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Performance Evaluation of Soil Subgade using Fly Ash as an Industrial Waste

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Abstract

The rapid economic growth of country directly influences the development and replacement of older infrastructure. Fly ash from thermal power plants are waste products produced in large quantity in India. Fly ash (FA) is a coal combustion product that is produced in coal fired thermal power plants. Around 10-15% of total ash generated in these power plants is fly ash. In the present study, using bottom ash with various proportions i.e. 5%, 10%, 15%, 20%, 25% & 30%, in soil sample is studied.

Engineering Soil properties viz liquid limit, plastic limit, plasticity index, maximum dry density (MDD), optimum moisture content (OMC), California bearing ratio (CBR), on a number of soil samples were prepared with mixing of existing soil and fly ash and the results were compared compared.

It was found that the soil plasticity increase in liquid limits and reduction in plastic limits with increase in percentage of fly ash. Further, it is found that MDD reduces slightly that shows weak nature of the waste mix whereas OMC increases due to moisture absorption of fly ash. CBR values have shown a mixed nature. CBR values of soil samples observed to be increasing with the increasing percentage of fly ash (up to 20 %). Due to these characteristics, fly-ash occasionally is been utilized as soil subgrade stabilization.

Key Words: FlyAsh, CBR, Soil Mix, Soil Subgrade

1.0 Introduction

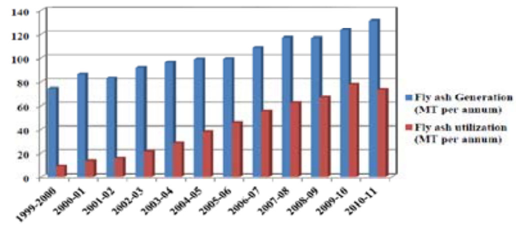
The pavement generally consists of sub grade, sub base, base course and wearing course respectively. The soil sub grade is an important part of the road construction as the load of heavy vehicles continuously transmitted to the soil sub grade through pavement. However, if the sub grade is weak due to improper compaction, excessive moisture, etc.) or having a very low strength (e.g. highly plastic clays), the sub grade cannot resist these high stresses and ruts will form, which could lead significant damage to the pavement. (Leema P, 2014).

Coal has played a significant role in electrical production since the first power plants that were built in the United States in the earlier 1880's, since then, million metric tons of high-volume Coal Combustion By-Products (CCB) including fly-ash, bottom ash, boiler slag, and flue gas desulfurization material, are generated on an annual basis within the United States (Panday and Singh,2010)). Fly-ash has been used as a soil stabilizer in the highway and transportation industry in different layers and different methods, fly-ash has been used to increase the stability of roads embankments by strengthening soft subgrade soil(Naik,TR, et al, 2002).Coal ash is an industrial waste obtained from thermal power plants by burning of coal. Coal ash consists of bottom ash (5-15%) and fly ash (85-95%). In India these plants produce 130MT Coal ash as a waste product. Therefore bulk stabilization of Coal ash becomes very essential in view of huge producing and to reduce the disposal areas under Environmental concerns (A rifaI et al 2009), (Robert M. and Brooks, 2009).

1.1Industrial Waste Material

1.1.1 Fly Ash

Fly ash is also known as 'Flue Ash' is one of the residue of coal combustion product composed of fine particles that are driven out of the boiler with the (Kaushik, R, 2014). In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Average fly ash content in Indian coal is 35-38 percent (Haque, E.M, 2013). Figure 1 shows percentage utilization trend in India.



(Source: CEA Annual report on fly-ash generation and utilization)

Figure 1 :Fly-ash generation and utilization in India

Figure 1 shows that the fly ash generation has increased tremendously (74.03 MT in 1999-2000 to 131.09 MT in 2010-11) while the fly ash utilization has increased 12.03% in 1999-2000 to 55.79% in 2010-11 respectively. It directly shows the encouragement for bulk utilization of fly ash in construction works.

