Int. J. of GEOMATE, Sept., 2012, Vol. 3, No. 1 (Sl. No. 5), pp. 273-279
Geotec., Const. Mat. and Env., ISSN:2186-2982(P), 2186-2990(O), Japan

Comparison Study of Geotechnical Behaviour of Lime Reinforced Pond Ashes Available in Delhi Region

Raju Sarkar[1], S.M. Abbas[2], and J.T. Shahu[3]
[1, 2]Department of Civil Engineering, Jamia Millia Islamia, New Delhi, India
[3]Department of Civil Engineering, Indian Institute of Technology, Delhi, India

ABSTRACT: Pond ash is a pozzolanic material and can be stabilized with lime. It can also be stabilized with other commonly available stabilizers like cement, bentonite etc. This paper deals with both geotechnical characteristics of the pond ashes alone as collected from various thermal power stations in the National Capital Region, Delhi and also when they are stabilized using lime. The purpose of mixing this additive with pond ash is to improve the strength, deformability, volume stability (shrinking and swelling), permeability, erodibility, durability etc. of the mix for their use in the road construction.

Keywords: Pond Ash, Lime, Geotechnical Characterization, Physical Properties, Triaxial Tests.

1. INTRODUCTION

Thermal power is the chief source of energy and produces nearly 70 percent of total energy production in India. Over 100 million tons per year (Gulhati and Dutta [1]) of coal ash is generated by these thermal power plants. Due to high ash content of coal along with a low percentage utilization of the fly ash, most of the fly ash is 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 the form of slurry in a ratio varying between 1 part ash to 6-10 parts of water. This ash is known as pond ash. Ash ponds are usually located within a few kilometer distances from the power plant. In the present study, pond ashes were collected from Badarpur and Dadri plant sites of National Thermal Power Corporation, and Rajghat plant site of Indraprastha Thermal Power to determine chemical and geotechnical characteristics of the material.

Calcium oxide (CaO), commonly known as quicklime, is a widely used chemical compound. It is a white, caustic and alkaline crystalline solid at room temperature. As a commercial product, lime often also contains magnesium oxide, silicon oxide and smaller amounts of aluminium oxide and iron oxide (refer Table I for a typical chemical composition).

Lime in the form of quicklime (calcium oxide - CaO), hydrated lime (calcium hydroxide –$Ca(OH)_2$), or lime slurry can be used to treat soils. Quicklime is manufactured by chemically transforming calcium carbonate (limestone – $CaCO_3$) into calcium oxide. Hydrated lime is created when quicklime chemically reacts with water (refer Table II for comparison). It is hydrated lime that reacts with clay particles and permanently transforms them into a strong cementitious matrix. Usually, limes used for soil treatment are "high calcium" limes, which contain not more than 5 percent of magnesium oxide or hydroxide. Lime, either alone or in combination with other materials, can be used to treat a range of soil types.

The mineralogical properties of the soils determine their degree of reactivity with lime and the ultimate strength that the stabilized layers will develop.

In general, fine-grained clay soils are considered to be good soil for lime stabilization. Soils containing significant amounts of organic material (greater than about 1 percent) or sulfates (greater than 0.3 percent) may require additional lime and/or special construction procedures.

Table I Chemical Composition of Lime

Minimum Array (Acidimetric)	95.00%
Maximum Limits of Impurities	
Chloride (Cl)	0.10%
Sulphate (SO_4)	0.50%
Iron (Fe)	0.10%
Lead (Pb)	0.02%
Loss on Ignition	10.0%

Table II Index properties for transition from quicklime to hydrated lime

Properties	Quicklime	Water	Hydrated lime
Molecular weight	56	18	78
Specific gravity	3.3	1	2.2
Relative weight	1	0.32	1.32
Relative volume	1	-	1.99

The geotechnical characteristics of pond ashes when mixed with lime in percentage of 2, 5, 8 and 10 by weight was also evaluated in the present study.

To check strength, deformability, volume stability (shrinking and swelling), permeability, erodibility, durability etc., lime is mixed with pond ash. 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

The chemical and geotechnical properties of ashes depend on various factors such as type of coal used as fuel, degree of combustion, disposal system used etc. The chemical and geotechnical properties of all three pond ash samples used in this study are given in Tables III and IV respectively.

