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Stabilization of Soil under Foundation and Pavements Using Fly Ash

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Abstract

State Chhattisgarh of India is having a vast area covered under forest and agricultural land. The black cotton soil is available in the vicinity of water bodies like ponds, regular/monsoon nullahs etc. Infrastructure projects like the houses in the villages and for the low-income grade communities, widening of national highways and new highways etc. requires a huge amount of soil (mud) for filling of sub-base preparation. Since black cotton soil shows properties like swelling and shrinkage with an effect of moisture, it needs stabilization other commercial uses. This work consists of an evaluation of soil properties on the addition of locally available industrial by-product which must be under budget. The present piece of work is an attempt to see the effect of fly-ash (industrial by-product) on stabilization of soil lies under such foundation and Pavements.

Introduction:

The soil stabilization is the process of improving the engineering property of the soil by either mechanical or by chemical method. The mechanical method of soil stabilization can be achieved by altering the basic nature of virgin soil by either induced vibration or by compaction. The chemical method of soil stabilization depends on the chemical reactions between stabilizer and soil minerals. This particular method was adopted in our study i.e., the soil stabilization by the process of chemical stabilization. Black cotton soil (Loose Soil) has a clay content namely known as Montmorillonite. Black cotton soil when gets wet, it swells and when dried it gets shrink. Thus such clays are unfit for construction purposes (Arora & Aydilek, 2005).

Fly-ash is a by-product of the burning of coal. It is abundant in nature and is always treated as the waste material produced by thermal power plants all over India. The effective fly-ash content which improves the engineering properties of soil ranges between 15- 20% (Pandian *et al.*, 2002). It has been proposed that fly-ash can be used in embankments and fills. In this piece of work, the effect of different percentages of fly-ash in addition to black cotton soil on California Bearing Ratio (CBR) values was tested (Pandian *et al.*, 2001). Black cotton (BC) soil is expansive in nature due to its combination of clay with an expanding lattice structure (Murthy *et al.*, 2000; Sridharan *et al.*, 1998). Lime and fly-ash change the soil property by a

chemical reaction where as other admixtures changes mechanical soil nature. Till date, few attempts have been carried out for improving engineering properties of poor soils using different additives (Nagraj *et al.*, 1994; Edil *et al.*, 2006; Muley *et al.*, 2010). Indeed most of the attempts had made to correlate California Bearing Ratio with basic soil properties. But, we have used fly-ash, a waste material to enhance the soil properties by (Fig.-1).

Figure-1: The methodology adopted by us in our study

Methodology:

Fly-ash and bottom ash were collected from NTPC-SAIL Power Corporation Limited (NSPCL) Bhilai and Dr. Shyama Prasad Mukherjee (DSPM) Thermal Power Station (TPS) Korba thermal power plants. Fly-ash was collected from the silos exist in those thermal power plants. As per the report of the power plants by Government of India in 2017 3500 metric tonnes of fly-ash have been produced regularly from the DSPM TPS Korba power plant and 15000 metric tonnes

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from NSPCLBhilai. But the utilization is around 33% of the total generated fly-ash. The total of 50 kg of both fly-ash and bottom ash were collected from the thermal power stations. Both were dried in an oven before use.

Table-1: Constituents of Fly-ash collected from both the power plants

Compound	Plant-1 (NTPC-SAIL)	Plant-2 (DSPM)
SiO ₂	62.32%	56.85%
Al ₂ O ₃	26.72%	21.40%
Fe ₂ O ₃	08.00%	13.82%
CaO	00.50%	03.29%
MgO	00.57%	00.74%
So ₃	00.18%	00.00%
Na ₂ O	00.10%	00.00%
K ₂ O	00.52%	01.85%
Ti ₂ O ₃	00.04%	00.00%
P ₂ O ₅	1.05%	00.00%

Soil was collected from the outskirts of Raipur city of Chhattisgarh. These samples have been identified for their swell potential and have been broadly grouped into three categories based on their degree of expansiveness and problematic nature as (i) Highly expansive and problematic group, (ii) Moderately expansive and problematic group and (iii) Least expansive and problematic group (Hakari & Puranik, 2010)

Engineering properties of soil which have been considered in this work were: Liquid Limit, Plastic Limit, Plasticity Index, Specific Gravity, Classification Group, Differential Free Swell Index, Optimum Water Content, Maximum Dry Density

Results and Discussion:

Variation of liquid and plastic limits on replacement of soil have been shown in Fig.- 2.

Figure-2: Liquid limit versus plastic limit on soil remold

fly-ash has more liquidity than that of natural soil which had plastic behavior. The liquid limit decreases with increase in fly-ash content from 0% to 25%. The reduction in the liquid limit was found out to be 5.55%. On the other hand, the plastic limit of the soil decreases with increase in the percentage of fly-ash from 0% to 25% which indicates that on an addition of fly-ash the soil loses its plastic state. It means that the soil started to act like sand. As on addition of

Fly-ash to the soil, the soil started losing its cohesive nature and thus it was observed that soil changed into the cohesionless soil which resembles sand. This indicates a good sign for the tackling of the unequal settlement of the soil during the construction process.

Free swell index(F.S.I.): the free swell index was performed in a 100 ml cylinder jar with 10g soil sample (IS: 2720 (Part 40) – 1985, Determination of Free Swell Index). The results are shown in Table-3. The relations between swelling behavior and mixture prepared have been shown in Fig.- 4 & Fig.- 5. After conducting the free swell index it was observed that as the water content increased the soil swell or concomitantly the plasticity also increased with an increase in the Liquid limit. Therefore F.S.I. also increased with increases in the plasticity index, which in turn revealed swelling and shrinkage properties in the soil.

