Experimental Analysis on the Behaviour of Lime on Pond Ash Treated Expansive Clay

B. Eswara Rao, Rajasekharam K.,G. Saranya
Assistant Professor, AITAM, Tekkali

Abstract- **Stabilizing the locally available weak soils is of paramount importance in contemporary practices in construction industry. This paper presents results of laboratory investigation made on strength behaviour of a weak soil blended with pond ash and lime. The soil found in agriculture field, Tekkali, srikakulam district is classified as expansive soil. The properties of expansive soil depend significantly on its initial conditions. The properties of saturated expansive soil differ significantly from moist soil and dry soil. Expansive clay is microcrystalline in nature and clay minerals like Montmorillonite, kaolinite and illinite and non-clay minerals like quartz and feldspar are present in the soil. The soils have higher proportion of organic matters that acts as a cementing agent. Clay is an impermeable soil, meaning it holds water, as opposed to permeable soil that allows water to rapidly drain, like a gravel or sand. It is an expansive soil, such as the expansive clay which predominates in almost all countries of the world, which when swelling and shrinking, can damage foundations and structures. The shrink and swell movements are due to changes in soil moisture. Providing uniform soil moisture next to and under your foundation is the only best thing to reduce or minimize the damaging effects of expansive soil. Accumulation of various waste materials is now becoming a major concern to the environmentalists. Expansive clay is blended with pond ash, a solid-waste from the thermal power stations. Lime is added to soil and pond ash mix as binding material. Pond Ash by itself has little cementitious value but in the presence of moisture it reacts chemically and forms cementitious compounds and attributes to the improvement of strength and compressibility characteristics of soils. So in order to achieve both the need of improving the properties of expansive clays and also to make use of the industrial wastes, the present experimental study has been taken up. In this paper the effect of Pond ash and Lime on strength properties of expansive clay has been studied.**

Index Terms: **Pond Ash (PA), OMC, MDD, CBR.**

I. INTRODUCTION

The development of any country depends on the transportation facilities and the construction projects. For the projects to be successful, the soil used for the foundation beds must be strong which requires better soil properties. Effective and bulk utilisation of both locally available weak construction material and large quantity of disposed industrial waste is of global concern. Two major subjects of serious concern are availability of good construction material and safe disposal of huge amount of solid waste from industries. The very first decade of second millennium India saw sudden boost in infrastructure development and it is still in boom state, which might continue for long. Mega road projects like, Golden Quadrilateral, North-South and East- West Corridor, Pradhan Mantri Gram Sadak Yojana (PMGSY), and many other highway improvement projects are creating heavy demand on the earth resources. Availability of good construction materials to meet the high specifications and standards for these projects is of serious concern. Solely depending on crushed aggregates and on granular material for construction activities will endorse severe threat to ecological balance. Another issue is for safe disposal of huge amount of coal ash generated at a rate of more than 110 Metric tonne per annum as a waste by-product from the large number of thermal power stations. Indiscriminate disposal of fly ash will cause hazards and environmental problems. As the disposal of coal ash requires large area, therefore it is important to have its bulk utilisation in base and sub base courses of the pavement, embankments, backfills etc., to increase ash utilisation in the country.

Many innovative foundation techniques have been devised as a solution to the problem of expansive soils. The selection of any one of the techniques is to be done after detailed comparison of all techniques for the well suited technique for the particular system. The various additives used for stabilizing expansive soils are lime, calcium chloride, Rice Husk Ash, fly ash, gypsum and others. All over the world, problems of expansive clay have appeared as cracking and break-up of pavements, railway and highway embankments, roadways, building foundations, irrigation systems, water lines, canal and reservoir linings. The estimated damage was very expensive to the pavements running over the expansive clay sub grades.

Various remedial measures like soil replacement, pre-wetting, moisture control, chemical stabilization have been practiced with varying degrees of success. Unfortunately the limitations of these techniques questioned their adaptability in all conditions. So work is being done all over, to evolve more effective and practical treatment methods, to elevate the problems caused to any structures laid on expansive clay strata. Investigation on chemical stabilization (Petry and Armstrong, 1989; Prasada Raju, 2001) revealed that electrolytes like potassium chloride, calcium chloride and ferric chloride may be effectively used in place of conventionally used lime, because of their ready dissolvability in water and supply of adequate cations for ready cation exchange.

II. OBJECTIVE OF STUDY

The objectives of the present experimental study are

I. To determine the properties of the Expansive clay and Pond Ash.
II. To evaluate the performance of Expansive clay when stabilized with Pond Ash as an admixture and its suitability for the pavement sub grade.
III. To evaluate the performance of stabilized Expansive clay with an optimum of Pond Ash, Lime and their suitability for the pavements.

III. STABILISATION OF EXPANSIVE CLAYS

Soil stabilization is a procedure where natural or manufactured additives or binders are used to improve the properties of soils. Chemical additives, such as lime, cement, Fly Ash, and other chemical compounds have been used in expansive clays stabilization for many years with various degrees of success. The clay minerals have the property of absorbing certain anions and cations and retaining them in an exchangeable state. The exchangeable ions are held around the outside of the silica-alumina clay mineral structural unit.

Compositional variation through ionic or isomorphism substitution within the clay mineral crystal lattice can leave the structural unit with a net negative charge. Substitution also reduces the crystal size and alters its shape. Exposed hydroxyl groups and broken surface bonds can also lead to a net negative charge on the structural unit. The presence of this net negative charge means that soluble cations can be attracted or adsorbed on to the surface of the clay mineral structural units without altering the basic structure of the clay mineral. The ability of clay to hold cations is termed as its cation exchange capacity. The most common soluble cations are Na+, K+, Ca2+, Mg2+, H+, and NH4+. Cation exchange capacity (C.E.C.) has major significance in determining clay mineral properties, particularly the facility with which they adsorb water. Cation exchange capacity (C.E.C.) measures two of the fundamental properties of clays: 1. The surface area and the charge on this surface area. 2. The surface of clay can be of two sorts; external and internal. The external exchange capacity measures nothing more than the average crystalline size. The surface capacity of adsorption is largely dependent upon broken bonds and surface growth defects.