Table III 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

2.2 Lime

The lime used in the present study was procured from the open market in the form of quick lime. This lime was then mixed with pond ash and water in required proportion by weight. Since the lime was procured from the open market, it is expected that its chemical composition will be similar to that given in Tables I and II.

3. EXPERIMENTAL INVESTIGATIONS

3.1 Introduction

Bulk quantities of pond ashes in wet state were collected from the sites of Badarpur, Dadri and Rajghat thermal power stations in and around National Capital Region, Delhi. All pond ashes were collected personally and procured freshly at the beginning of the study and stored properly. The collected pond ash from Badarpur, Dadri and Rajghat power plant were characterized in the geotechnical laboratory of Jamia Milia Islamia and Delhi Technological University. Tests were conducted to determine physical and geotechnical properties of all pond ashes. The specific gravity test and grain size analysis were performed on all three of them. Standard and modified Proctor tests were also performed on all pond ash samples, and optimum moisture content (OMC) and maximum dry density (MDD) were calculated. The consolidated undrained (CU) triaxial tests and California Bearing Ratio (CBR) tests were performed on compacted specimens of all three pond ashes alone as well as their mixes with an increasing percentage of lime by weight. Thus, the tests were conducted on different compositions of pond ash – lime mixes wherein 2, 5, 8 and 10% of the lime by weight was used. The details of the experimental program are summarized in Table V. The tests were performed conforming to Indian standard specifications listed in Table VI.

Table IV 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
LL and PL	Non-plastic	Non-plastic	Non-plastic
MDD, kN/m^3	12	11	11.9
OMC, %	32	33	30.9
CBR value	12.2	10.4	11.2
Triaxial (CU) Test			
c, kPa	0	0	0
Φ, (°)	32.2	33.2	28.9

3.2 Details of Tests Conducted

3.2.1 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 recommendations (RILEM [2]).

3.2.2 Grain size distribution

The grain size distribution was carried out as per the Indian standard specifications [3].

3.2.3 Atterberg limit test

The tests for Atterberg limits were conducted as per the Indian standard specifications [4]. Liquid limit tests were carried out using Casagrande's equipment.

3.2.4 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 as per Indian standard specifications [5] and [6].

3.2.5 Shear strength characteristics

Consolidated undrained (CU) triaxial tests under confining pressures of 100 kPa, 200 kPa and 300 kPa were carried out on all three pond ashes alone as well as on different pond ash lime mixes. The tests were performed as per Indian standard specifications [7] to determine the total shear strength characteristics of the specimens in terms of Mohr-Coulomb total strength parameters, namely, cohesion (c) and angle of shearing resistance (Φ). The cylindrical specimens used for the triaxial tests were 38 mm in diameter and 76 mm high. The sample was first compacted in standard Proctor mould. The test specimen was then extruded from the mould using hydraulic extruder. All specimens were first subjected to required confining pressure in one step in the triaxial cell for 12 hours under drained condition. Next, the deviator stress was applied and the specimens were sheared under undrained condition at a deformation rate of 0.20 mm/min till the specimens failed in shear.

3.2.6 California Bearing Ratio test

California Bearing Ratio (CBR) tests were carried out to determine CBR value of all pond ashes and their mixes as per Indian standard specifications [8]. The California bearing ratio test is a penetration test that evaluates subgrade strength of roads and pavements. The results obtained by CBR tests are used with empirical curves to determine the thickness of pavement and its component layers. It is the most widely used method for the design of flexible pavements.

3.3 Test Results and Discussion

3.3.1 Specific gravity

The specific gravity of Badarpur, Dadri and Rajghat pond ashes are summarized in Table IV. 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 [9] is 1.46 to 2.66. The specific gravity of the above three pond ashes fall within this range.

3.3.2 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 IV. McLaren and Digioia [10] 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 fall within this range.

3.3.3 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. Havanagi [11] has determined 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 (SM) type soil.

