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APPLICATION OF STEEL SLAG IN SUB GRADE LAYER OF FLEXIBLE PAVEMENT

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ABSTRACT

Steel slag is an industrial waste which is produced in huge quantities as a byproduct in the process of steel manufacturing. It is imperative to utilize the steel slag effectively with technical enhancement in each area. Disposal of steel slag as a landfill causes various health and environmental hazards. Steel slag is gradually achieving importance in road construction industries due to considering it's disposal, environmental and health issues. In this paper, a typical steel slag was collected from M/S Gallant Steel Industry Pvt. Ltd., Gorakhpur and it's suitability for use in sub grade layer and side trenches of flexible pavement was determined. To improve geotechnical engineering properties of sub grade, the steel slag was mechanically mixed and stabilized with locally available soil in the range of 10% to 40%. Geotechnical standards of these stabilized mixes were analyzed to investigate their feasibility in the construction of different layers of road pavement. Key experiments conducted to adjudge the suitability and proportion of steel slag to be used are California Bearing Ratio Test (CBR Test) and Standard Proctor's Compaction Test. Technical specification of steel slag is developed for it's utilization in the fabrication of sub-grade and side trenches of flexible pavement.

Keywords: CBR test, Index Properties, Standard Proctor's Compaction Test, Steel Slag, Sustainability.

I. INTRODUCTION

The iron and steel slag that is produced as a byproduct of iron and steel manufacturing mechanism can be roughly classified into blast furnace slag and steel making slag. Blast furnace slag is produced by melting separation from blast furnace that produce molten pig iron. It consists of non-ferrous components contained in the iron ore with limestone as an auxiliary material and ash from coke. Depending on the cooling method used, it is classified either as air cooled slag or granulated slag. Steel slag is produced during steel making process in electric arc furnace that uses steel scrap as the raw material. The waste material is adjudged to be neutral and non hazardous in nature as per chemical analysis report of Central Pollution Control Board of India. The amount of generation of this slag is about 24 lakh metric tonnes per year from various steel industries in India.Presently, steel slag is employed as a land fill cover liner. Pazhani and Jeyaraj (2010,Ref. No.- 8) studied feasibility of Granulated Blast Furnace slag (GBFS) for production of high performance concrete. Application of steel slag in asphaltic concrete minimizes potential expansion and take the advantage of positive features in giving high stability, stripping resistant asphalt mixes with excellent skid resistance.

Study is conducted to use the steel slag in different layers of road construction. Being cohesion less material, it is mixed with local soil in the range of 10 to 40 % and their geotechnical characteristics are analyzed. Technical specification of slag is developed for its use in the construction of sub grade layer and side trenches of flexible pavement. Steel slag is also investigated for its usability in bituminous layers.

II. MATERIALS USED

Steel slag sample is collected from M/S Jalan Steel Pvt. Ltd. industry in Gorakhpur district of Uttar Pradesh, India. It is selected from different location of the heap and mixed thoroughly before using it for laboratory study. Local soil is collected from agricultural field nearby. Local soil and steel slag is mixed in various percentages and the geotechnical properties of each mix is analyzed.

Laboratory results for geotechnical properties of local soil are given below:

Table 1: Geotechnical properties of soil

S.No.	Properties	Values
1	Specific Gravity	2.15
2	Grain Size Analysis:	
	Gravel (>4.5mm)	0 %
	Sand (0.075mm-4.5mm)	16 %
	Silt (0.002-0.075)	76 %
	Clay (<.0.002)	8 %
3	Atterberg Limit:	
	Liquid limit	49 %
	Plastic limit	31 %
4	Optimum Moisture Content	12.1 %
5	Maximum Dry Density	19.3 KN/m^3
6	CBR value	2.26 %
7	Permeability	$1.44*10^{-5}$ cm/s

From the test results obtained, steel slag is analyzed to be non plastic and grain size of slag covers the whole range between silt and sand. The laboratory test has also shown hydraulic conductivity of slag is 1.50×10^{-2} cm/s. Angle of internal friction, ϕ = 41° and Cohesion, c = 1.44 KN/m^2 and hence, it can be said that steel slag is cohesive-friction in nature.

