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Enhancing Weak Soil Subgrade in Highways Using Steel Slag as Earth Reinforcement Material

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Abstract: *The subgrade of roads constructed on soil may undergo differential settlement. Perhaps, the need to find an alternative solution to strengthen the existing road is the need of the hour. This paper provides how to improve various engineering properties like compaction, strength and bearing capacity of subgrade with addition of steel slag to the natural soil below the bitumen paving. The technology of adding steel slag waste in soil stabilization leads to proper utilization of these waste and also solve the problem of mass disposal. In this experimental work, soil is partially replaced with steel slag at different percentages and optimum percentage of steel slag is determined from conducting tests like Specific gravity, Proctor compaction and CBR.*
Keywords: *steel slag, stabilization ,subgrade, specific gravity, CBR.*

I. Introduction

Road construction is an activity in which natural resources are utilized. Large quantities of natural materials like gravel, rock and sand are used in kilometers of newly-laid roads. At the same time, the sustainable development concept requires a more efficient management of waste materials, preservation of environment and cost. In present scenario safe disposal of different wastes produced from industries causes several problems. Several million metric tons of wastes are produced in these establishments. The utilization of these materials in road making is based on technical, economic and ecological criteria. The lack of traditional materials used for making roads in protecting the environment makes it imperative to investigate the possible and careful use of these materials.

Steel slag is becoming more attractive to reuse and recycle industrial wastes rather than disposing them off. Steel slag (Fig 1.1), a by-product obtained as a result of conversion from iron to steel, is one of the industrial waste having a large percentage still being disposed off in land fills and dumpsites. Past years, steel slag was not attractive because of the availability of large amount of blast furnace slag, which is considered more suitable for direct use as a construction material than steel slag. In 2002, 50 million metric tons of steel slag was estimated to be produced world wide and 12 million tons was estimated to be produced in Europe.

Fig 1.1Steel Slag

Currently, the world annual production of steel slag is estimated to range between 90-135 million metric tons. Approximately 15 to 40% of the 10-15 million metric tons of steel slag generated in the United States in 2006 was not utilized and a larger percentage of the 0.35-0.45 million metric tons of steel slag estimated by Akinwumi et al. to be generated annually in Nigeria is disposed-off in an environment-unfriendly manner. Use of steel slag in asphaltic concrete minimizes potential expansion and takes advantage of the positive features in giving high stability, stripping resistant asphalt mixes with excellent skid resistance. Presently, this steel slag is not utilized and is dumped on the costly land available near the plants. Study was carried out to utilize the slag in different layers of road construction. Being cohesion less material, it was mixed with local soil in the range of 5-25% and their geotechnical characteristics were evaluated. Technical specifications of slag were developed for utilization in the construction of sub grade, sub base layers of road pavement.

II. Experimental Work

2.1 TEST MATERIALS

a) Gravelly Soil

The soil used in this project was sand gravel soil collected from Vikravandi – Kumbakonam state highway(SH) at Kappiyampuliyur in Villupuram District of Tamilnadu, India. This soil was air dried and sieved with IS sieve 4.75mm as required for laboratory test.

b) Steel Slag

Steel slag used in this project was collected from Madagadipet, Pondicherry, India. It was air dried and sieved with IS 4.75mm sieve as required for laboratory test. The local soil and steel slag were mixed in various percentages to check the geotechnical properties.

2.2 PROPERTIES OF TEST MATERIAL

The physical and chemical properties of the earth reinforcement material are given in Tables 2.1 & 2.2 respectively

Table 2.1 Physical Properties of Steel Slag

S.No	Physical Properties	Result
1	Particle shape	Irregular
2	Appearance	Gray & black
3	Type	Air cooled
4	Specific gravity	3.2
5	Percentage of voids	45%
6	Bulk density	1.04 g/cc
7	Fineness modulus	2.86
9	Water absorption	0.25%
10	Moisture content	0.1%

Table 2.2Chemical Properties of Steel Slag

S.No	Chemical Properties	Result
1	Silica (SiO_2)	19
2	Magnesium oxide (MgO)	0.49
3	Calcium oxide (CaO)	0.16
4	Aluminum oxide (Al_2O_3))	13.96
5	Iron oxide (Fe_2O_3)	3.64
6	Potassium oxide (K_2O)	1.82

2.3 TEST PLAN

The details of the test conducted on earth reinforcement material are given in Table 2.3.