3.3.4 Compaction Characteristics

Pond Ash alone

Light compaction (or standard Proctor) and heavy compaction (or modified Proctor) tests were carried out to determine the corresponding MDD and OMC of Badarpur, Dadri and Rajghat pond ashes. Fig. 2 shows the comparison of compaction curves for Badarpur, Dadri and Rajghat pond ashes. Badarpur pond ash had maximum dry density than the other two pond ashes. The standard and modified Proctor MDD and OMC of all three pond ashes are shown in Table VII.

Table V Experimental program

Type of Pond ash	Details of experiments
Badarpur, Dadri and Rajghat	Specific gravity
	a) Grain size distribution
	b) Atterberg limit tests
	c) Compaction tests: Light compaction (standard Proctor) test and heavy compaction (modified Proctor) test
	d) Consolidated undrained triaxial tests under confining pressures of 100, 200, and 300 kPa
	e) California Bearing Ratio test

Table VI 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
Consolidated undrained triaxial shear test	IS: 2720 (Part 11) – 1981
California Bearing Ratio test	IS: 2720 (Part 16) – 1987

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.

Eq. (1) indicates that as the specific gravity of a fly ash increases, its MDD also increases. However, the MDD and OMC are inversely correlated. Kaniraj and Havanagi [12] has 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 in 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 23.7 – 37.6%. 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.

Based on the analysis of fifty seven fly ashes from different countries, Kaniraj and Havanagi [12] have suggested an empirical correlation between MDD, OMC and specific gravity G as

$$MDD = 25.234\ G^{0.488}\ OMC^{-0.336} \quad (1)$$

Table VII Proctor compaction test results of pond ashes

Type of Pond Ash	Type of Proctor Compaction Test		Value
Badarpur	Standard	MDD (kN/m^3)	12.0
		OMC (%)	32.0
	Modified	MDD (kN/m^3)	14.9
		OMC (%)	24.0
Dadri	Standard	MDD (kN/m^3)	11.0
		OMC (%)	33.0
	Modified	MDD (kN/m^3)	13.8
		OMC (%)	22.1
Rajghat	Standard	MDD (kN/m^3)	11.9
		OMC (%)	30.9
	Modified	MDD (kN/m^3)	14.4
		OMC (%)	25.2

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. (1) gives the value of MDD as 11.57 kN/m^3, 10.82 kN/m^3 and 11.44 kN/m^3 which is quite close to the experimental value of 12.0 kN/m^3, 11.0 kN/m^3 and 11.9 kN/m^3, respectively.

Pond Ash mixed with Lime

From Fig. 3, it is observed that with the addition of lime in the pond ash, the maximum dry density increases upto to a certain value (= 8%) and decreases thereafter. The increase in the strength due to lime stabilization confirms the pozzolanic nature of the ash, and thus its capability to react with lime and develop substantial strength. As mentioned above, in the present study, addition of lime in the pond ash upto 8% increases the MDD value; possibly, the silica present in the finer particles of pond ashes are completely exhausted up to this value and addition of more lime actually becomes counterproductive after this value.
In the case of standard Proctor test, MDD lies in the range of 11.8-12.8 kN/m^3, 12.7-13.5 kN/m^3, 13.1-13.9 kN/m^3 and 12.2-13.1 kN/m^{3}for the pond ashes mixed with 2%, 5%, 8% and 10% lime, respectively. In the case of modified Proctor test, the values of MDD lie in the range of 14.4-15.6 kN/m^3, 15.4-16.6 kN/m^3, 15.6-16.9 kN/m^3 and 15.0-16.3 kN/m^3 when 2%, 5%, 8% and 10% lime, respectively, is added to the pond ashes.

3.3.5 Consolidated Undrained Triaxial test

The purpose of triaxial test is to study the stress-strain behaviour and to determine the shear strength of the material under lateral pressure. In the current study, Consolidated Undrained (CU) triaxial shear tests with pore water pressure measurements ($C\bar{U}$) were carried out on compacted Badarpur, Dadri and Rajghat pond ash specimens alone and on the specimens of the pond ash mixed with admixtures at maximum dry density and optimum moisture content as determined by standard proctors tests under confining stresses of 100, 200 and 300 kPa. The particle sizes of pond ash being equivalent to that of the fine sand, the consolidation at all confining pressures took place rapidly and were nearly complete within 4 minutes. The variation of deviator stress and pore water pressure rise with axial strain, and mean effective confining stress p′ with deviator stress q are shown in Figs. 4 and 5 for the pond ash specimens alone, where

$$p' = \frac{(\sigma 1' + \sigma 3')}{2}$$
$$q = \frac{(\sigma 1 - \sigma 3)}{2}$$

with σ_1' and σ_3' being major and minor effective principal stresses.