Table 2: Geotechnical properties of steel slag

S.No.	Properties	Values
1	Specific gravity	4.3

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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	8.5 %
5	Max. dry density	24 KN/m^3
6	CBR value	12.4 %
7	Permeability	$1.50*10^{-2}$ cm/s
8	Coefficient of Uniformity (C_u) Coefficient of Curvature ($C_{c)}$	12.86 1.92
9	Moisture Absorption %	12%

III. METHODOLOGY

The geotechnical properties of Steel Slag, indigenous soil and their mixtures is investigated to study their feasibility in different layers of road pavement. Construction of road embankment fill using steel slag only would not be fruitful as it is cohesion less material. Such embankments would be highly erodible. The complete road can be washed off during rainy season. Therefore, it is mixed with local soil in the range of 10-40% and their geotechnical characteristics is analyzed. Various mix proportions with their corresponding mix designations are provided in following table.

Table 3: Different mixes of soil and steel slag and their mix designations

MIX DESIGNATION	**MIXES**
100LS	100% local soil
10S+90LS	10% steel slag +90% local soil
20S+80LS	20% steel slag +80% local soil
30S+70LS	30% steel slag +70% local soil
40S+60LS	40% steel slag +60% local soil
100S	100% steel slag

Mixing of steel slag and soil: Soil and steel slag is mixed manually as per percentage by weight in the laboratory for experiments. Significant important geotechnical properties namely Moisture Absorption Test, Specific Gravity, Atterberg limit, Grain Size Analysis, Standard Proctor compaction Test, California Bearing Ratio Test is carried out.

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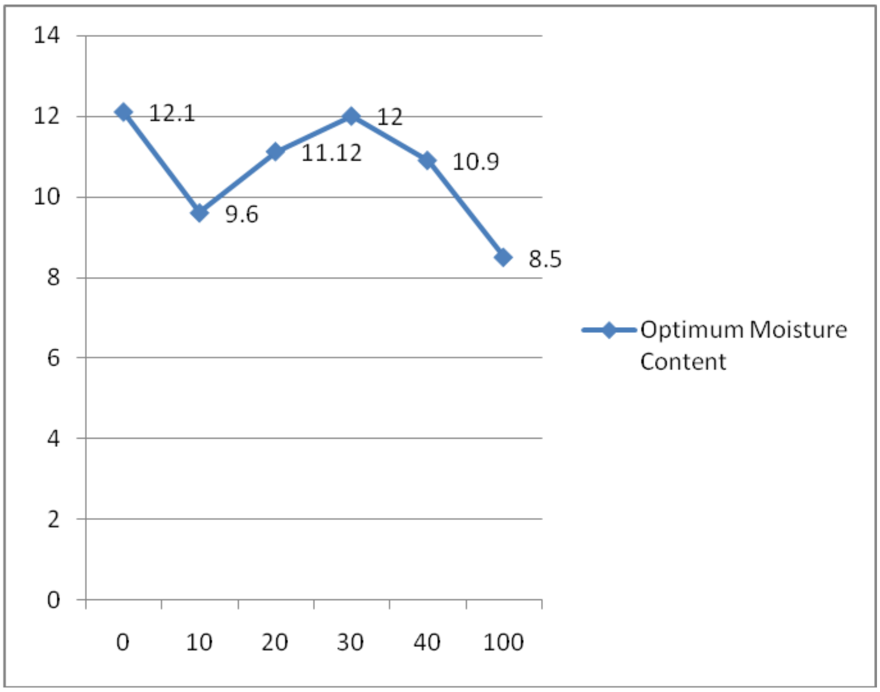
IV. RESULT AND DISCUSSION

