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Stabilization of Expansive Soil

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***Abstract*— Since long, improvement in characteristics of expansive soil by using different materials has been a challenging job for engineers. In modern days of industrialization it becomes imperative to use waste materials from various industries to use for expansive soil stabilization so as to reduce the polluting effect of waste materials from various industries and to achieve worthwhile results. The objective of this study was to evaluate the effect of fly ash, pond ash and lime derived from combustion of thermal Power plants in stabilization of expansive Soil. The Aim of this research is to stabilize and improve the locally available soil around Nashik district. An experimental program is to be undertaken to examine the effects of fly ash , pond ash and lime on the compaction and strength performance of expansive soil. The soil samples are prepared with different proportions of fly ash (5%) and pond ash, (10%,20%,30% , 40%) and lime (4%, 6%, 8%, 10) A series of test are conducted including Index Properties, Consistency Limits ,Modified Proctor Test, laboratory Unconfined Compression Strength Tests and c – ϕ properties of soil. CBR Value .The probable variations in the strength of Fly ash, Pond ash and lime specimens are observed and recorded.**

Key word: **Pond Ash, Fly Ash, Lime, Expansive Soil (Black Cotton Soil) Stabilization CBR, UCS.**

I. INTRODUCTION

Expansive soils are found in various parts of the world such as USA, South Africa, Australia, Spain, Israel, Myanmar and India. In India these expansive soils are known by local name such as black cotton soils (BC Soil) in central India, Bentonite in Rajasthan and Kashmir, Mar or kabar in Uttar Pradesh. These soils occupy about 30 to 40 % of the land area of India.

Expansive soil bar have their own characteristics to the presence of swelling clay minerals. As they get wet, the clay minerals absorb water molecules and expand; conversely, as they dry they shrink, leaving large voids in the soil. Swelling clays can control the behavior of virtually any type of soil if the percentage of clay is more than about 5 percent by weight. Soils with clay minerals, such as montmorillonite, exhibit the most profound swelling properties. Potentially expansive soils can typically be recognized in the lab by their plastic properties. Inorganic clays of high plasticity, generally those with liquid limits exceeding 50 percent and plasticity index over 30, usually have high inherent swelling capacity. Expansion of soils can also be measured in the lab directly, every year millions of tonnes of fly ash is produced all over India which is categorized as hazardous waste material. Its a medium grain size ash, mixture of ESP ash and bottom ash. 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. It is better to use such waste materials in variety of ways, including roadbeds, construction fill, Ceramic tiles, Refractory aggregates, Refractory Bricks, Synthetic Granite or cement admixture.

Amol Shingarey [1] Indian fly ashes are not self-cementing and contain very low Calcium oxide. Hence improvement in strength properties of soil, when mixed with fly ash alone, is very maginal, however it can be used in combination with lime or cement for strength. Fly ashes can provide only cation exchange and weak pozzolonic reaction, but these reaction effectively reduce swelling properties.Kolay et al. [15].Based on their experimental study found that the MDD for pond ash sample is increased, due to addition of pond ash in soil. While the OMC decreases with increase in the pond ash content. The UCS value for peat and pond ash mixed sample increases. The compressive strength of peat-pond ash sample almost doubled in comparison with original peat soil with addition of 20% pond ash of weight of modified soil Ghosh et al. (2010)[13] presents the laboratory test results of a Class F pond ash alone and stabilized with varying percentages of lime (4, 6, and 10%) and PG (0.5, and 1.0), to study the suitability of stabilized pond ash for road base and sub-base construction. Standard and modified Proctor compaction tests have been conducted to reveal the compaction characteristics of the stabilized pond ash. Bearing ratio tests have been conducted on specimens, compacted at maximum dry density and optimum moisture content obtained from standard Proctor compaction tests, cured for 7, 28, and 45 days. Both un-soaked and soaked bearing ratio tests have been conducted. This paper highlights the influence of lime content, PG content, and curing period on the bearing ratio of stabilized pond ash. The empirical model has been developed to estimate the bearing ratio for the stabilized mixes through multiple regression analysis. Linear empirical relationship has been presented herein to estimate soaked bearing ratio from un-soaked bearing ratio of stabilized pond ash. The experimental results indicate that pond ash-lime-PG mixes have potential for applications as road base and sub base materials. Numerous investigators [12] & [16], have studied the influence of lime, cement, lime-cement, lime-fly ash, lime–rice husk- ash and cement – fly ash mixes on soil properties, mostly focusing on the strength aspects to study their suitability for road bases and sub basses. As lime and cement are binding materials, the strength of soil-additive mixtures increases provided the soil is reactive with them. However, for large-scale field use, the problems of soil