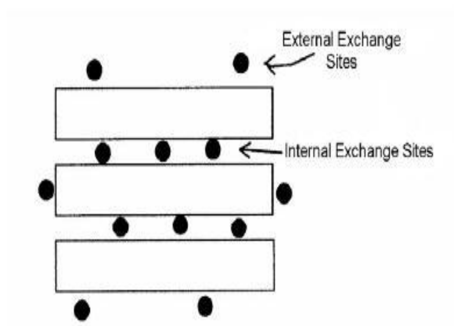


Fig 1: Different Types of Exchange Sites on Clay Particles, Surface and Absorbed Ion Interlayer Sites.

The internal exchange capacity is much more interesting in that it reflects the overall charge imbalance on the layer structure and the absorption capacity of the clays. The exchange capacity is an estimate of both the number of ions adsorbed between the layers of a clay structure and of those adsorbed on the outer surfaces. C.E.C., measured in terms of milli equivalent of the atomic weight of solvent/100 gram of the dry solid, which varies widely for various types of clay minerals.

The exchange capacity is almost always measured as a function of the number of cations (positively charged) which can be measured on the clay surface once it is washed free of exchange salt solution. The operation is performed by immersing a quantity of clay in an aqueous solution containing a salt, usually chloride or ammonium hydroxide. The soluble ions adsorbed with the water onto the interlayer structure can affect the adsorbed water arrangement in several ways. Principally, they act as a bond of varying strength holding the structural layer together and controlling the thickness of adsorbed water. Their effectiveness will depend on the size and charge. Thus Na+, K+ will tend to be weak and a clay-water system containing these ions will be capable of adsorbing large amounts of water. Ca2+, Mg2+, on the other hand, will have stronger links and a clay-water system containing them will possess substantially lower water content. Inclusion of Fe3+ or Al3+ would reduce the water content and plasticity and this is in fact the basis of the electro-chemical or electro-osmotic method of clay stabilization In this study, Granulated Blast Furnace Slag (GBFS), Granulated Blast Furnace Slag-FeCl3 Blends (GBFS-FeCl3) will be utilized as cementitious materials while trying to stabilize the expansive clay sample.

IV. POND ASH

Fly ash produced by thermal power plants takes huge disposal area and creates environmental problems like leaching and dusting .Actually, there are three types of a ash produced by thermal power plants , viz.,1.fly ash,2.bottom ash, 3.pond ash, Bera et al. 2007.Fly ash is collected by mechanical or electrostatic precipitators from the few gases of power plant, whereas, bottom ash is collected from the bottom of the boilers. When these two types of ash, mixed together, are transported in the form of slurry and stored in the lagoons, the deposit is called pond ash. The volume of pond ash produced by thermal power plants is very large compared to that of the other two ash, viz. fly ash and bottom ash. India has a total installed capacity of 100,000 MW of electricity generation. Seventy-three percent of this is based on thermal power generation. The coal reserves of India are estimated around 200 billion metric tons. Because of this, 90% of the Indian thermal power stations are coal based. There are 85 coal based thermal power stations and other power stations in the country. The Indian coal has a low calorific value of 3,000–4,000 kcal/kg and a high ash content of 35–50%. To achieve the required energy production, a high coal fired rate is required, generating greater ash residue. Presently, India produces nearly 100 million metric tons of coal ash; that is expected to double in the next 10 years. The most common method adopted in India for the disposal of coal ashes is the wet method. This method requires, apart from a large capital investment, about 1 acre of land for every 1 MW of installed capacity. Thus, ash ponds occupy nearly 26,300 ha of land in India.

Fig 2: Pond Ash

Table 1: Physical Properties of Pond Ash

S. No	Property	Symbol	Value
1	Gravel (%)		0
2	Sand (%)		22.8
3	Fines (%)		77.2
4	Liquid Limit (%)	W_L	No plastic
5	Plastic Limit (%)	W_P	
6	Plastic Index (%)	I_P	
7	Soil Classification	--	SP-SM
8	Specific Gravity	G	2.04
9	Differential Free Swell (%)	DFS	No swelling
10	Optimum Moisture Content (%)	O.M.C	16.45
11	Maximum Dry Density (gm/cc)	M.D.D	1.55
12	Cohesion (t/m^2)	C	1.4
13	Angle of Internal Friction (^{0})	ø	35.45
14	CBR Value (soaked) (%)		2.18

Table 2: Chemical Properties of Pond Ash

CONSTITUENTS	POND ASH
Silica (SiO2)	67.40
Alumina (Al2O3)	19.44
Iron Oxide (Fe2O3)	8.5
Calcium Oxide (CaO)	2.7
Magnesium Oxide (MgO)	0.45
Sulphur (SO3)	0.30
Loss of Ignition	3.46

V. USES OF POND ASH

A. As a stabilizer

It is best suited for use in agriculture, waste land development and forestry applications. It's also a good material for geotechnical applications as a substitute of soil. Other important utilisation of pond ash is in manufacture of clay bricks. When pond ash is mixed with good clay to the extent of 20-30% depending on the clayness of clay, it improves the quality of clay brick (now clay fly ash brick), reduces breakage at the kiln as well as during transit/use and also reduces fuel consumption in the kiln.

B. In lightweight fill

The ash would appear to be a very suitable light weight fill and should not present great difficulties in compaction, provided its initial moisture content is kept within reasonable limits (say less than 50%). The very high angle of internal friction of the material will mean that its stability will be high. However, its lack of cohesion may lead to problems in construction due to erosion and shearing under heavy rollers. To overcome these it will probably be desirable to place a 3 to 6 inch thick blanket layer of cohesive material every 2 to 3 ft.

C. Other uses

For ceramic , metallurgical and other high value added applications of fly ash one of the three portions of fly ash is stated above would be best suited depending on the properties of fly ash that contribute to that particular application. Other portions of fly ash can also be utilized but the result/impact would be sub-optimised.