Table 2.3 Details of Test Plan

S.No	Category	Proportioning of Earth Reinforcement Material	Tests conducted for each Category
1.	Category – A	Soil (100%)	1.Specific gravity test conforming to IS 2720 (PART III)-1980. 2.Proctor compaction test conforming to IS 2720 (PART VII)-1983. 3. California bearing ratio test conforming to IS 2720 (PART XVI)-1987
2.	Category – B	Soil (90%) + Steel slag (10%)	
3.	Category – C	Soil (80%) + Steel slag (20%)	
4	Category – D	Soil (70%) + Steel slag (30%)	

III. Experimental Results And Discussion

This section provides the results of the tests conducted on various categories of earth reinforcement material used in road construction. The test results are given through Tables 3.1 to 3.4 and shown through Figs 3.1 to 3.7.

3.1 Specific Gravity Test

The results of specific gravity test conducted for various categories of earth reinforcement material are given in Table 3.1 and shown in Fig 3.1.

Table 3.1 Result of Specific Gravity Test

S.No	Category	Proportioning of Earth Reinforcement Material	Specific Gravity
1.	Category – A	Soil (100%)	2.38
2.	Category – B	Soil (90%) + Steel slag (10%)	2.45
3.	Category – C	Soil (80%) + Steel slag (20%)	2.62
4	Category – D	Soil (70%) + Steel slag (30%)	2.67

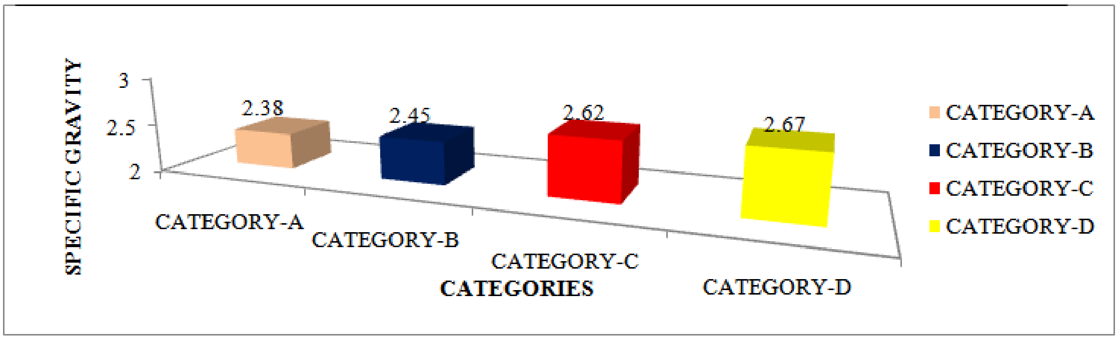

Fig 3.1Specific Gravity for different Categories

It was observed from the tests results, Table 3.1 and Fig 3.1 that the specific gravity increased with increase in percentage of steel slag. It also indicated that, the additional of steel slag reduced the porosity and voids ratio of soil.

3.2 Proctor Compaction Test

The results of proctor compaction test conducted for various categories of earth reinforcement material are given in Table3.2 and shown in Fig3.2.

Table 3.2 Result of Proctor Compaction Test for different Categories

DRY DENSITY (g/cc)					
MOISTURE CONTENT (%)	4	7	10	13	166
CATEGORY-A	2.12	2.1	1.97	1.89	1.8
CATEGORY-B	2.14	2.13	1.97	1.91	1.79
CATEGORY-C	2.13	2.61	2.05	1.92	1.81
CATEGORY-D	2.08	2.14	2.07	1.94	1.87