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pulverization and mixing of additives with soil have been reported by several investigators.Mallela *et al*., 2004[17] Yong and Ouhadi, 2007[19],These pozzolonic reactions can be clarified using the following chemical equations

$Ca(OH)_2 + SiO_2 \rightarrow CaO\text{-}SiO_2\text{-}H_2O$ (1)

$Ca(OH)_2 + Al_2O_3 \rightarrow CaO\text{-}Al_2O_3\text{-}H_2O$ (2)

Erdal Cokca (2001)[11] has showed that Fly ash consists of often hollow sphere of silicon, aluminum and iron oxides and unoxidised carbon. Fly ash is pozzolans which are defined as Siliceous and aluminous materials. Thus Fly ash can provide an array of divalent and trivalent cations like Ca+2, Al+3, Fe+3 etc under ionized condition that can promote flocculation of dispersed clay particles. Thus expansive soil can be potentially stabilized effectively by cation exchange using Fly ash. Jakka et al. (2010) [14] studied that densities of compacted ash is lower than natural soil due to their low value of specific gravity and intraparticle voids Chand et al[9]the effects of lime stabilization on the strength and durability aspects of a class F pond ash, with a lime constituent as low as 1.12%, are reported. Lime contents of 10 and 14% were used, and the samples were cured at ambient temperature of around 30°C for curing periods of 28, 45, 90, and 180 days. Samples were subjected to unconfined compression tests as well as tests that are usually applied to rocks such as point load strength tests, rebound hammer tests, and slake durability tests. Unconfined compressive strength (UCS) values of 4.8 and 5.8 MPa and slake durability indices of 98 and 99% were achieved after 180 days of curing for samples stabilized with 10 and 14% lime, respectively. Mir and Sridharan [18] studied the effect of high calcium and low calcium fly ashes on the physical, compaction, and swelling potential of black cotton soils

II. MATERIALS USED

Soil Sample

Soil sample used for this experimental study was locally available Expansive soil in Nashik District of Maharashtra state India. Results of soil sample tested are given in Table 1. Results are obtained by testing the soil in laboratory by specific procedure for particular test as prescribed in Indian Standards

Table 1- Properties of Soil

Soil Properties	Values
Soil IS Classification	CH
Sand (%)	3 to 25%
Silt (%)	25 to 45%
Clay (%)	45 to 75 %
Specific Gravity (G)	2.64
Liquid Limit (%)	39.67
Plastic Limit (%)	19.2
Maximum Dry Density (g/cc)	1.49
Optimum Water Content (%)	17.9
Unconfined Shear Strength (kN/mm^2)	
Cohesion (c) (N/mm^2)	52
Angle of internal friction (Ø)	20
CBR % (Soaked)	2.56
CBR % (unsoaked)	7.5

The Dirk Laboratories are fully equipped for the testing and evaluation of the physical and chemical parameters of fly ash specified in the Indian standard (IS 3812), European standard (EN 450), British Standard (BS 3892) and the American standard (ASTM 618). The following physical and chemical properties are measured in the factory laboratories: Its a medium grain size ash, mixture of ESP ash and bottom ash. 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 utilization of pond ash is in manufacture of clay bricks. When pond ash is mixed with good clay to the extent of 30-80% 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. 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-optimized. Properties of Pond Ash are as below:

Fig 1 Pond Ash & Ash Pond

Table 2: Properties of Pond Ash

Soil Properties	Values
Soil IS Classification	-
Sand (%)	78
Silt & Clay Content (%)(Below 0.075)	22
Gravel Content (%)	00
Specific Gravity (G)	2.24
Liquid Limit (%)	-
Plastic Limit (%)	-
Maximum Dry Density (g/cc)	1.34
Optimum Water Content (%)	21.03
Unconfined Compressive Strength (kg/cm^2)	-
Cohesion (c) (N/mm^2)	19.2
Angle of internal friction (j)	1.49
CBR %	1.35

Fly Ash

Thermal Power stations using pulverized coal or lignite as fuel generate large quantities of ash as a by-product. There are about 82 power plants in India, which form the major source of fly ash in the country. The current production of ash is

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about 85 million tonnes per year. This figure is likely to go up to 100 million tonnes per year by the year 2000 AD and pose serious ecological problems. The physical, geotechnical and chemical parameters to characterize fly ash are the same as those for natural soils, e.g., specific gravity, grain size, Atterberg limits, compaction characteristics, permeability coefficient, shear strength parameters and consolidation parameters. The procedures for determination of these parameters are also similar to those for soils. The engineering properties of the fly ash are shown below.

Fig 2: Fly Ash

Fig 3: Lime

Table 3- Geotechnical properties of fly ash

Parameters	Range
Specific Gravity	1.90 – 2.55
Plasticity	Non plastic
Maximum dry density (gm/cc)	0.9 – 1.6
Optimum moisture content (%)	38.0 – 18.0
Cohesion (c) (N/mm^2)	Negligible
Angle of internal friction (φ)	$30^0 – 40^o$

Lime

White caustic alkaline substance consisting of calcium oxide, which is obtained by heating limestone and which combines with water with the production of much heat is known as lime. Commercial limes are collected from local market.

III . OBJECTIVE AND SCOPE OF PRESENT STUDY

An investigation has been carried out to evaluate the efficiency in utilization of pond ash in geotechnical field in order to justify safe reuse, management and disposal of pond ash samples. To achieve this aim, the following objectives have been identified:

- To incorporate the pond ash, fly ash. lime in some collected soil materials and assess performance.
- To analyze the results and make appropriate recommendations for optimal use.

The research work shall be limited to the use of pond ash for improvement of soil. The material to be used in the research work will be most abundantly available black cotton soil, pond ash, fly ash which is a waste product from the thermal power plants and research work would involve the collection of soil materials and determination of their geotechnical properties both disturb and undisturbed soil sample after which the pond ash, fly ash and lime will be incorporated into the soil sample and the appropriate recommendations would be made for their best use.

III. METHODOLOGY

Method adopted to improve the properties as various materials in specific proportions are used and are tested in laboratory to compute their properties. Details of material, test performed and proportion used is described below.

[A]*Proportion*: Proportions were selected based on study of pervious literature as well as maximum further experimentation as much as twenty two trials to get the specific knowledge about the improvement in soil properties and utilization of waste material. Proportion used in sated in Table 6 along with the values of various Abbreviations: S=Soil, P.A= Pond Ash,
F.A= Fly Ash, L=Lime

Table 4 Material Used and their Proportion used

Sr.No.	Material Description	% Variation
1	Expansive Soil	
2	Pond Ash	10
		20
		30
		40
3	Fly Ash	5
4	Lime	4
		6
		8
		10

Table 5 – Test program and coding

Sr.No.	Description	Coding
1	S	S1
2	S + P.A 10%	S2
3	S + P.A 20%	S3
4	S + P.A 30%	S4
5	S + P.A 40%	S5
6	S + F.A 5%	S6
7	S + P.A 10% + F.A 5% + L 4%	S7
8	S + P.A 20% + F.A 5% + L 4%	S8
9	S + P.A 30% + F.A 5% + L 4%	S9
10	S + P.A 40% + F.A 5% + L 4%	S10
11	S + P.A 10% + F.A 5% + L 6%	S11
12	S + P.A 20% + F.A 5% + L 6%	S12
13	S + P.A 30% + F.A 5% + L 6%	S13
14	S + P.A 40% + F.A 5% + L 6%	S14

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15	S + P.A 10% + F.A 5% + L 8%	S15
16	S + P.A 20% + F.A 5% + L 8%	S16
17	S + P.A 30% + F.A 5% + L 8%	S17
18	S + P.A 40% + F.A 5% + L 8%	S18
19	S + P.A 10% + F.A 5% + L 10%	S19
20	S + P.A 20% + F.A 5% + L 10%	S20
21	S + P.A 30% + F.A 5% + L 10%	S21
22	S + P.A 40% + F.A 5% + L 10%	S22

[B] Test Performed

Sieve analysis

The Grain size analysis on natural soil and the soil additive Mixture were con- ducted according to I.S. 2720 (PartIV)-1985.