Table 4 : Properties of sample prepared

S.No.	Mix Designation	Optimum moisture content (%)	Maximum dry density (KN/m^3)	CBR value (%)
1.	100LS	12.1	19.30	2.26
2.	10S+90LS	9.6	19.9	3.41
3.	20S+80LS	11.12	20.5	3.95
4.	30S+70LS	12	20.65	2.25
5.	40S+60LS	10.9	20.8	2.13
6.	100S	8.5	24	12.4

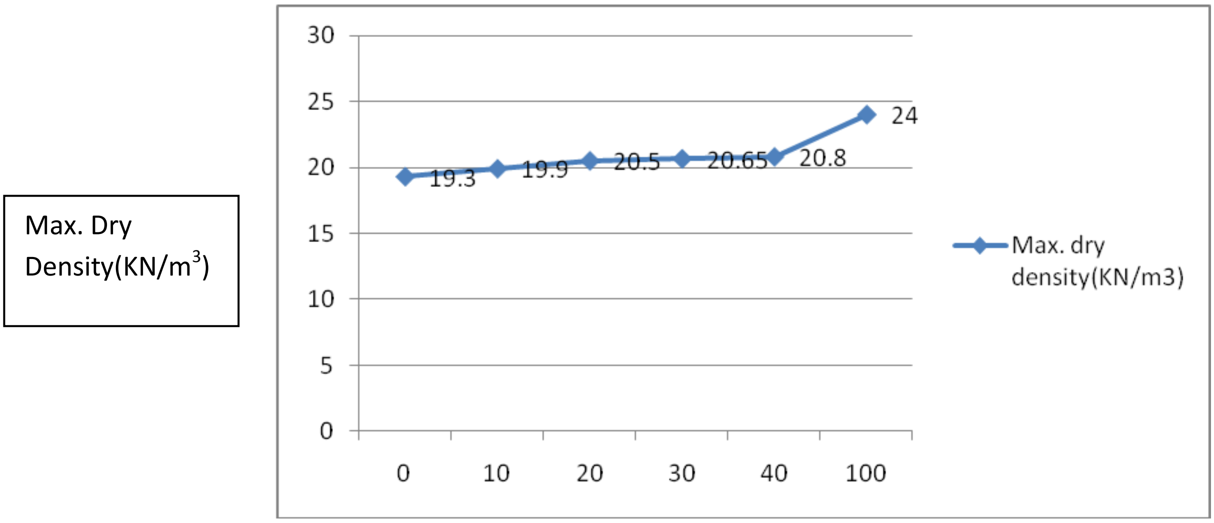
OMC (Optimum Moisture Content)