Table 3 Free Swell Index with various solvents

Soil Type	Kerosene	Water	FSI
Natural Soil	11 ml	18.5 ml	68.18%
fly-ash	10 ml	11 ml	10%
Soil + 10% fly-ash	10.5 ml	14.5 ml	41.06 %
Soil + 15% fly-ash	10 ml	12.75 ml	27.5%
Soil + 25% fly-ash	9 ml	11 ml	22.22%

Figure-3: Variation in Swell Property with respect to Fly-ash

Figure-4: Variation of Atterberg's Limits with respect to Swelling

Modified Proctor Test: since the degree of compaction of soil is measured as the dry density of soil, the degree of compaction is dependent on compaction energy, type of soil and moisture content. The soil attains a maximum dry density at a particular water content which is termed as

optimum water content (IS: 2720 (Part 7)–1985, Modified Proctor Test). Compaction in the form of increased in dry density is presented in Table-3; plotted in Fig.-5 and Fig.-6.

Table 4 Modified Proctor Test

Soil + fly-ash	Optimum Water Content	Dry Density
0%	12.5%	1.862gm/cc
10%	14.8%	2.38 gm/cc
15%	19.05%	3.84 gm/cc
25%	18.14%	3.78 gm/cc

Figure-5: Variation in optimal water content and maximum dry density with respect to Fly-ash

The optimum water content of the soil when mixed with varying percentages of fly-ash increased upto 15% and then decreased to 25%, thus increasing the maximum dry density from 1.862 gm/cc to 3.84 gm/cc at varying percentages from 0% to 15% and there on decrease to 3.78 gm/cc at 25%. This indicates that the soil when mixed with fly-ash gives optimum results at an around 15%.

Specific Gravity : the specific gravity of the samples such as fly-ash and soil was determined as per IS 2720 (Part-III; IS: 2720 (Part III) – 1985, Determination of Specific gravity of soil). On determination through IS 2720 (Part-III) specific gravity of fly-ash was found out to be 2.16 and that of soil was 2.63.

Soil Classification: on conducting sieve analysis of the soil by passing through 4.75mm gauge was 100 % and thus it was considered as Sand (S). Since on sieving the soil while passing percentage through 75 μ was 18% i.e. less than 50%. Thus the soil could be classified as coarse-grained soil. Since fineness is greater than 12% it could be either termed as Silt (M) or Clay (C).

Since, IP = 37 %

As per IS 1498-1970, if IP > 7,
C > M

As per A - Line Equation = (IS 1498-1970)*,
IP = 24.57 %

As per U - Line Equation = (IS 1498-1970)*
IP = 41.103 %

*Classification and Identification of
Soils for General Engineering Purposes.

The plasticity chart soil is classified in SC (IS 1498-1970,

Classification and Identification of Soils for General Engineering Purposes). Since the IP of the soil found was above A - line (24.51%) and below U - line (41.10%) and the liquid limit was greater than 50% and as per IS 1498-1970 it could be referred as highly compressible soil. These properties of soil match with Black cotton soil (Loose Soil). pH - Fly-ash is found to be acidic in nature but on addition of fly-ash to the soil, no variation has been found and thus the soil as a whole was observed as neutral i.e. it lies within 6.5–8.5.

Cost analysis : when we use moorum (red laterite soil), the cost of stabilization increases upto 6 times and also disturb the natural resources, whereas when using Soil+15% Fly-ash it could be economical i.e. upto 35% reduction in cost, as the fly-ash has to be provided free of cost in vicinity of thermal power plants i.e., within 150 km. This makes the stabilization quite economical and thus reducing the harm to mother earth by utilization of the fly-ash instead of disposing it in nature. It is to be noted that fly-ash not only pollutes the environment but also is a hazard to human being.

Pandian *et.al.* (2002) reported the beneficial aspects of the fly-ash soil mixes in road construction from Raichur and Neyveli fly-ash on the CBR characteristics of black cotton soils from Karnataka, India. Çokça (2001) studied the effect of fly-ash on expansive soils and he concluded that fly-ash can be recommended as an effective stabilizing agent for the improvement of expansive soils. Phanikumar & Sharma (2004) presented the effect of fly-ash on free swell index, swell potential, plasticity, compaction, strength characteristics of expansive soils and concluded that the fly-ash improves the plasticity, compaction and strength characteristics of black cotton soils obtained from Andhra Pradesh, India. Report of Sivapullaiah *et.al.* (1996) suggested that the addition of fly-ash decreased the liquid limit of black cotton soils, they also reported the effect of fly-ash on the index properties of these soils from Karnataka, India.

Conclusions:

- Soil properties improve on an addition of fly-ash upto 25%, which may be due to the filling up of fly-ash in the airvoids of soil. Thus enhancing the rigidity of the soil.
- A liquid limit decreased with an increase in the percentage of fly-ash upto 25% in the natural soil thus it could be concluded that the mixing fly-ash in specific proportion with the soil is an effective way to tackle the problem of shrinkage, swelling and unequal settlement.
- The liquid limit of fly-ash didn't show any change in its property due to the absence of cohesive nature of fly-ash.
- Approximately 25-35% cost may be reduced on use of fly-ash as a replacement and preservation of mother

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earth may be observed.

- The plasticity index of the remolded soil is indicative of the plastic capacity of the soil which was observed as a decreasing value as the proportions of fly-ash was increased. The plasticity index showed a decreasing trend as the plastic and liquid limit both were decreasing on regular basis (Arora, 2009)
- The optimum water content was found to increase with the addition of fly-ash in different proportions as the water required by the fly-ash present in the soil is very fine and therefore water content needed to be increased (IS: 2720 (Part 40) – 1985, Determination of Free Swell Index).
- The maximum dry density was found to increase due to the increase in optimum water content of the flocculated soil.

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