D. Lime

Lime, chemically known as, Calcium oxide (CaO), commonly known as quicklime or burnt lime, is a widely used chemical compound. It is a white, caustic, alkaline crystal solid at room temperature.

Fig 3: Lime

Properties of lime

- Lime is a white amorphous solid.
- It has a high melting point of 2600oC.
- It is highly stable and even fusion cannot decompose it.

E. Chemical Properties

On hydration, quick lime forms slaked lime or lime water. When water is added to lime it becomes hot and cracks to form a white powder. This is called slaking of lime.

$$CaO + H_2O \longrightarrow \underset{\text{slaked lime}}{Ca(OH)_2}$$

Calcium oxide is a basic oxide. It can react with acids to give calcium salts.

$$CaO + \underset{\text{sulphuric acid}}{H_2SO_4} \longrightarrow \underset{\text{calcium sulphate}}{CaSO_4} + H_2O$$

With acidic oxides like silicon dioxide and phosphorus pent oxide, it forms silicates and phosphates. This property makes lime useful as a flux in metallurgy to remove impurities.

$$CaO + SiO_2 \longrightarrow \underset{\text{calcium silicate}}{CaSiO_3}$$

$$3CaO + P_2O_5 \longrightarrow \underset{\text{calcium phosphate}}{Ca_3(PO_4)_2}$$

Lime is routinely used as a soil modification agent to improve the performance of sub grade soils with the primary goal of reducing volume change. Effective mixing of lime and soil is critical to ensuring that the expected improvements occur throughout the soil mass. Lime also decreases the apparent amount of fines in a soil by causing flocculation and agglomeration of the clay particles (Little 1995). This results in an increase in the percentage of sand and silt size particles as measured by standard grain size distribution methods (Basma and Tuncer 1991.Lime also tends to reduce the swell potential of fine grained soils (Kennedy et al 1987). Moisture content plays an important role in the swell potential of a lime treated soil; soils with moisture content below optimum show a much greater swell potential than soils with moisture content above optimum (Sweeney et al 1988). It is found that soils with a significant amount of montmorillonite developed almost no increase in unconfined compressive strength. They concluded that most of the lime was used to break down the montmorillonite and the montmorillonite also had too great of a surface area for the cementitious compounds to significantly affect the strength.

VI. LABORATORY STUDIES

PROPERTIES OF EXPANSIVE CLAY

Table 3: Differential Free Swell

S. No.	Degree of expansion	DFS
1	Low	< 20%
2	Moderate	20 - 35%
3	High	35 – 50%
4	Very High	>50%

VII. MATERIAL USED

A. Expansive Clay

The soil used in this study is expansive clay, obtained ***in agriculture field, Tekkali, srikakulam district***, collected at a depth of 1 to 1.5 m from ground level. The Index & Engineering properties of expansive soil are determined as per IS code of practice and determined & presented in table 4.

B. Pond Ash

Pond Ash is collected from Simhadri NTPC, parawada, Vishakhapatnam, Andhra pradesh State, India.

The physical properties are determined and presented in Table 5.

C. Lime

Commercial grade lime mainly consisting of 58.67% CaO and 7.4% Silica was used in the study.

The soil was initially air dried prior to the testing. The tests were conducted in the laboratory on the expansive clay to study the behaviour of expansive clay, when it was untreated, treated (with chemicals, GBFS and reinforcement techniques) for the modal flexible pavements and also for the foundation soil beds.

The following tests were conducted as per IS Codes of practice.

i . The grain size distribution

ii. Index Properties –Liquid Limit, Plastic Limit and Shrinkage Limit.

iii. Differential free Swell test

iv. Strength tests – California bearing ratio.

Table 4: Physical properties of Expansive Clay

S.No	Property		Symbol	Value
1	Gravel (%)			0
2	Sand (%)			2
3	Fines (%)	Silt		31
		Clay		67
4	Liquid Limit (%)		W_L	83.12
5	Plastic Limit (%)		W_P	33.16
6	Plastic Index (%)		I_P	49.96
7	Soil Classification		CH	
8	Specific Gravity		G	2.51
9	Differential Free Swell (%)		DFS	150
10	Optimum Moisture Content (%)		O.M.C	24.32
11	Maximum Dry Density (gm/cc)		M.D.D	1.53
12	Cohesion (t/m^2)		C	10
13	Angle of Internal Friction (^{0})		ø	0
14	California Bearing Ratio value (soaked) (%)		CBR	1.7

VIII. PROPERTIES OF POND ASH

Table 5: Grain Size of Pond Ash

S.No	Property	Symbol	Value
1	Gravel (%)		0
2	Sand (%)		22.8
3	Fines (%)		77.2
4	Liquid Limit (%)	W_L	No plastic
5	Plastic Limit (%)	W_P	
6	Plastic Index (%)	I_P	
7	Soil Classification	--	SP-SM
8	Specific Gravity	G	2.04
9	Differential Free Swell (%)	DFS	No swelling
10	Optimum Moisture Content (%)	O.M.C	16.45
11	Maximum Dry Density (gm/cc)	M.D.D	1.55
12	Cohesion (t/m^2)	C	1.4
13	Angle of Internal Friction (^{0})	ø	35.45
14	CBR Value (soaked) (%)		2.18

Modified Proctor Compaction for Soil and Pond Ash

Compaction tests were conducted to get the OMC and MDD of the mix of different proportions of soil and Pond Ash using Modified proctor compaction test

Table 6: Optimum moisture content and Maximum Dry Density values of expansive clays and Pond Ash

Mix proportion	Water Content (%)	Dry Density (g/cc)
100% Expansive Clay	24.32	1.53
10% Pond Ash +E.C	26	1.57
15% Pond Ash +E.C	23.54	1.66
18% Pond Ash +E.C	20.32	1.715
20% Pond Ash +E.C	24.37	1.645
25% Pond Ash +E.C	23.87	1.641