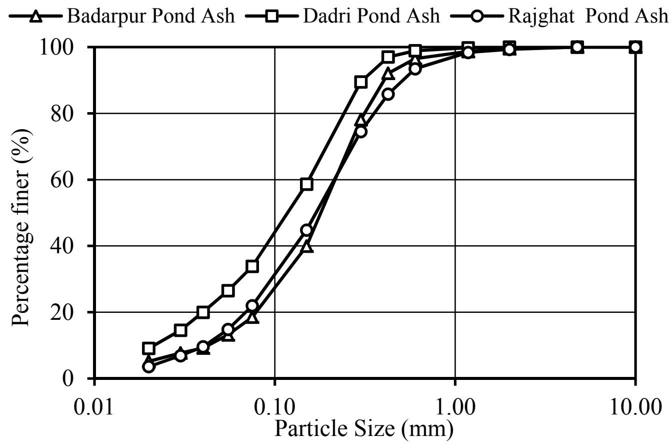


Fig. 1 Grain size distribution curves of Badarpur, Dadri and Rajghat Pond Ash

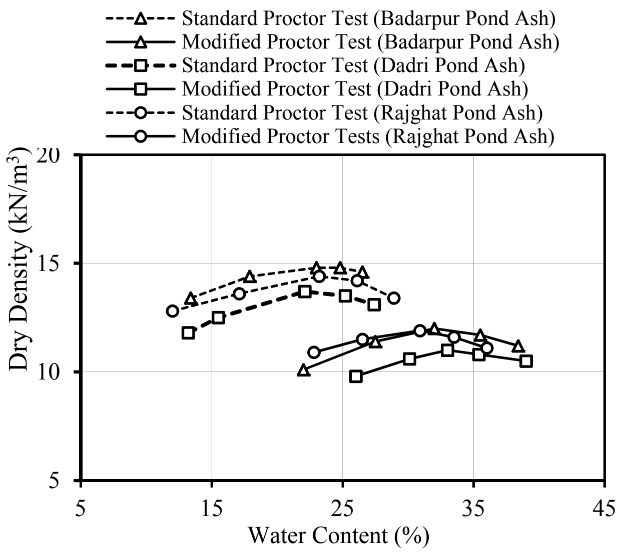


Fig. 2 Standard and modified Proctor test results for Badarpur, Dadri and Rajghat Pond ashes

Pond Ash

The variations of deviator stress and pore water pressure rise with axial strain for the three pond ashes are shown in Fig. 4. The corresponding plots of mean effective confining stress p′ versus deviator stress q for the three pond ashes are shown in Fig. 5. The effective cohesion and angle of shearing resistance were 0 and 30.4° for Badarpur pond ash, 0 and 32.0° for Dadri pond ash and 0 and 28.9° for Rajghat pond ash. Sridharan [9] has reported that the range of values of drained shear strength parameters for some of the compacted and saturated Indian fly ashes are c′ = 0 kPa and Φ′= 33°-43°. 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.