1.1.2 Bottom Ash

Bottom ash is a Coal Combustion Product and is composed of clustered ash particles in nature which are usually coarser than fly ash particles (Dey A and Pandey K M, 2016). It is the slag which builds up on the heat absorbing surfaces of the furnace, and subsequently falls down to the furnace bottom. It is typically grey to black in color and is quite angular and has a porous surface structure. According to Central Electricity Authority annual Report (2011-12) total bottom ash generated in India annually is about 15 to 20 million tonnes. It poses a great threat to environment if not taken care of properly. This can pollute already polluted air, water and soil and it is also harmful to human and animal health. Bottom ash not quite as useful as fly ash, although power plant owners have tried to develop beneficial use options, such as structural fill and road-base material (Palmer B, 2015). Studies (Singh, M. 2014) have shown that bottom ash can be used in pavement construction as filler, as a replacement of binder material.

2.0 Objectives

1. To increase stability and strength of soil samples. The soil samples were tested with various proportions of soil with fly ash.

2. To determine different properties like specific gravity, liquid limit, plastic limit, plasticity index, etc. of different mix proportions.

3. To conduct California bearing ratio (CBR), maximum dry density (MDD), optimum moisture content (OMC) test on various proportions of soil with fly ash mixture.

3.0 Literature Review

Various research studies have been carried out in different parts of world. some of them are discussed below.