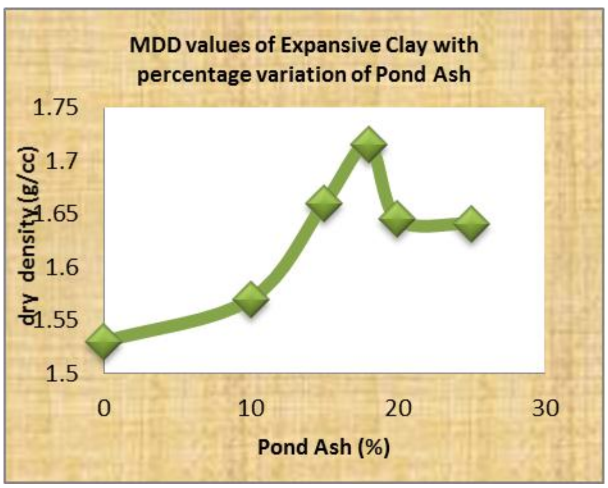


Fig 4: Variation of MDD with Pond Ash content

CBR TEST RESULTS FOR EXPANSIVE CLAY WITH POND ASH:

The soaked and un soaked CBR values of various mixes of expansive clay and Pond Ash using OMC obtained from compaction are determined .The soaked CBR after immersing in water for four days , that is when full saturation is likely to occur, is also determined. Variation of CBR with % variation in Pond Ash is presented.

(1) CBR Curve for 100% soil

The soaked CBR Curve for soil without any admixture and chemical was shown in Fig 5

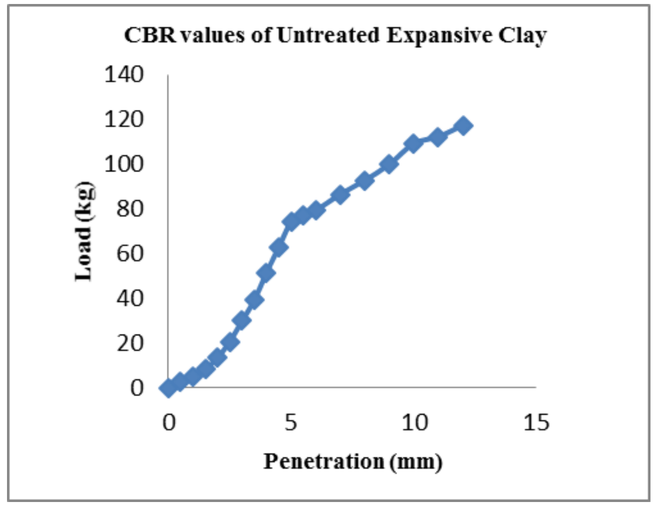


Fig 5 : CBR curve for untreated expansive clay

Soaked CBR value: 1.54%

(2) **CBR Curve for expansive clay + 10% Pond Ash**

The soaked CBR Curve for soil with 10% Pond Ash was shown in Fig 6

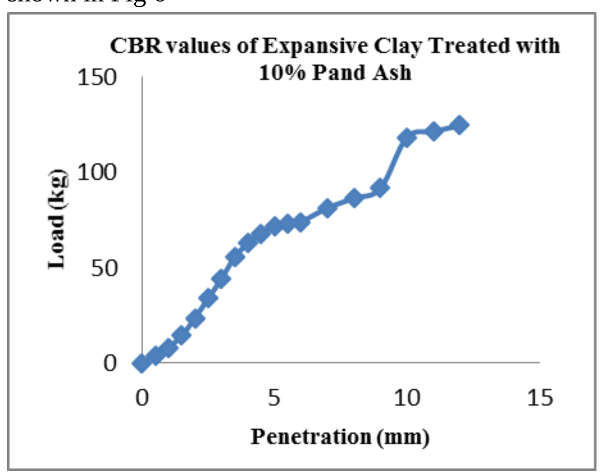
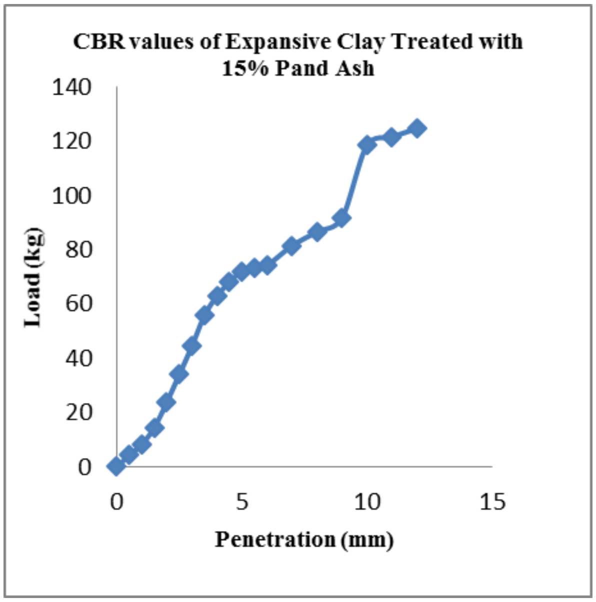


Fig 6 : CBR curve for 85% EC + 10% Pond Ash

Soaked CBR value: 2.01%

(3)CBR value of Expansive Clay Treated with 15% Pond Ash

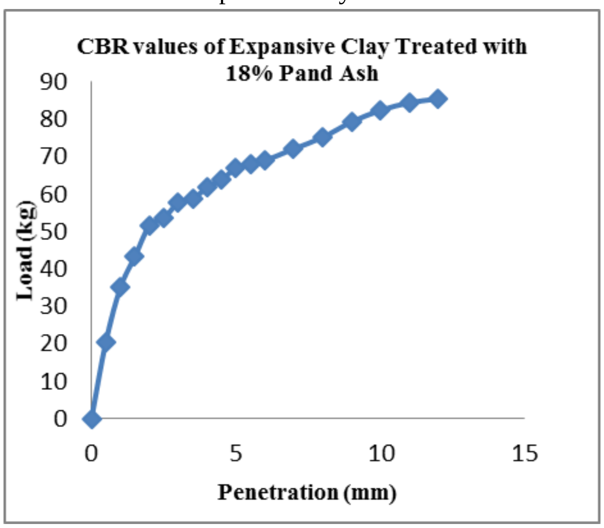
Fig7 :Presents the experimental value of CBR of 15% Pond Ash treated expansive clay.