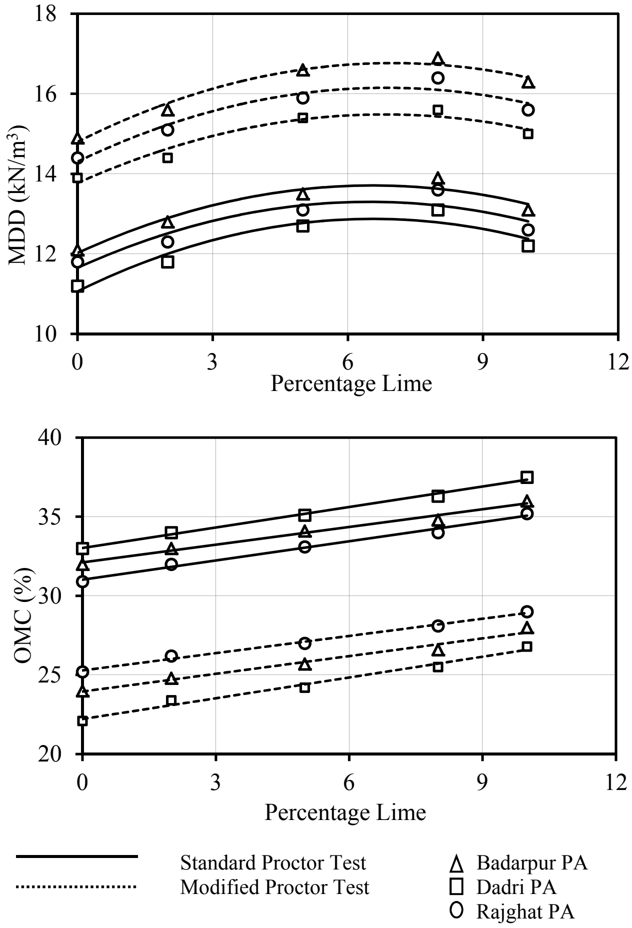


Fig. 3 Variation of MDD and OMC Value with Percentage of Lime

All specimens exhibited compression during application of deviator stress at all confining pressures. The axial strain at failure showed increase with the increase in confining pressure for all the pond ash specimens alone and the pond ash specimens mixed with admixtures. The peak value of the pore water pressure rise also showed increase with the increase in confining pressure. The deviator stress attained the peak value at axial strains in the range of 1.5-3.0% for all the specimens and thereafter remained almost constant. p' versus q relationships were plotted by considering peak deviator stress.

Pond Ash mixed with Lime

From Fig. 6, it is observed that addition of lime in pond ash increases Φ' value but does not show any changes in original zero value of c'. The Φ' values for the mixes ranges from 30.3°-33.0°, 32.0°-34.5°, 34.5°-36.4° and 36.3°-38.3° when the above pond ashes are mixed with 2%, 5%, 8% and 10% lime, respectively.

3.3.6 California Bearing Ratio Test

The purpose of California bearing ratio test is to study the strength behavior of material when used as a subbase material. In the current study, California Bearing Ratio (CBR) tests were carried out on Badarpur, Dadri and Rajghat pond ash specimens and on the specimens of the above pond ashes mixed with lime.

Pond Ash

As shown in Table IV, the CBR value for Badarpur, Dadri and Rajghat pond ashes are 12.2%, 10.4% and 11.2%, respectively.

Pond Ash mixed with Lime

Lime causes the pond ash particles to coagulate, aggregate, or flocculate. Thus pond ash becomes more easily workable and its strength and stiffness increases. From Fig. 7, it is observed that with the addition of lime in the pond ash, the CBR value increases upto to a certain percentage of lime (= 8%) and decreases thereafter. As mentioned above, addition of lime in the pond ash upto 8 %, increases the CBR value since silica in all the finer particles of pond ashes are used up upto this value and addition of more lime actually becomes counterproductive thereafter.