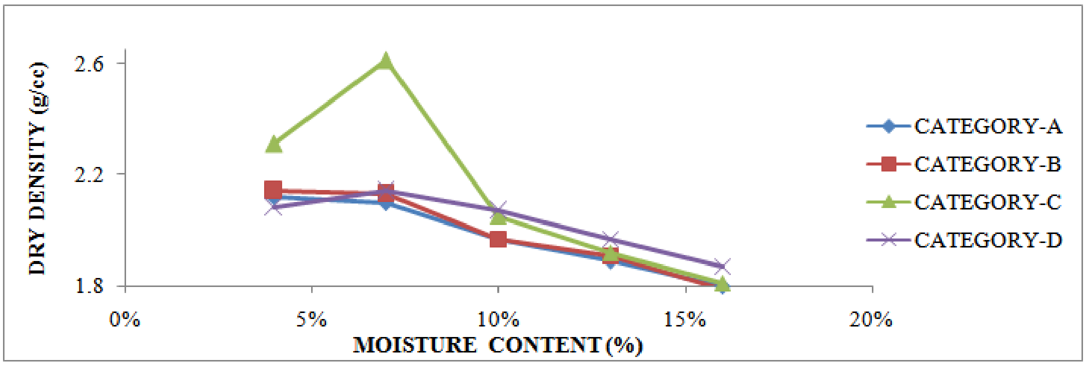

Fig 3.2 Effect on OMC & MDD for different Categories

In Category – A, the dry density gradually decreased with increase in percentage of moisture content. Hence for Category – A, the optimum moisture content and its corresponding dry density was 4% and 2.12 g/cc respectively.
In Category – B, the dry density gradually decreased with increase in percentage of moisture content. Hence for Category – B, the optimum moisture content and its corresponding dry density was 4% and 2.14 g/cc respectively.
In Category – C, the dry density increased from 2.13 to 2.61 g/cc for a moisture content upto 7% and then decreased with increase in percentage of moisture content. Hence for Category – C, the optimum moisture content and its corresponding dry density was 7% and 2.61 g/cc respectively.
In Category – D, the dry density increased from 2.08 to 2.14 g/cc for a moisture content upto 7% and then decreased with increase in percentage of moisture content. Hence for Category – D, the optimum moisture content and its corresponding dry density was 7% and 2.14 g/cc respectively.

Table 3.3 Result of Dry Density for different Categories

Categories	Category-A	Category-B	Category-C	Category-D
OMC (%)	4	4	7	7
Dry density (g/cc)	2.12	2.14	2.61	2.14

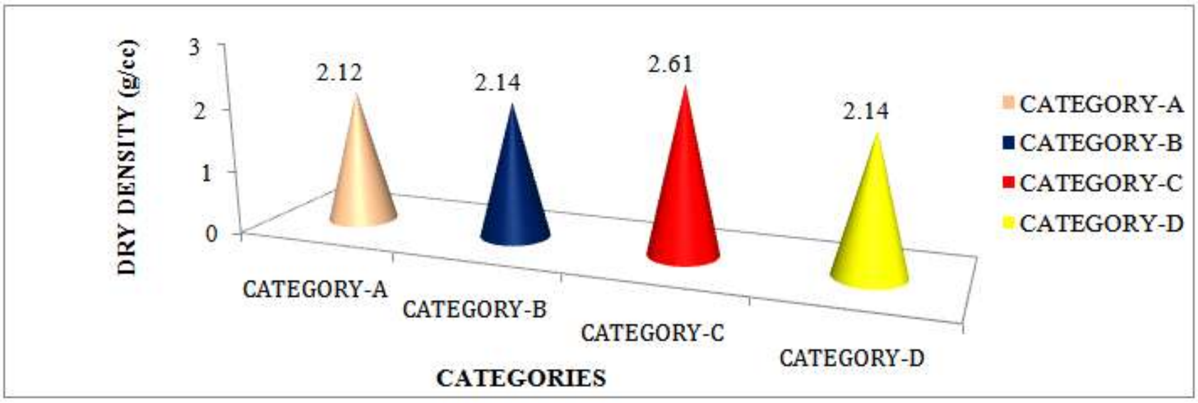

Fig 3.3 Dry Density for different Categories

It was observed from the test results, Table 3.3 and Fig 3.3 that the dry density increased, with increase in percentage of steel slag upto 20%. Hence it can be inferred from test results that the addition of steel slag with natural soil will have significant impact on dry density and strength of soil subgrade.

3.3 California Bearing Ratio (CBR) Test

To determine the CBR value of different categories of earth reinforcement material, the optimum moisture content values are extracted from Fig 3.2. The results of CBR tests including bearing capacity conducted for different categories of earth reinforcement materials are given in Table 3.4 and shown in Fig 3.4.