CBR value = 2.48%

(4)CBR value of Expansive Clay Treated with 18% Pond Ash

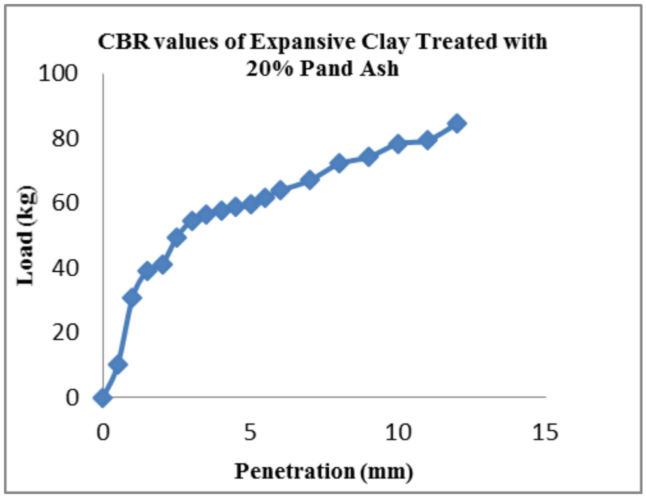
Fig.8: Presents the experimental value of CBR of 18% Pond Ash treated expansive clay.



CBR value = 3.91%

(5)CBR value of Expansive Clay Treated with 20% Pond Ash

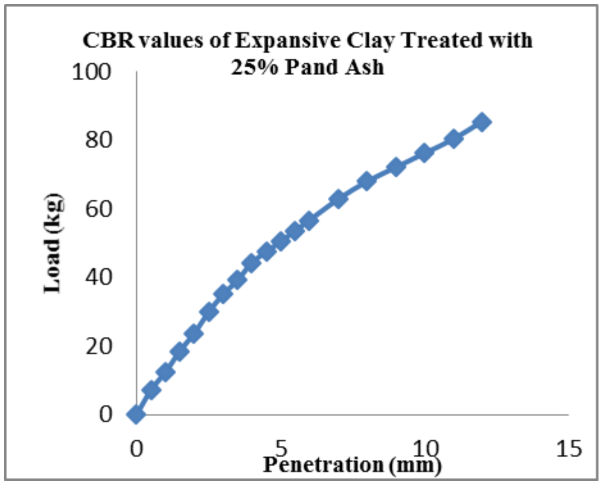
Fig.9: Presents the experimental value of CBR of 20% Pond Ash treated expansive clay.



CBR value = 3.6%

(6)CBR value of Expansive Clay Treated with 25% Pond Ash

Fig.10: Presents the experimental value of CBR of 25% Pond Ash treated expansive clay.



CBR value = 2.18%

Table 7 and Fig. 11 CBR values of Expansive Clay treated with percentage variation of Pond Ash

Table 7 CBR values of Expansive Clay treated with percentage variation of Pond Ash

SI.NO.	Mix proportion	CBR(%)
1	100% Expansive Clay	1.5
2	10% Pond Ash + E.C	2.01
3	15% Pond Ash + E.C	2.48
4	18% Pond Ash + E.C	3.91
5	20% Pond Ash + E.C	3.60
6	25% Pond Ash + E.C	2.18

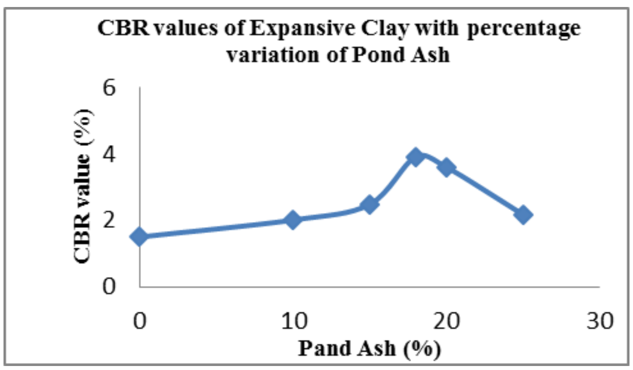


Fig 11:Presents CBR values with varying percentages of Pond Ash

Table .8 :Differential Free swell index

SI.NO.	Mix proportion	DFS(%)
1	100% Expansive Clay	150
2	10% Pond Ash + E.C	130
3	15% Pond Ash + E.C	120
4	18% Pond Ash + E.C	90
5	20% Pond Ash + E.C	80
6	25% Pond Ash + E.C	70

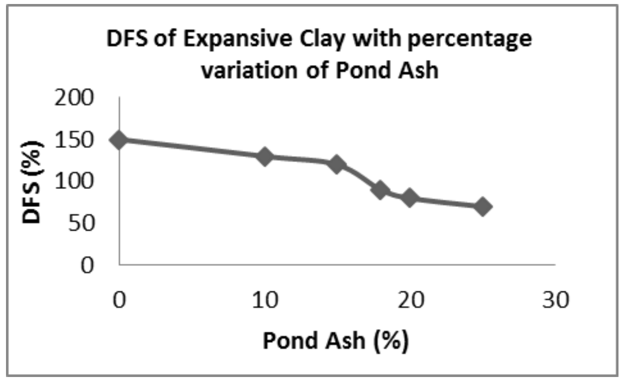


Fig.12: Shows DFS increasing with varying percentage pond ash

Table 9 Properties of Expansive Clay treated with an optimum percentage of Pond Ash

SI.NO	Property	Symbol	Expansive Clay	MC treated with 18% Pond Ash
1	Liquid Limit (%)	W_L	81.50	54
2	Plastic Limit (%)	W_P	35.49	26.47
3	Plasticity Inex (%)	I_P	46.01	27.53
4	Soil Classification	--	CH	CL
5	Specific Gravity	G	2.63	2.4
6	OptimumMoisture Content(%)	O.M.C	24.32	20.32
7	Maximum Dry Density (g/cc)	M.D.D	1.53	1.715
8	Cohesion (t/m^2)	C	10	6.5
9	Angle of Internal Friction (^{0})	ø	0	27.28
10	CBR value (%)	Soaked	1.5	3.91
11	Differential Freeswell Index	DFS	180	110