Specific Gravity

The specific gravity determination of soil fraction passing 4.75mm IS Sieve by pycnometer was conducted according to I.S. 2720(Part II) 1973

Atterberg's limits

The tests on the liquid limit (LL), plastic limit (PL), and Plasticity index (PI) of the soil-additive mixture were conducted according to I.S. 2720 (Part v)-1985.

Compaction characters

The compaction tests to obtain the moisture-density relationship of the soil-additive mixtures were conducted according to I.S. 2720 (Part VIII)-1983.

Unconfined compression Strength

The purpose of this test is to obtain a quantitative value of compressive and shearing strength of soils in an undrained state. The test may be performed on both remoulded and undisturbed soil specimen. I.S.2720 (part X)-1991

Direct Shear Test

The test is conducted to determine the shear parameters of soil with the help of shear box test. According I.S. 2720(part XIII)-1983

California Bearing Ratio (CBR)

The CBR tests were conducted according to I.S.2720 (part 16)- 1997 A standard CBR mold with a detachable collar was used. The soil-additive mixtures were compacted at the optimum moisture content and soaked in water for 4 days under a surcharge weight of 5.72 kg before testing.

IV. RESULTS AND DISCUSSIONS

Table 6: Index Properties of different proportion of mix pond ash, fly ash and lime

Sr. No.	Coding	Sp.Gravity	Liquid Limit (%)	Plastic Limit (%)
1	S1	2.64	39.67	19.2
2	S7	2.67	42.16	19.4
3	S8	2.79	43.5	19.7
4	S9	2.86	43.8	20.6
5	S10	2.88	42.63	22.2
6	S11	2.89	43.33	23.03
7	S12	2.71	43.33	23.93
8	S13	2.9	46.67	25.45
9	S14	3.06	49.3	26.03
10	S15	3.13	51.87	27.39
11	S16	3.18	53.26	28.59
12	S17	3.18	53.7	29.56
13	S18	3.19	54.9	29.82
14	S19	3.2	57.11	32.1
15	S20	3.21	59.02	32.4
16	S21	3.23	59.05	33.75
17	S22	3.24	60.6	34.73

Fig 4 shows the result of specific gravity test for different proportion, specific gravity of soil is 2.64,it goes on increasing with addition of lime and pond ash , for 10% lime it gives the result 3.24.

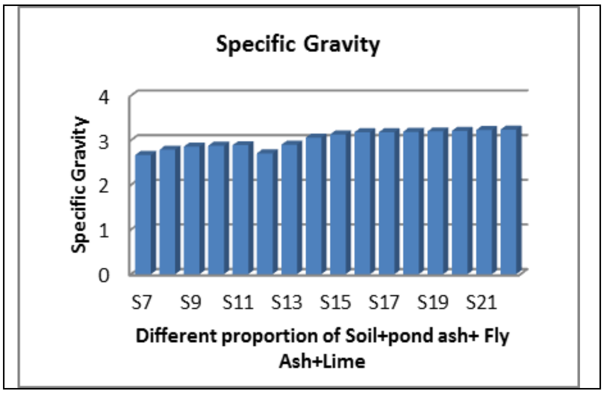

Fig 4; Result of Specific Gravity

Following fig (5) & Fig(6) represent the variation in the result for liquid limit & plastic limit test respectively liquid limit goes on increasing with 39.6% to 60.6% liquid limit goes on increasing with 19.2% to 34.7%by adding lime(4%) and 6% it gives nearly same

