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Soil stabilization using steel slag

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ABSTRACT

Construction of structures over weak or soft soils leads to differential settlements, poor strength and high compressibility. The safety of structure depends on the stability of foundation and any kind of failure in foundation may cause distortion to structure. If the in-situ soil does not possess the required strength, then it should be either replaced by good quality/ good bearing soil or stabilized by mechanical or chemical means. Soil stabilization is one of the modification technique used to improve the geotechnical properties of soil and have found major application in construction engineering which enables the effective utilization of industrial wastes as a stabilizer.

This paper describes a study carried out with an aim to enhance the bearing capacity of clayey silts of medium plastic soil, on mixing it with steel slag in varied proportion. In this study, various geotechnical properties such as OMC, Atterberg's limit and CBR of both modified and unmodified soil has been computed.

KEYWORDS : soil stabilization, maximum dry density, California bearing ratio, steel slag

INTRODUCTION

Stabilization in a broad sense includes the various methods employed for modifying the properties of a soil to improve its engineering performance. The most common application being in the road construction and airfield pavements, where the main objective is to increase the strength or stability of soil and to reduce construction cost by making best use of locally available materials.

Generally, soil at any particular location does not suit, wholly or partially, to the requirements of construction engineer. A basic decision must be therefore made whether to replace the site material with a superior one or alter the properties of soil to meet the specific engineering requirements. This alteration can be done by blending industrial waste such as steel slag or fly ash with soil in variable proportion and recording the optimum ratio which will be dispensable for construction work.

Rapid rise in steel production has resulted in India becoming 4th largest producer of steel. Total production of steel in 2014-15 is estimated around 65.197 million tones. Therefore, expansion of steel industry leads to increase in volume of residues and steel produced. Beneficial properties of slag such as strength, durability etc. makes it suitable for engineering applications. It can be used in road construction, soil stabilization and construction of low permeability barrier liners.

MATERIALS USED

A national highway is passing through Narhi Village near in Suba Bazaar, Gorakhpur which has a low CBR value/strength. Thus, it was decided to enhance the bearing strength of soil by using soil stabilization techniques. For stabilization we have used steel slag as secondary construction material, since it is available locally and thus, can be obtained easily.

Laboratory results for geotechnical properties of soil used are given in Table 1.

Table 1: Geotechnical properties of soil

S.NO.	Properties	Values
1	Specific gravity	2.65
2	Grain size analysis Gravel (>4.5mm) Sand (0.075mm-4.5mm) Silt (0.002-0.075) Clay (<.0.002)	 0% 15% 77.06 7.94
3	Liquid limit Plastic limit	42.708% 27.662%
4	Optimum moisture content	17.50%
5	Maximum dry density	1.72g/cc
6	CBR value	2.246%
7	Permeability	1.43×10^{-5}cm/s

From liquid and plastic limit test, IP (plasticity index) is found to be 16.57 %. Hence, from plasticity chart it can be said that soil is MI i.e. silt of medium compressibility. CBR value is very less and permeability is of the order 10^{-5} cm/sec. Therefore, it needs to be stabilized using some admixture.

For this research, Iron slag was obtained from Gallant industries, Gorakhpur. Slag is the granular material formed when molten iron blast furnace slag is rapidly chilled by immersion in water. It is a granular product with very limited crystal formation and is highly cementitious in nature

Physical properties for slag are given in Table 2.

Table 2: Physical and Engineering Properties of Slag

S.NO	Properties	Values
1	Specific gravity	3.03
2	Grain size analysis Gravel (>4.5mm) Coarse sand (2.00mm-4.75mm) Medium sand (0.425mm-2.00mm) Fine sand (0.075mm-0.425mm) Fines (silt and clay) (<0.075)	 0% 0% 4.6% 70.2% 25.2%
3	Liquid limit Plastic limit	Not obtainable Not obtainable
4	Optimum moisture content	19.80%
5	Maximum dry density	2.425g/cc
6	CBR test	12.35%
7	permeability	1.53×10^{-2} cm/s

From the test results obtained, slag is found to be non plastic and particle size distribution (PSD) of slag covers the whole range between silt and sand. The laboratory test has also shown hydraulic conductivity of slag is 1.53×10^{-2} cm/s. Angle of internal friction, $\phi = 41°$ and Cohesion, c = 1.44 KN/m^2 and hence, it can be said that slag is cohesive-friction in nature.

RESULT AND DISCUSSION

After computation of properties of soil and slag separately, samples are mixed in various proportion. Preliminary test were conducted on 9 soil samples with 0%, 3%, 7%, 11%, 18%, 21%, 25% and 30% slag added to it and variation of maximum dry density, optimum moisture

content, California bearing ratio, and hydraulic conductivity with slag are checked out and are listed in Table 3.