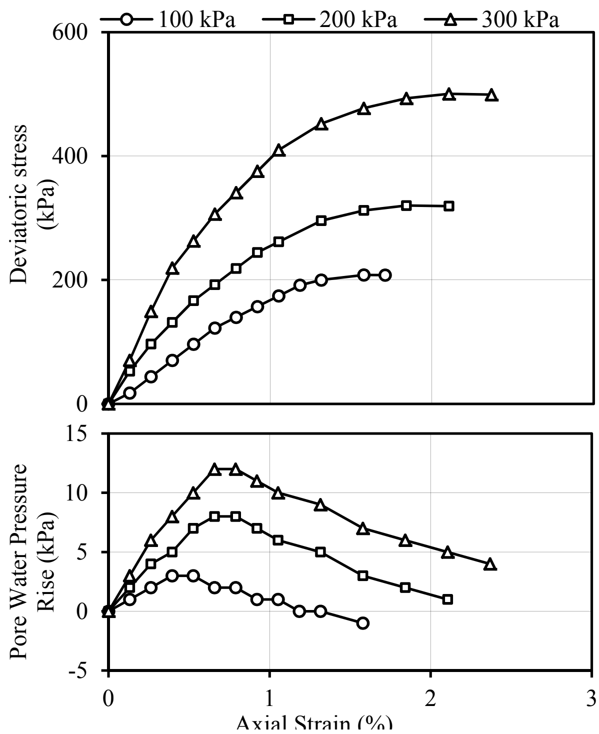


Fig. 4a Deviatoric Stress and Pore Water Pressure Rise vs. Strain Behavior of Badarpur Pond Ash

4 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.

1. All the pond ash samples collected from Badarpur, Dadri and Rajghat were predominantly sand with nearly

72%, 56% and 66% sand size particles and 22%, 34% and 31% of silt size particles (refer Table VIII).

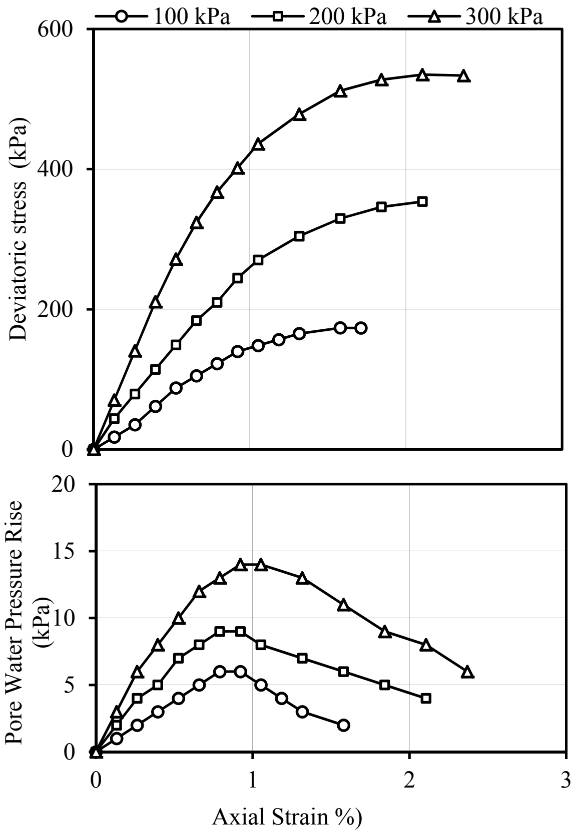


Fig. 4b Deviatoric Stress and Pore Water Pressure Rise vs. Strain Behavior of Dadri Pond Ash