Singh, A.K. and Yadav, R.K. (2016) studied the influence of jute fiber reinforcement on CBR properties of expansive soil with reinforcement of jute fiber between two layers of soil. It was observed that inclusion of Jute Geo Textile layer into the soil could increase the unconfined compressive strength and CBR value corresponding to 4 layers reinforcement. The MDD was increased at 2 layer reinforcement from 1.698 gm/cc to 1.74 gm/cc and reduced to 1.72 gm/cc at 4 layer reinforcement. On the other hand CBR value was remarkably increased as 11.85% at 4 layer reinforcement and it was 6.07% after 2 layer reinforcement. **Swaidani, A, Hammoud, I and Meziab, A (2016)** studied the effect of adding natural pozzolana materials on some geotechnical properties of lime-stabilized clayey soils. Natural pozzolana and lime were added to soil within the range of 0%-20% and 0%-8%, respectively. Atterbergs limits, MDDand OMC, California bearing ratio (CBR) and linear shrinkage properties were particularly investigated. The test results showed that the investigated properties of lime treated clayey soils could be considerably enhanced when the natural pozzolana was added as a stabilizing agent. The results showed that the CBR increased from 2.89 to 55.76 and 66.02 with an increasing in lime content from 0% to 4% and 8% respectively. The natural pozzolana alone increased the CBR value from 2.89 to 22.34 with an increment from 0 to 20%. **Hasan, H, Dang, L, Khabbaz, H, Fatahi, B and Terzaghi, S (2016)** studied the effects of bagasse ash & hydrated lime in black soil samples, collected from Queensland Australia. Samples were prepared using different contents of bagasse ash and hydrated lime (0%, 6%, 10%, 13,18% and 25% by the dry mass of soil), at a ratio of 3:1, respectively. The results of free swell ratio (FSR) test, unconfined compression strength (UCS) and California bearing ratio (CBR) tests were presented for untreated and treated samples after various curing time periods of 3, 7 and 28 days. The results demonstrated that stabilization of expansive soils using bagasse ash and hydrated lime not only improved the strength, but also facilitates to cope with environmental concerns through reduction of sugar industry waste material. It was observed that the CBR values increased for 6%, 10%, 18% and 25% of bagasse ash and lime mixes at 7 and 28 days curing. Similarly UCS was also increased by 80% when mix content increased from 0 to 25%. **Li, J, Tang, C, Wang, D, Pei, X and Shi, B (2014)** studied the effects of fiber content, dry density and water content on the tensile strength. The results indicated that the developed test apparatus was applicable in determining tensile strength of soils. They found that the fibre inclusion could significantly increased soil tensile strength and soil tensile failure ductility. The tensile strength increased with increasing fiber content. As the fiber content increased from 0% to 0.2%, the tensile strength increased by 65.7%. The tensile strength of fiber reinforced soil increased with increasing dry density and decreased with decreasing water content. For instance, the tensile strength at a dry density of 1.7 Mg/m3 is 2.8 times higher than that at 1.4 Mg/m3. It decreased by 30% as the water content increased from 14.5% to 20.5%. Furthermore, it was observed that the tensile strength of fiber reinforced soil was dominated by fiber pull-out resistance, depending on the interfacial mechanical interaction between fiber surface and soil matrix. **Sobolev, K (2014)** prepared different types of bitumen mixes with 5% to 60% of binder replacement by weight of fly ash. Rutting factor and dynamic viscosity were determined for different types of performance graded (PG) bitumen (PG-58-28 and PG-70-22) using dynamic shear viscometer (DSR). Two types of fillers were used (Class C and Class F fly ash). They found that the addition of 5% to 60% of Class C fly ash increased rutting factor by 14% to 82%. Similar increment values for Class F fly ash were 11% to 117% for same amount of fly ash. For dynamic viscosity, use of fly ash 5%, 15% and 30% in bitumen type PG-58-28 increased viscosity by 18%, 22% and 55% . While for bitumen type PG-70-22 increment was 17%, 31% and 79% for similar values of fly ash. **Peter, L, Jayasree, P. K, Balan, K and Raj, A. (2014)**, studied that the Coir waste consisted coir pith and coir fiber, is a by-product of coir manufacturing industry and obtained from coconut husk during the extraction of coir fiber. The pollution caused due to the poly phenol leaching and the resistances to degradation due to the stable lignin structure made the coir waste a potential threat to the land resources. This paper presented an investigation on the behavior of soft soil stabilized with varying percentages of coir pith (0-3%) and coir fibre (0-1%) by carrying out Standard Proctor Test, Static Triaxial Test and California Bearing Ratio (CBR) tests. The test results showed that stabilization with coir waste had a significant effect on the compaction, Elastic modulus as well as CBR characteristics. The CBR value was increased by 192% and 335% for 2% coir pitch and 0.6% of coir fiber addition. The elastic modulus for the combined treatment increased from 7.92MPa to 9.66MPa. **Butt, W.A, Gupta, K, Naik, H, and Bhat, M.S (2014)** investigated the strength variations of the cohesive soils using human hair fibers (natural fiber) as a soil reinforcing material. By increasing the human hair fiber content percentages MDD decreased and OMC increased. CBR value at 0.5% fiber content was much less (11.85%) than unreinforced soil (13.26%). But after increasing the fiber content percentage CBR value increased up (13.87% to 17.21%) to 2 percent of fiber, then again started decreasing (15.82%) at 2.5 percent fiber content. **Tiwari, A and Mahiyar, H. K (2014)** conducted various test on black cotton soil using different percentages of Fly Ash (FA) at 10%, 15%, 20%, 25%, Coconut Coir Fiber (CCF) at 0.25%, 0.5%, 0.75%, 1% & Crushed Glass (CG) at 3%, 5%, 7% (glass crushed to have gradation of sand size) and concluded improvement in engineering properties of soil. California Bearing Ratio up to 3.5 times for optimum combination (20% FA + 5% CG + 1% CCF with soil).

Kulkarni, V.R and Patil, G.K (2014) studied the effect of blast furnace slag and glass fibers on certain properties of soil such as Optimum Moisture Content (OMC), Maximum Dry Density (MDD), Differential free swell and California Bearing Ratio (CBR) the experiments conducted on the samples by using blast furnace slag, 6mm and 12mm glass fibers and carried a series of CBR tests on black cotton soil by varying percentage of blast furnace slag (0%, 5%, 10%, !5%, 20% 25%, 30%) and glass fiber with different length (6mm & 12mm) and proportions (0%, 0.25% 0.50%, 0.75%, 1.00% and 1.25% by weight of dry soil with optimum percentage of slag 25%) and concluded that Mixing of soil with varying percentage of slag increased CBR value from 1.27% to 3.98% for soaked condition. It was observed that CBR value increased with increment in length of fibre.

