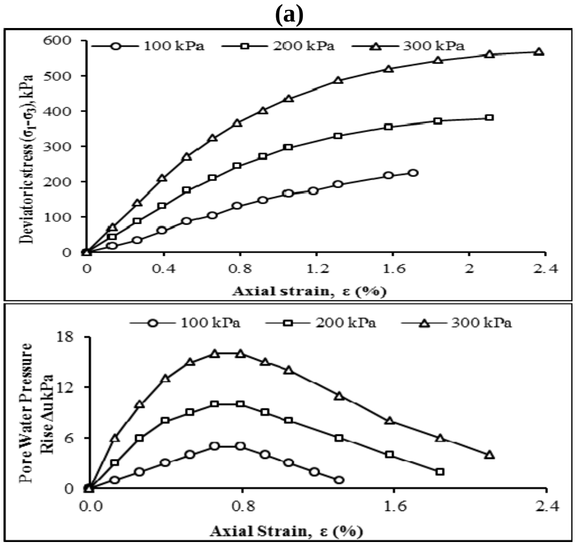
Soaked CBR tests were conducted on all the materials. In case of pond ash a layer of local soil (poorly graded sand type) was used to sandwich the pond ash as it was unable to take the load after four days of soaking. From Table 2, the CBR values are 12.2%, 10.4% and 13.2% for Badarpur, Dadri and Rajghat pond ashes respectively.

Pond Ash mixed with Marble Dust

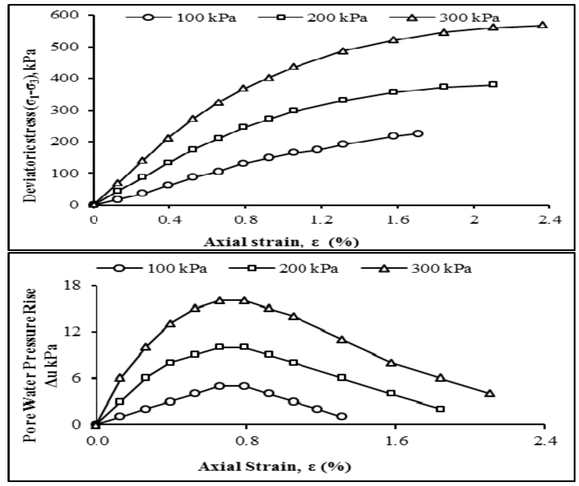
From Fig. 5, it is observed that addition of marble dust in pond ash increases CBR value. The CBR value changes linearly by addition of lime which ranges between 13.27-16.28%, 17.26-17.89%, 23.66-25.32% and 28.99-30.71% when pond ashes mixed with 2%, 5%, 8% and 10% marble dust respectively.



(a)



(b)



(c)

Fig. 3 Deviatoric stress and Pore Water Pressure Rise vs. Axial Strain Curve of
(a) Badarpur Pond Ash (b) Dadri Pond Ash and (c) Rajghat Pond Ash

CONCLUSIONS

Experimental studies were conducted to characterize Badarpur, Dadri and Rajghat Pond ashes. The study included the determination of physical properties and geotechnical characteristics. The following conclusions are arrived at from the study.

All the pond ash particles collected from Badarpur, Dadri and Rajghat are predominantly sand with nearly 72%, 56% and 66% particles of sand size and 28%, 44% and 34% of the particles being finer than 75 micron size respectively.

The ratio of light (standard Proctor) compaction characteristics and heavy (Modified Proctor) compaction characteristics of Badarpur, Dadri and Rajghat pond ashes were different. The Badarpur pond ash could be compacted to a somewhat greater dry unit weight than the other two pond ashes. The ratio of MDD and OMC of the two Proctor tests were found for these three pond ashes as 75% and 133%; 77% and 126% and 86% and 125% respectively.

In the consolidated undrained triaxial shear tests of the Badarpur, Dadri and the Rajghat pond ash specimens (MDD-OMC state), the deviator stress attained peak value at axial strains in the range of 1.5-3.0% for all the samples and thereafter remained almost constant. The drained cohesion and angle of shearing resistance were 0 kPa and 30.4^{o}; 0 kPa and 32.0^{o} and 0 kPa and 28.9^{o} respectively. The cohesion intercept value for all the pond ashes mixed with admixtures found to be zero except in case of fiber distinct cohesion intercept value was found.