Table 3.4 Results of CBR and Bearing Capacity

S.No	**Category**	**Bearing Capacity (kN/m^2)**	**CBR Value (%)**
1	Category-A	134.4	6.54
2	Category-B	217.6	10.35
3	Category-C	305.2	15.02
4	Category-D	320.5	16.23

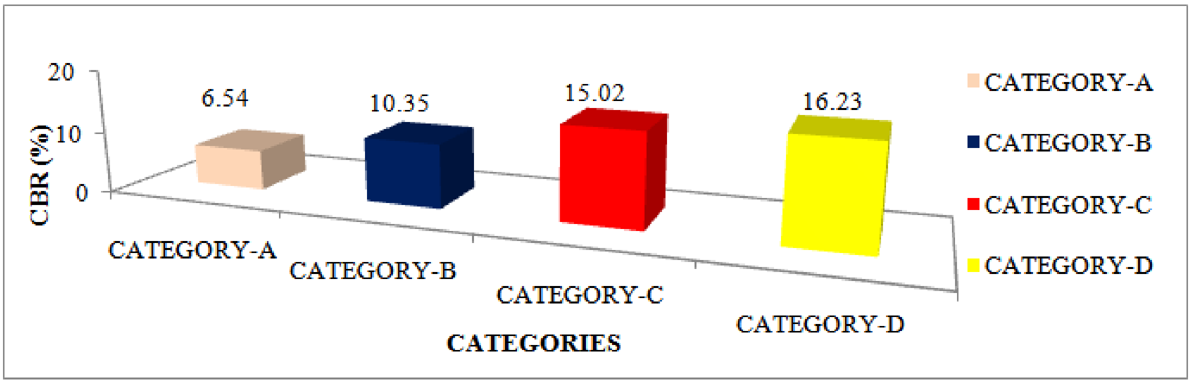

Fig 3.4 CBR for different Categories

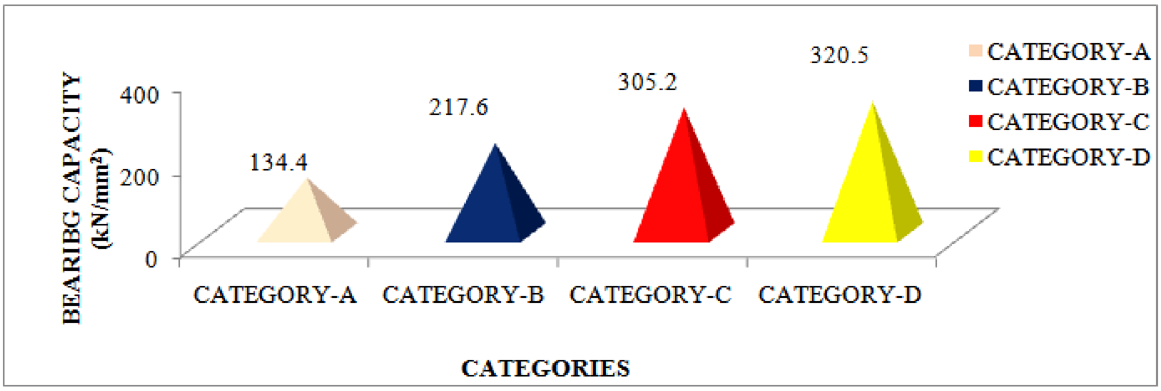

Fig 3.5 Bearing Capacity for different Categories

The percentage variation in CBR for different categories of earth reinforcement material with respect to Category-A is shown in Fig 3.6. It was inferred from the test results that the CBR of Category-B ,Category-C and Category-D increased to 58.25%, 129.66% and 148.16% respectively, when compared to natural soil Category-A.

The percentage variation in bearing capacity for different categories of earth reinforcement material with respect to Category-A is shown in Fig 3.7. It was inferred from the test results that the bearing capacity of Category-B, Category-C and Category-D increased to 61.90%, 127.08% and 138.46% respectively, when compared to natural soil Category-A.