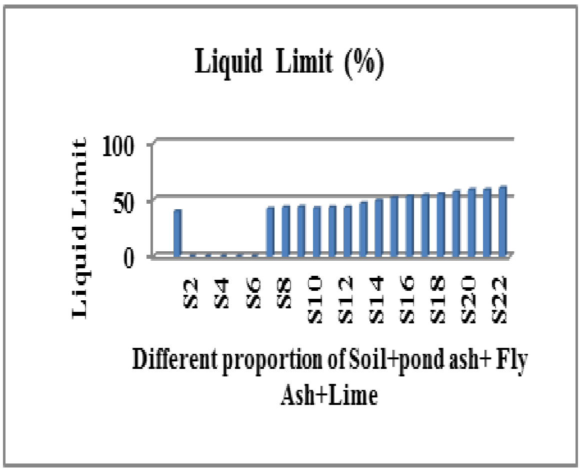

Fig 5: Result of Liquid Limit Test

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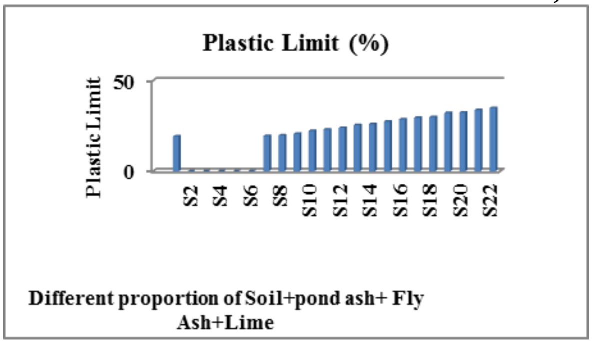

Fig 6: Result of Plastic Limit

Table 7: Properties of Soil with various Proportions

Sr.No.	Coding	MDD (g/cm3)	OMC (%)	UCS (N/cm2)
1	S1	1.49	17.9	7.7
2	S2	1.55	26.74	12.15
3	S3	1.56	35.59	18.2
4	S4	1.58	42.79	16.35
5	S5	1.59	50.65	16.98
6	S6	1.51	46.75	19.88
7	S7	1.64	21.15	22.5
8	S8	1.67	18.92	19.25
9	S9	1.69	18.72	19.35
10	S10	1.7	19.03	20.1
11	S11	1.68	18.24	19
12	S12	1.73	18.51	19.5
13	S13	1.73	18.53	18.3
14	S14	1.75	17.55	18.5
15	S15	1.77	15.95	23.85
16	S16	1.79	14.75	22.88
17	S17	1.8	14.15	22.5
18	S18	1.82	14.03	22
19	S19	1.77	15.23	23.65
20	S20	1.78	14.79	22.65
21	S21	1.78	14.23	22.65
22	S22	1.8	14.23	23

Cotton soil- fly ash mixes reveal that the MDD decreases and the OMC increase With increasing fly ash content. That is shown in fig.7& fig.8 MDD &OMC respectively

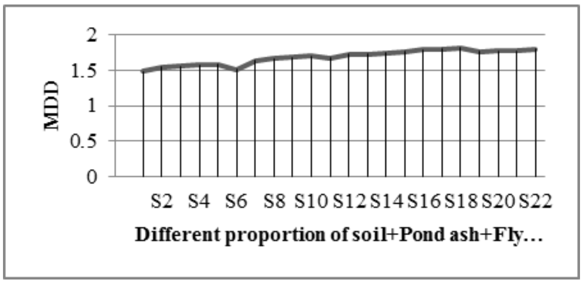

Fig 7: Result of Maximum Dry density

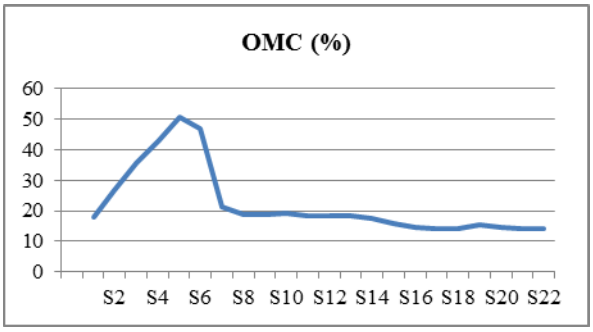

Fig 8: Result of Optimum moisture content

Fig 9 shows the result of unconfined compression test, which differs from 7.7N/ cm2 to 23.85 N/ mm2 by adding 10% lime with 30% pond ash gives the maximum compressive strength.