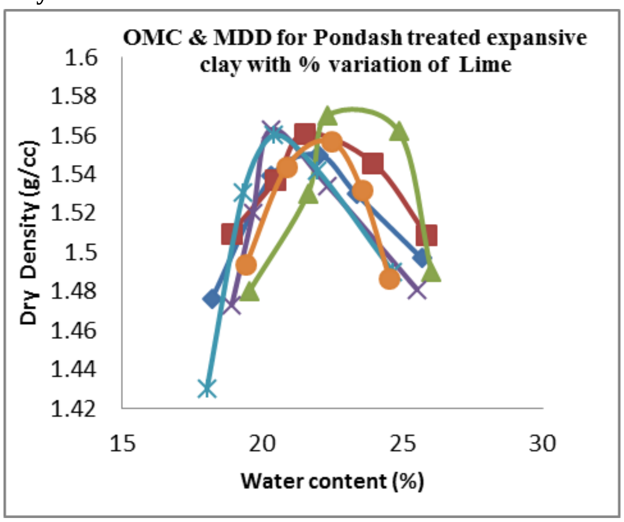
MODIFIED PROCTOR COMPACTION AND CBR TEST RESULTS OF POND ASH TREATED EXPANSIVE CLAY WITH PERCENTAGE VARIATION OF LIME

Table 10 and Fig 13 present the OMC and MDD of 18% Pond Ash treated expansive clay with percentage variation of lime.

Table 10: Optimum Moisture Content and Maximum Dry Density of 18% Pond Ash treated expansive clay with percentage variation of lime.

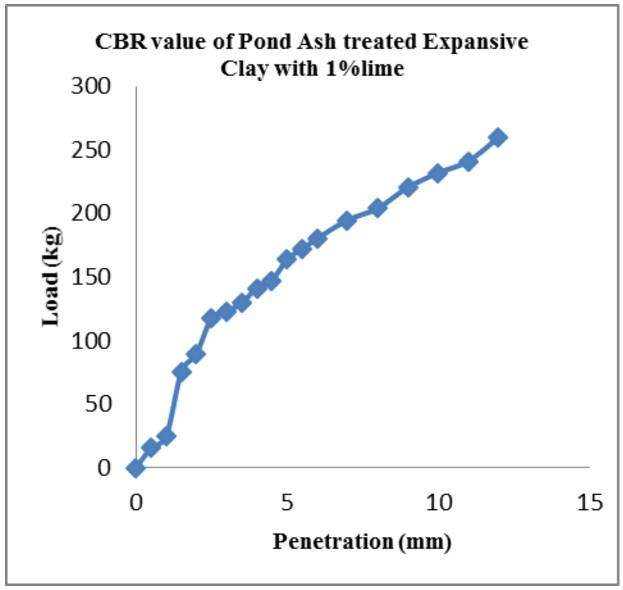
SI.NO	Composition		OMC	MDD
1.	E.C +18% Pond Ash	1% Lime	22.03	1.550
2.	E.C +18% Pond Ash	2% Lime	21.52	1.561
3.	E.C +18% Pond Ash	3% Lime	22.32	1.570
4.	E.C +18% Pond Ash	5% Lime	20.98	1.563
5.	E.C +18% Pond Ash	7% Lime	20.40	1.560
6.	E.C +18% Pond Ash	9% Lime	22.45	1.557

Fig 14: OMC & MDD for Pondash treated expansive clay with % variation of Lime



CBR VALUE OF POND ASH TREATED EXPANSIVE CLAY WITH 1% LIME

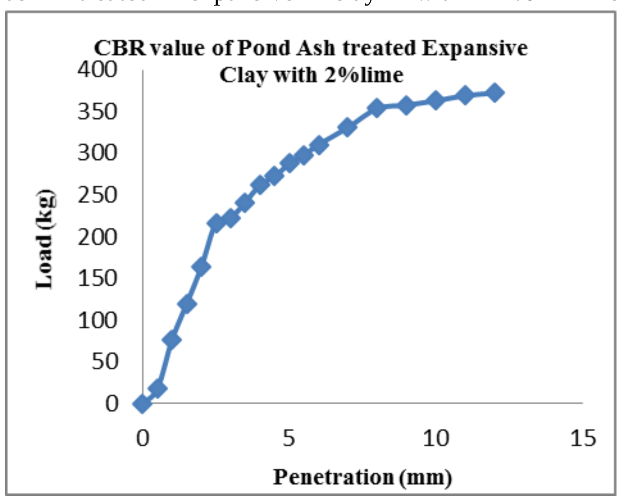
Fig 15: Present the Experimental CBR value of pond ash treated expansive clay with 1% lime



CBR VALUE = 8.57%

CBR VALUE OF POND ASH TREATED EXPANSIVE CLAY WITH 2% LIME

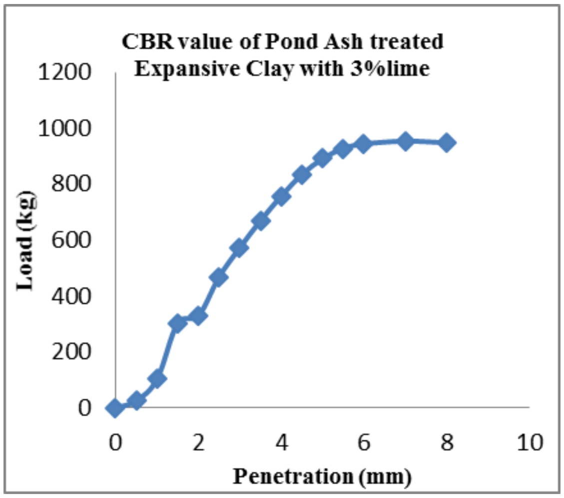
Fig16: Present the Experimental CBR value of pond ash treated expansive clay with 2% lime