Table 3: Properties of Sample Prepared

S.NO.	SAMPLE	OMC(%)	MDD (g/cc)	CBR (%)	LIQUID LIMIT
1	Natural soil	17.50	1.72	2.25	42.70
2	Natural soil +3%slag	14.30	1.656	2.43	40
3	Natural soil +7%slag	14.450	1.765	2.62	37.06
4	Natural soil +11%slag	15.05	1.773	3.37	31.05
5	Natural soil +15%slag	15.50	1.783	3.556	27.01
6	Natural soil +18%slag	16.50	1.835	3.650	24.03
7	Natural soil +21%slag	17.00	1.935	3.930	
8	Natural soil +25%slag	17.9	1.950	4.211	20.23
9	Natural soil +30%slag	18.73	1.912	2.246	17.7

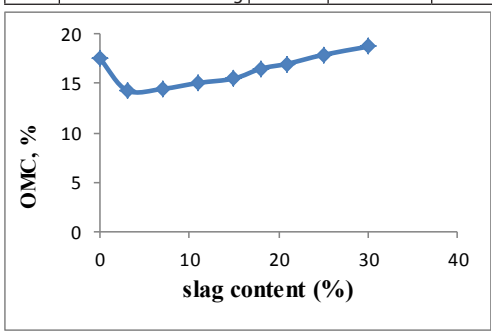

Figure 1: Variation of OMC vs Slag Content

The Fig. 1 shows variation of OMC with percentage of Slag content varying from 0% to 35%. The graph is almost linear showing that OMC is not much affected with change in the slag content in the soil. This little variation in OMC is found.

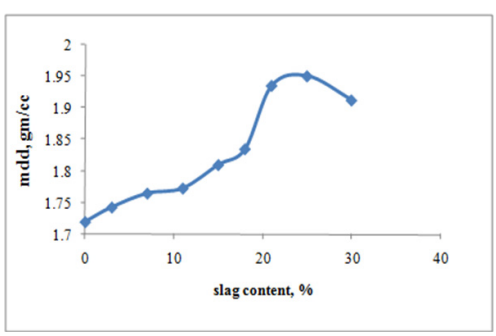

Figure 2: Variation of MDD vs Slag Content

Fig. 2 shows variation of dry density with percentage of slag content in the soil. It is observed that dry density first decreases on mixing slag and then increases as the slag content is increased. As the Slag content increases it goes into the pores of soil and makes a very well packed structure. After increment in SLAG content, the particles of the soil were replaced by the SLAG material and due to its less unit weight, the dry density of soil reduced with the addition of additive.

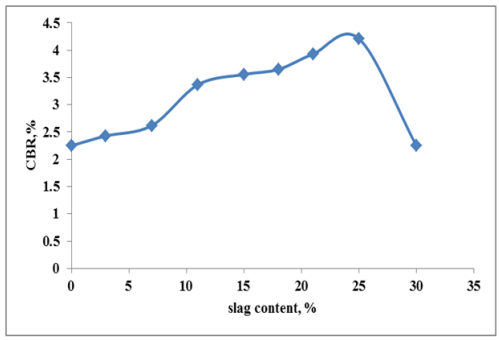

Figure 3: Variation of CBR vs Slag Content

Fig. 3 shows variation of CBR value with percentage of slag content in the soil. It is observed that CBR value increases with increase in slag content in the mixture. The variation in CBR value comes because of variation in bonding forces between the particles. Initially the amount of Slag improved the bonding forces and the CBR value will increase upto 25% percentage of slag. After this optimum proportion, the slag content becomes in excess in the mixture which will reduce the CBR value due to its less cohesive strength.

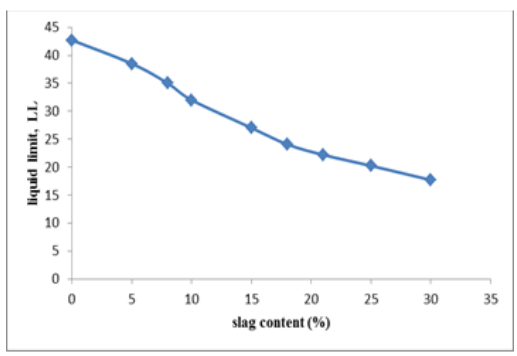

Figure 4: Variation of Liquid Limit vs Slag Content

The graph shows that, with increase in slag plasticity decreases. This is due to replacement of soil by slag content which is non – plastic.

CONCLUSION

- There is not much effect on optimum moisture content of soil.it increases from 17.50% to 18.73.
- Maximum dry density of soil increases with increase in slag content making it a well packed structure.
- CBR value of soil increases with increase slag content and therefore increasing its strength up to 25% mix.

Slag content in natural soil increases its workability by reducing its plasticity.

RECOMMENDATIONS

Natural soil with 25% slag is considered as optimum stabilization ratio for soil and can be used for sub grade as well as in construction of low permeability liners with addition of some additives such as Bentonite.

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