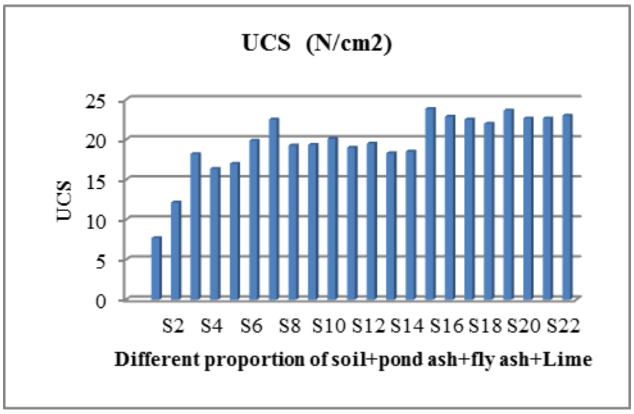

Fig 9: Result of Unconfined compression test

Table 8: Result of direct shear test

Sr. no	Coding	Direct shear	
		C	Ø
1	S1	52	21
2	S2	47	22.5
3	S3	42	23.5
4	S4	41	26
5	S5	39	27
6	S6	40	24
7	S7	52	21
8	S8	47	25
9	S9	35	28
10	S10	32	31
11	S11	50	22
12	S12	45	26

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13	S13	37	28
14	S14	34	32
15	S15	54	24.5
16	S16	45	26.5
17	S17	42	27
18	S18	32	29.5
19	S19	49	24
20	S20	47	24
21	S21	39	27
22	S22	35	28

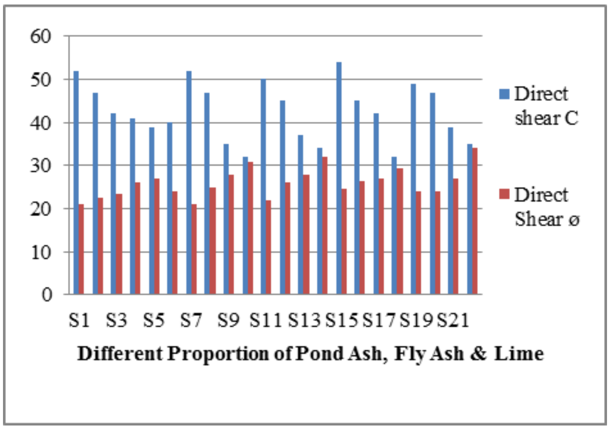

Fig 9: Result of Direct Shear test

V . DISCUSSION

Improvement in characteristics of expansive soil by using different materials has been a challenging job for engineers. In modern days of industrialization it becomes imperative to use waste materials from various industries to use for expansive soil stabilization so as to reduce the polluting effect of waste materials from various industries and to achieve worthwhile results.The specific gravity of pond ash is 2.24 This property helps in building light embankments over soft soil. Cotton soil- fly ash mixes reveal that the MDD decreases and the OMC increase with increasing fly ash content. Cohesion value and angle of friction increases with increase in percentage of lime content in pond ash. Power generation in India is likely to go up from 1,12,090 MW to 2,12,000 MW in the year 2013 Every year about 65 to 75 million tons of ash continue to remain unutilized and dumped in ash ponds and the quantity of ash in ash ponds has increased from about 450 million tons in 1999-2008 to more than 900 million tons in 2010-2011.Soil is a peculiar material. Some waste materials such Fly Ash, rice husk ash, pond ash may use to make the soil to be stable

VI . CONCLUSION

From above discussion it has been concluded that Industrial waste material which is cheaply and easily available in abunt amount i.e. pond ash and fly ash can improve the soil with the help of admixture like lime. This solution for soil improvement is environmental friendly and eco-friendly pond ash can replaces the conventional earth material in some of the geotechnical constructions also.

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