% of Steel slag in composition

Fig. 1: variation of OMC with steel slag content

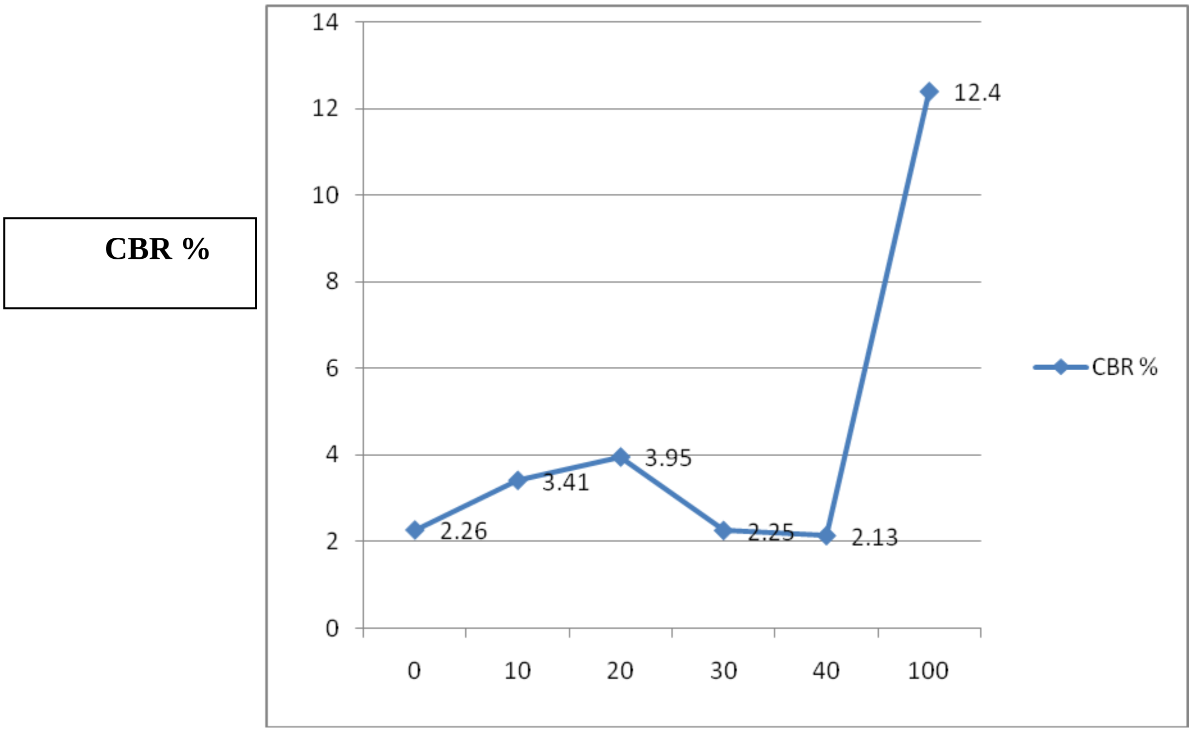
Fig. 1 shows variation of optimum moisture content with percentage of steel slag. It is observed that OMC first decreases upto 10 % steel slag content. Then it starts increasing and attains it's maximum value at 30 % steel slag content. After 30 % steel slag, it's value starts decreasing.



% of Steel slag in composition

Fig. 2: variation of MDD with steel slag content

Fig. 2 shows variation of Maximum Dry Density with percentage of steel slag. It varies from 19.3 KN/m^3 at 0 % steel slag content to 20.8 KN/m^3 at 40 % steel slag content.



% of Steel slag in composition

Fig. 3: variation of CBR values with Steel slag content

Fig. 3 shows the variation of CBR values with percentage of steel slag content in the composition. It is observed that CBR % increases upto 20 % steel slag content. Then it starts falling upto 40 % steel slag content. The variation in CBR value occurs due to variation in bonding forces between the particles. Initially the amount of steel slag improved the bonding forces and the CBR value will increase upto 20% of steel slag. After this optimum proportion, the steel slag amount becomes in excess in the mixture which causes weaker bonding between soil and slag. Furthermore, CBR value of 100% steel slag is 12.4 because of good interlocking and high specific gravity of steel slag.

V. CONCLUSIONS

For the suitability of utilizing Steel Slag with local soil in construction of sub grade layer of flexible pavement with variation of Percentage in steel slag, the following conclusions have been drawn:

1. Local soil is a material having specific gravity of 2.15 and Steel Slag having specific gravity 4.30.
2. It is found that in the Local Soil and steel slag mix, with the increase in Steel Slag content there is an increase in MDD.
3. High specific gravity (4.3) and maximum dry density (24KN/m^3) of steel slag as compared to soil is due to high amount of iron oxide present in the steel slag.
4. Steel slag is observed to be highly crushable while soil is non crushable. When generated slag is being rolled by a roller, it is observed that gravel size material gets changed to sand size material. The material is also observed to be porous as indicated by moisture absorption test (12%).
5. CBR value is highest for composition of 20 % steel slag and 80 % soil. Although CBR value for 100% steel slag is highest, it cannot be used alone because it is highly erodible. During floods, whole road layer can be washed away.
6. Utilization of steel slag in soil increases it's workability by decreasing it's plasticity.

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