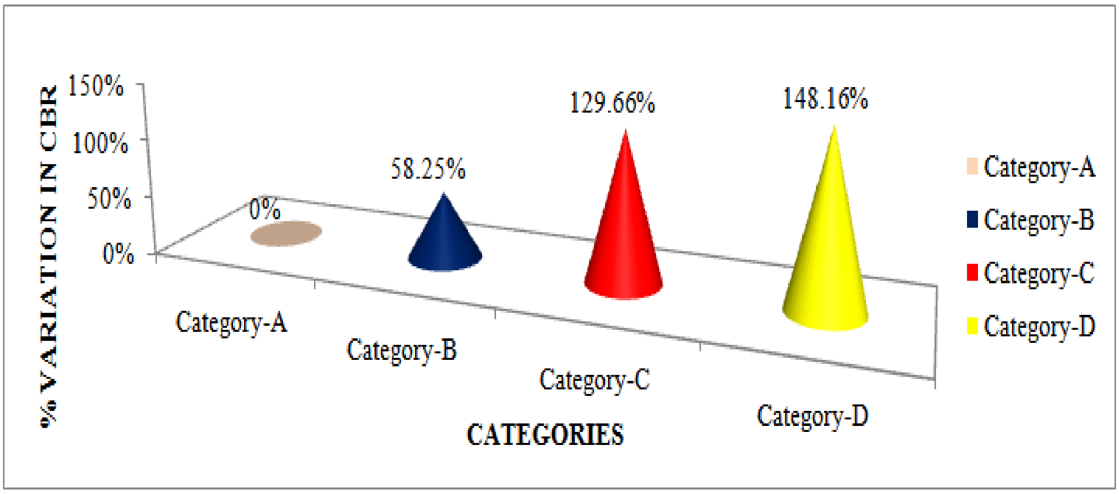

Fig 3.6 Percentage variation in CBR for different Categories compared to Category-A

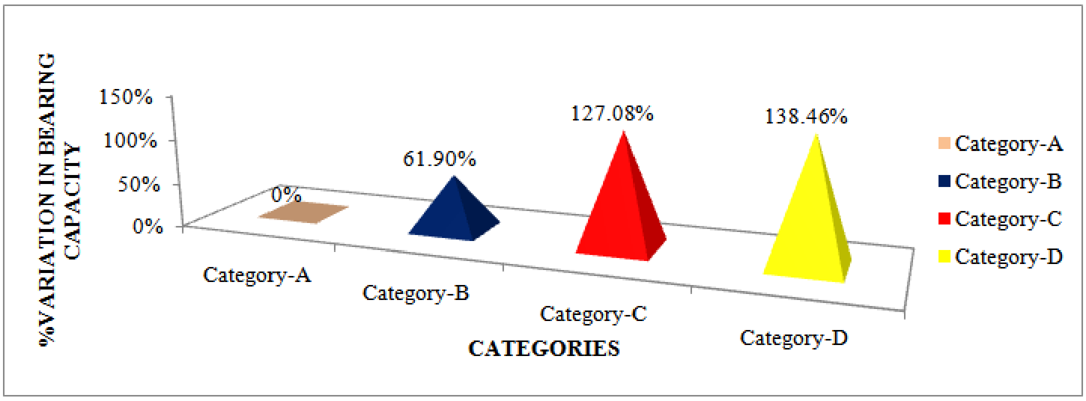

Fig 3.7 Percentage variation in Bearing Capacity for different Categories compared to Category-A

IV. Conclusions

The replacement of industrial waste materials as earth reinforcement in road construction by the combination of soil and steel slag resulted in higher strength when compared to the natural soil. From the experimental investigation, the following conclusions are drawn.

- The CBR of Category-B earth reinforcement material was 58.25% higher than Category-A. The bearing capacity of Category-B earth reinforcement material was 61.90 % higher than Category-A.
- The CBR of Category-C earth reinforcement material was129.66 % higher than Category-A. The bearing capacity of Category-C earth reinforcement material was 127.08 % higher than Category-A.
- The CBR of Category-D earth reinforcement material was148.16% higher than Category-A. The bearing capacity of Category-Dearth reinforcement material was 138.46 % higher than Category-A.

From the over all analysis of the test results conducted, it was observed that the optimum percentage of steel slag required based on dry density to enhance the subgrade of weak soil was 20% (Category-C).

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