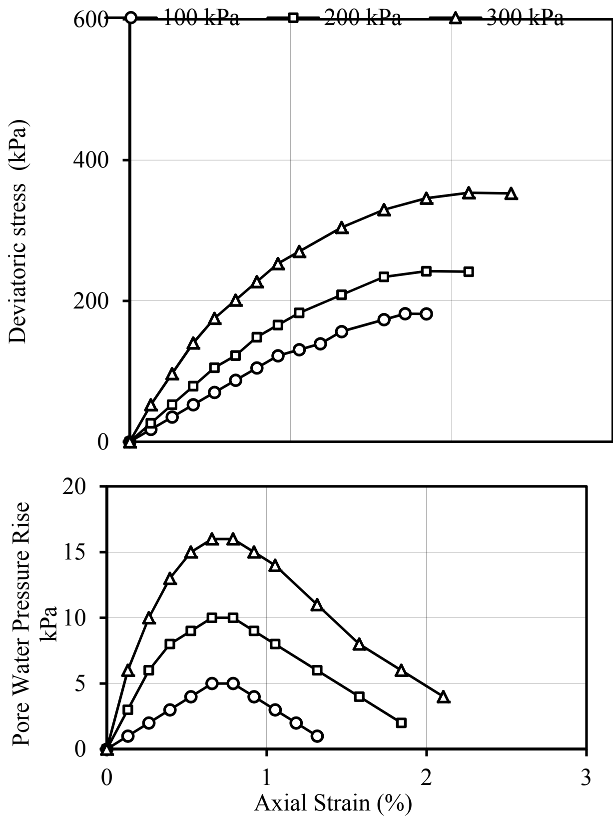
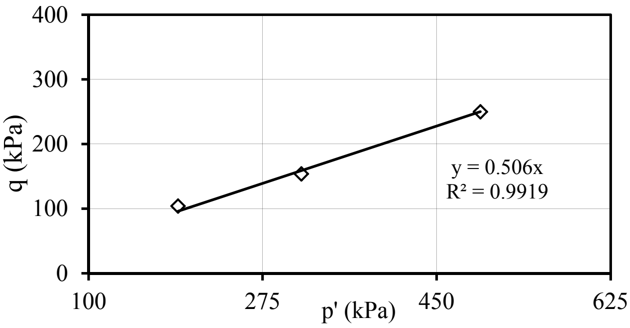
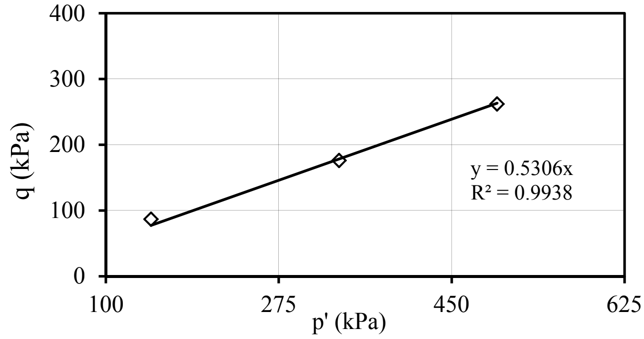


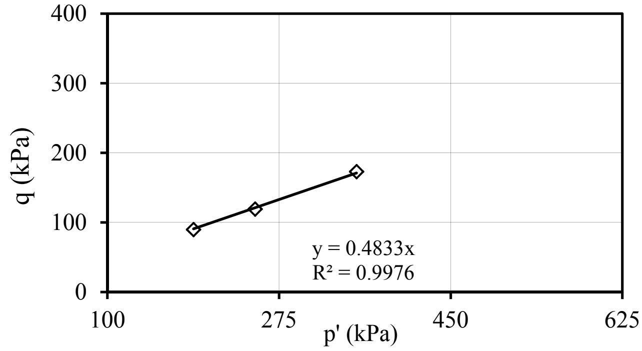
Fig. 4c Deviatoric Stress and Pore Water Pressure Rise vs. Strain Behavior of Rajghat Pond Ash



(a)



(b)



(c)

Fig. 5 p' vs. q curve of (a) Badarpur Pond Ash (b) Dadri Pond Ash (c) Rajghat Pond Ash

2. The ratio of light (standard Proctor) compaction characteristics and heavy (modified Proctor) compaction characteristics of Badarpur, Dadri and Rajghat pond ashes were different. As shown in Table IX, Badarpur pond ash could be compacted to a somewhat greater dry density values as compared to the other two pond ashes. The ratios of MDD values of the two Proctor tests were found to be 75%, 80% and 83%, respectively for Badarpur, Dadri and Rajghat pond ashes.
3. In the consolidated undrained triaxial shear tests of Badarpur, Dadri and Rajghat pond ash specimens compacted at MDD, deviator stress attained peak value at axial strains in the range of 1.5-3.0% for all the specimens and thereafter remained almost constant. The drained cohesion and angle of shearing resistance were 0 kPa and 30.4°; 0 kPa and 32.0° and 0 kPa and 28.9° respectively. The cohesion intercept values for all the pond ashes mixed with lime were found to be zero.

4. In the California Bearing Ratio tests, the value of CBR increases with the increase of the lime percentage in the pond ash lime specimens upto 8% and decreases thereafter.