In the California Bearing Ratio tests, the value of CBR increases with the increase of marble dust content.

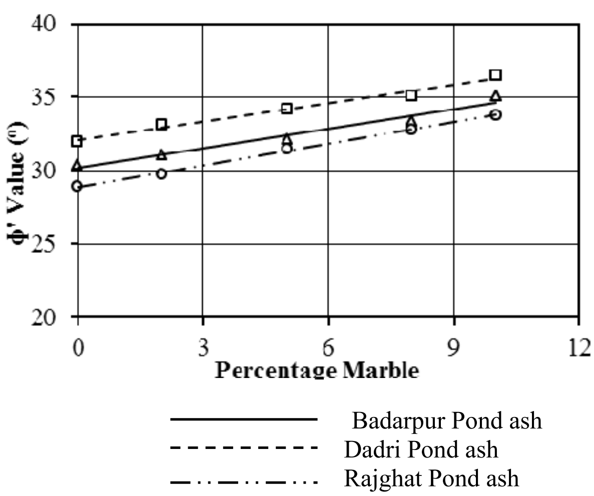


Fig. 4 Variation of Φ' value with Percentage Marble Dust

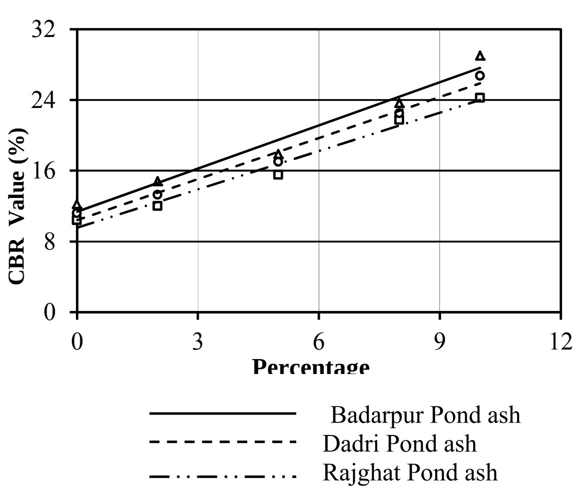


Fig. 5 Variation of CBR value with Percentage Marble Dust

4. REFERENCES

1. Gulhati S.K. and Datta M. (2005) 'Geotechnical Engineering', Tata McGraw-Hill Pub, Delhi

2. Kaniraj, S.R., and Havangi, V.G. (2001), 'Correlation Analysis of Laboratory Compaction of Fly Ashes', Practice Periodical of Hazardous, Toxic And Radioactive Waste Management, ASCE, 5(1), 25-32

3. Havanagi, V.G. (1999) 'Geotechnical characterization, strength and erosion aspects of fly ash-soil mixtures', Ph.D Thesis, Deptt. of Civil Engineering, IIT-Delhi, India

4. IS: 2720 (1967) 'Compendium of Indian Standards on Soil Engineering', Part-I, Bureau of Indian Standards, New Delhi, India

5. McLaren, R.J., & Digioia, A.M. (1987) 'The typical engineering properties of fly ash', Proceeding Conference on Gotech. Practice for Waste Disposal, Geotechnical Spe Badarpur Pond ash CE, Wood (ed.), New York, Dadri Pond ash
Rajghat Pond ash

6. RILEM TC FAL 67 (1989) 'Use of fly ash in building, fly ash in concrete – test methods', Mat. And Structures: Mat. Of Construction, 22, 304

7. Singh, R.B., and Khanna, P. (1999), 'Studies on a Reinforced System for Utilization of Thermal Power Plant Waste Fly Ash', Fly Ash disposal and Deposition: Beyond 2000 AD, Narosa Publishing House, New Delhi, India

8. Sridharan, A. (2001), 'Physical, chemical and engineering properties of Indian coal ashes', National Seminar on Utilization of Fly Ash in Water Resources Sector, Central Soil and Material Research Station, New Delhi, pp15-28