4.0 Methodology

4.1 Atterberg Limits

Atterberg limits including Liquid limit, Plastic Limit and Plasticity Index were determined on the collected soil samples as per IS: 2720 Part V-1985. According to IS: 1498-1970, if value of plasticity index (IP) of soil lies above A-line (IP >7) as per plasticity chart in IS: 1498-1970 then the soil is classified as Clay (C) and if liquid limit of soil sample is less than 35 (WL < 35) then the soil is classified as soil with low plasticity (L).Table 1 shows the various Engineering Properties of tested Soil Sample.

Table :1 Engineering Properties on Soil Sample

S.No	Property	Value	Tested Value for existing soil sample	Reference :IS Code
1	Classification of Soil	CL	CL	IS:1498-1970
2	Specific Gravity	2.63	2.22	IS:2720Part III-1980
3	Liquid Limit	25.31 %	22.23 %	IS:2720Part V-1985
4	Plastic Limit	15.47 %	14.98 %	IS:2720Part V-1985
5	Plastic Index	9.85%	8.48%	IS:2720Part V-1985
6	MDD	1.8 g/cc	1.08%	IS:2720Part V-1983
7	OMC	10.39 %	38%	IS:2720Part VII-1983
8	CBR(Soaked)	5.46%	-	IS:2720Part XVI-1987

The Sampled soil was mixed with fly ash and a homogeneous mix was prepared. The fly ash percentage was varied from 0%, 5%, 10%, 15%, 20%, 25% and 30%.

5.0 Results and Discussions

Table 2 shows the various engineering properties with different proportions of soil sample and fly ash mix.

S.No	Mix Proportions	LL	PL	MDD(g/cc)	OMC %
1	100 % Soil + 0% FA	22.95	17.70	1.67	11.28
2	95% Soil + 5% FA	23.75	15.89	1.87	10.89
3	90% Soil + 10% FA	25.68	18.90	1.80	12.56
4	85% Soil + 15% FA	31.23	23.34	1.78	14.67
5	80% Soil + 20% FA	31.10	19.32	1.67	15.78
6.	75% Soil + 25% FA	19.5	16.82	1.63	17.54

It was observed that It was observed that there is increase in liquid limits up to optimum mix (85:15%) and then decrease which indicates that waste mix absorbs moisture within the moist soil.

Figure 2 shows the detailed CBR test results with different mix proportions.

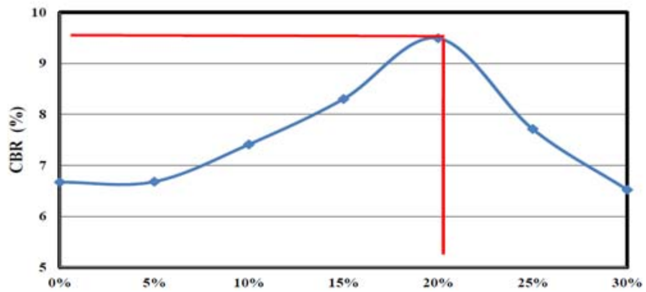


Figure: 2 CBR test results with different mix proportions

It was observed that CBR value continuously with increasing content of fly ash (0% - 25%).The CBR value at optimum mix was found to be 9.79 % as compared to untreated soil which is 5.46 %. After the optimum mix, CBR value found to be decreasing.

Conclusion

It was observed that The characteristics and strength of a highly expansive soil can be improved by fly ash stabilization. The main aim of the present research was to use fly ash effectively to bring down the cost of construction of the roads and achieved the goal of research. It was found that Engineering Soil properties viz liquid limit, plastic limit, plasticity index, maximum dry density (MDD), optimum moisture content (OMC), California bearing ratio (CBR), on a number of soil samples were prepared with mixing of existing soil and fly ash and the results were compared.

It was found that the soil plasticity increase in liquid limits and reduction in plastic limits with increase in percentage of fly ash. Further, it is found that MDD reduces slightly that shows weak nature of the waste mix whereas OMC increases due to moisture absorption of fly ash. CBR values have shown a mixed nature. CBR values of soil samples observed to be increasing with the increasing percentage of fly ash (up to 20 %). Due to these characteristics, fly-ash occasionally is been utilized as soil subgrade stabilization.

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