CBR VALUE = 15.84%

CBR VALUE OF POND ASH TREATED EXPANSIVE CLAY WITH 3% LIME

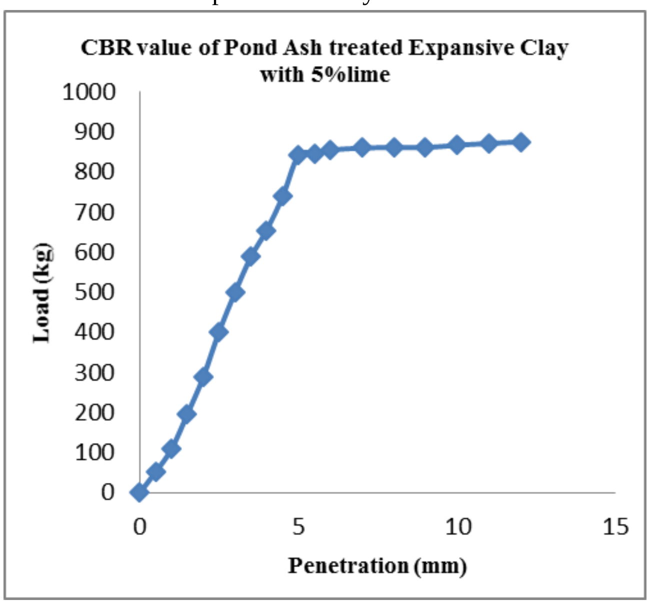
Fig 16: Present the Experimental CBR value of pond ash treated expansive clay with 3% lime



CBR VALUE = 34.02%

CBR VALUE OF POND ASH TREATED EXPANSIVE CLAY WITH 5% LIME

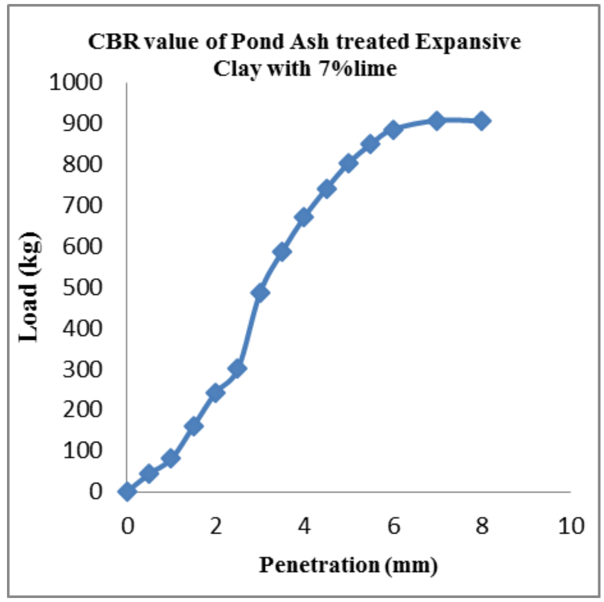
Fig.18: Present the Experimental CBR value of pond ash treated expansive clay with 5% lime



CBR VALUE = 29.32%

CBR VALUE OF POND ASH TREATED EXPANSIVE CLAY WITH 7% LIME

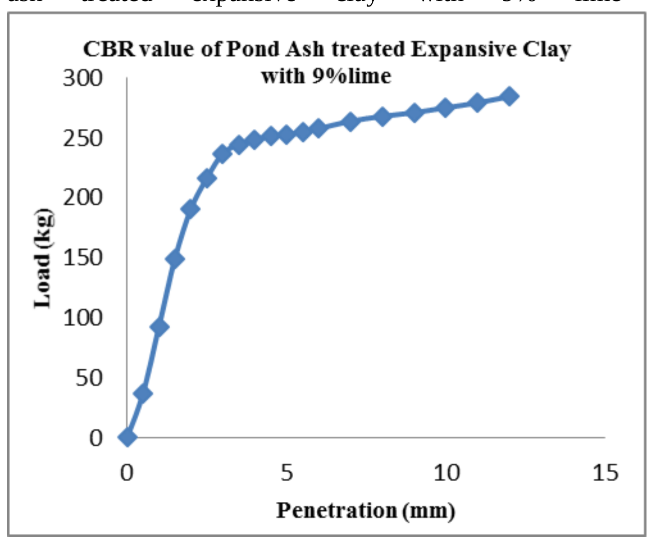
Fig 19: Present the Experimental CBR value of pond ash treated expansive clay with 7% lime



CBR VALUE = 21.94%

CBR VALUE OF POND ASH TREATED EXPANSIVE CLAY WITH 9% LIME

Fig 20: Present the Experimental CBR value of pond ash treated expansive clay with 9% lime

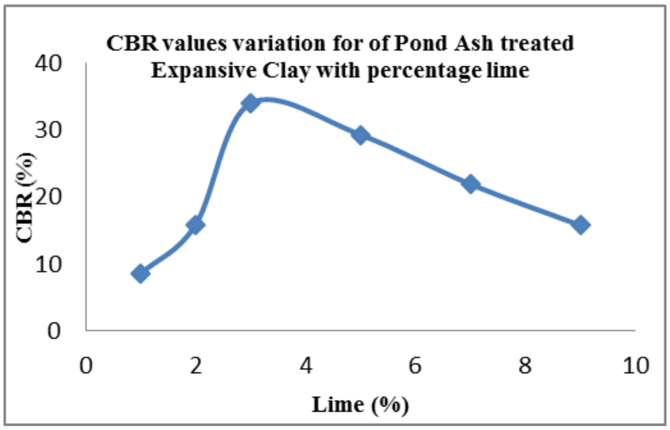


CBR VALUE = 15.78%

Table 11 And Fig 21: Presents the CBR Values of Expansive Clay Treated with an Optimum of Pond Ash and various percentages of Lime

EXPANSIVE CLAY +18% POND ASH +	**CBR (%)**
1% Lime	8.57
2% Lime	15.84
3% Lime	34.02
5% Lime	29.32
7% Lime	21.94
9% Lime	15.78

Fig 21: Presents the CBR values variation of Pond



Ash treated Expansive Clay with percentage lime

Table 12:Differential Free swell index for 18% Pond Ash and varying percentage Lime