Table VIII Particle sizes 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

Table IX Proctor compaction test results of pond ashes

Source of Pond Ash	Type of Proctor Compaction Test	MDD Value (kN/m^3)	Ratio of MDD Value (%)
Badarpur	Standard	12.0	75
	Modified	15.9	
Dadri	Standard	11.0	80
	Modified	13.8	
Rajghat	Standard	11.9	83
	Modified	14.3	

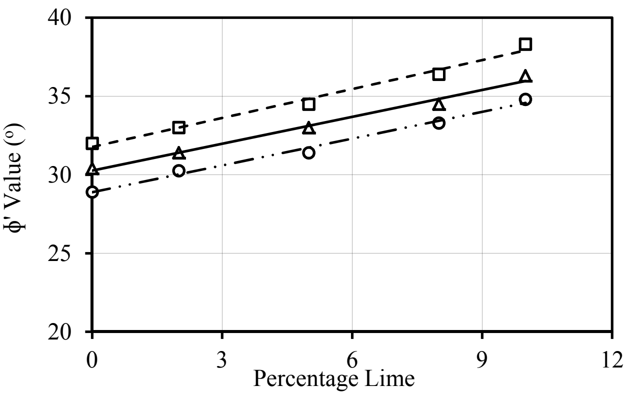


Fig. 6 Variation of Φ' Value with Percentage Lime

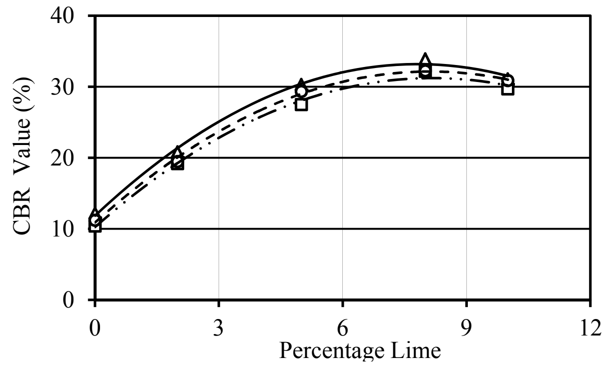


Fig. 7 Variation of CBR Value with Percentage Lime

5. REFERENCES

[1] Gulhati S.K. and Datta M. (1999). Geotechnical Engineering, Tata McGraw-Hill, New Delhi, 1999.

[2] RILEM (1989). TC FAB-67 Use of fly ash in building, Fly ash in concrete – Test methods, Mat. And Structures: Mat. Of Construction, 22, 304

[3] IS: 2720 (Part 4) (1985). Methods of Test for Soils: Determination of Grain Size Analysis, Bureau of Indian Standards, New Delhi, India

[4] IS: 2720 (Part 5) (1985). Methods of Test for Soils: Determination of Liquid and Plastic Limit, Bureau of Indian Standards, New Delhi, India

[5] IS: 2720 (Part 7) (1980). Methods of Test for Soils: Determination of Water Content-Dry Density Relation Using Light Compaction, Bureau of Indian Standards, New Delhi, India

[6] IS: 2720 (Part 8) (1983). Methods of Test for Soils: Determination of Water Content-Dry Density Relation Using Heavy Compaction, Bureau of Indian Standards, New Delhi, India

[7] IS: 2720 (Part 11) (1981). Methods of Test for Soils: Determination of Shear Parameters of a Specimen Test in Consolidated Undrained Triaxial Compression, Bureau of Indian Standards, New Delhi, India

[8] IS: 2720 (Part 16) (1987). Methods of Test for Soils: Determination of CBR Value, Bureau of Indian Standards, New Delhi, India

[9] 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, 15-28

[10] McLaren, R., and Digioia, A.M. (1987). The typical Engineering properties of Fly ash, Proc., Conf. on Gotech. Practice for Waste Disposal, Geotechnical Special publication, 13, ASCE, Wood (ed.), New York, 683-697.

[11]Havanagi, V.G. (1999). Geotechnical Characterization, Strength and Erosion Aspects of Fly ash-soil mixtures, Ph.D Thesis, Deptt. of Civil Engineering, Indian Institute of Technology, New Delhi, India

[12] 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

International Journal of GEOMATE , Sept., 2012, Vol. 3, No. 1 (Sl. No. 5), pp. 273-279
MS No. 3l received February 01, 2012, and reviewed under GEOMATE publication policies.

Corresponding Author: Raju Sarkar