EXPANSIVE CLAY +18% POND ASH +	DFS (%)
1% Lime	50
2% Lime	40
3% Lime	30
5% Lime	40
7% Lime	40
9% Lime	50

Table 13 Properties of Pond Ash treated Expansive Clay with an optimum percentage of Lime

SI. NO	**Property**	**Symbol**	**Expansive Clay**	**EC + 18% Pond Ash**	**EC+ 18% PA+ 3% Lime**
1	Liquid Limit (%)	W_L	81.50	54	48
2	Plastic Limit (%)	W_P	35.49	26.47	29.5
3	Plasticity Index (%)	I_P	46.01	27.53	18.5
4	Soil Classification	--	CH	CL	CL
5	Specific Gravity	G	2.63	2.4	2.5
6	OptimumMoisture Content(%)	O.M.C	24.32	20.38	22.23
7	Maximum Dry Density (g/cc)	M.D.D	1.53	1.715	1.57
8	Cohesion (t/m^2)	C	10	6.5	
9	Angle of Internal Friction (^{0})	ø	0	27.28	
10	CBR value (Soaked) (%)		1.5	3.91	34.02
11	Differential Freeswell Index	DFS	180	110	30

IX.CONCLUSION

- It is noticed that the liquid limit of the expansive clay has been decreased by 50.92% on addition of 18% Pond Ash and it has been further decreased by 12.50% when 3% lime is added.
- It is observed that the plastic limit of the expansive clay has been decreased by 34.07% on addition of 18% pond Ash and it has been further improved by 10.27% when 3% lime is added.
- It is observed that the plasticity index of the expansive clay has been decreased by 67.13% on addition of 18% Pond Ash and it has been further decreased by 48.81% when 3% lime is added.

- It is found that the O.M.C of the expansive clay has been decreased by 19.33% on addition of 18% Pond Ash and it has been further increased by 8.32% when 3% lime is added.
- It is found that the M.D.D of the expansive clay has been improved by 12.09% on addition of 18% Pond Ash and it has decreased by 8.45% when 3% lime is added.
- It is observed that the C.B.R. value of the expansive clay has been increased by 160.67% on addition of 18% Pond Ash and it has been further improved by 770.07% when 3% lime is added.
- It is observed that the DFS value of the expansive clay has been decreased by 36.36% on addition of 18% Pond Ash and it has been further decreased by 266.67% when 3% lime is added.

The soaked CBR of the soil on stabilizing is found to be 34.02 and is satisfying standard specifications. So finally it is concluded from the above results that the stabilized expansive clay is suitable to use as sub grade material for the pavement construction and also for various foundations of buildings.

REFERENCES

[1] PROMOD KUMAR JAIN, ARYA, I.R. and GIRDHAR, B.S. (1995), "Use of Pond ash – Soil Blend as Subgrade Material for Roads and Parking area of LPG Bottling Plant Complex – A Case Study", Proceedings of the National Seminar on Engineering Trends in Highway Engineering, Bangalore, pp. 32.1-32.7

[2]ARCHAN,KUSUM,MAJUMDAR(1998),"Pavement Design for Roads Using Coal Ash", International Conference on Fly Ash Disposal & Utilization, Central Board of Irrigation and Power (CBIP), Vol. 2, pp. 2-14.

[3] GURUVITTAL, U.K. and MURTHY, A.V.S.R. (1998), "Use of Coal Ash in Road Construction", International Conference on Fly Ash Disposal and Utilisation, Central Board of Irrigation and Power (CBIP), V

[4] D.Koteswara Rao et.al (2012), A Laboratory Study on the Affect of Rice Husk Ash & Lime on the Properties of Expansive Clay, IJESAT, Vol.1, Issue.1, March – july 2012.

[5] GURUVITTAL, U.K. and MURTHY, A.V.S.R. (1995), "Utilisation of Industrial Wastes in Roads Construction – Fly Ash", Proceedings of the National Seminar an Emerging Trends in Highway Engineering, Bangalore, pp. 23.1 -23.8

[6] KHANNA, S.K. AND JUSTO C.E.G. (1989), Highway Materials Testing, Nem Chand & Bros, Civil Lines, Roorkee, India

[7] NARENDRA KUMAR, DEVENDRA MOHAN and VIRENDRA SINGH (1996), "Use of fly ash in Soil Stabilization for Roads", Indian Geotechnical Conference, Madras,pp.,411-413.

[8] NANDA, A.K. (1998), "State of the Art Approach to develop Guide Lines for Design and Construction with Lime-Fly Ash and Soil Mixes for Road Bases", International Conference on Fly Ash Disposal & Utilization, Central Board of Irrigation and Power (CBIP), Vol. 1, pp. 6-35.

[9]A.U.RAVISHANKAR,S.N.SURESHA,M.V.S.,PHA NIKUMAR, (2006)"Strength Behaviour Of Shedi Soil - Lime - Pond Ash Mixes– An Experimental Study" Indian Roads Congress (IRC) -2006

[10] Seehra, S.S, Tike G.K. and Senugupta, J.B (1995), "Alternat Binder Materials for Semi-Rigid Pavement Construction Proceedings of International Conference on New Horizons in Roasds and Road Transport (ICORT-95), Vol.1, PP.524-533

[11] Swamy, R.K,, Guruvittal U.K. and Murthy A.V.S.R (1998), Use of Coal Ash in Road Construction International Conference on Fly Ash Disposal and Utilisation, Central Board of Irrigation and Power (CBIP), Vol 1, pp.V1.1 to VI.5

[12] Satander Kumar, Guruvittal,U.K. Deep Chandra and Sikdar. PK. (1999), Utilisation of Fly Ash for Road Construction Fly Ash in Construction, Civil Engineering & Construcion Review, Vol 12, No. 4, pp, 60-63

[13] Venkata Raja, G.. (2001) Suitability of Lime- Pond Ash Stabilised Soil for Pavement Layers- An Enperimental Study". M. Tech Thesis, Manglore University, Manglore (Unpublished).