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Strengthening Of Poor Soil Subgrade in Highways Using Copper Slag as Stabilization Material

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

Keywords: *copper 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 cause 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.

Fig 1.1 Copper Slag

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. Traditionally soil, stone aggregate, sand and others are used for road laying. Natural materials being exhaustible in nature, its quantity is declining gradually. In addition, cost of extracting good quality of natural material is increasing. If these materials can be suitably utilized in highway development as stabilization material in subgrade, the pollution and disposal problem is partly reduced. In the absence of other outlets, these solids waste have occupied several acres of cultivable lands throughout the country. Considering these aspects, the need for bulk use of solid waste in India, it was thought convenient to test this material, develop specifications and enhance the use in road making to obtain high rate of returns. Material such as copper slag from copper extracting industry, steel slag from steel extracting company, fly ash and other solid waste have already provided to be useful for road laying in many other countries. California Bearing Ratio (CBR) tests are conducted to check the effect of adding waste materials in determining the strength and performance of the soil and the results are compared with that of test results made with natural soil.

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) Copper Slag

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

2.2 PROPERTIES OF TEST MATERIAL

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

Table 2.1 Physical Properties of Copper Slag

S.No	Physical Properties	Result
1	Particle shape	Irregular
2	Appearance	Black & glossy
3	Type	Air cooled
4	Specific gravity	2.99
5	Percentage of voids	45%
6	Bulk density	2.08 g/cc
7	Fineness modulus	3.86
8	Angle of internal friction	$51^{o}20'$
9	Water absorption	0.4%
10	Moisture content	0.1%

Table 2.2 Chemical Properties of Copper Slag

S.No	Chemical Properties	Result
1	Silica(SiO_2)	71.52
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
7	Sodium Oxide(Na_2O)	4.12
8	Titanium Oxide(TiO_2)	0.013
9	Copper Oxide(CuO)	0.32
10	Manganese Oxide (Mn_2O_2)	0.072

2.3 TEST PLAN

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

Table 2.3 Details of Test Plan

S.No	Category	Proportioning of Stabilization 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 (80%) + Copper slag (20%)	
3.	Category – C	Soil (60%) + Copper slag (40%)	
4	Category – D	Soil (40%) + Copper slag (60%)	
5.	Category – E	Soil (20%) + Copper slag (80%)	

III. Experimental Results And Discussion

This section provides the results of the tests conducted on various categories of stabilization 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 stabilization material are given in Table 3.1 and shown in Fig 3.1.

Table 3.1 Results of Specific Gravity Test

S.No	Category	Proportioning of Stabilization Material	Specific Gravity
1.	Category – A	Soil (100%)	2.38
2.	Category – B	Soil (80%) + Copper slag (20%)	2.70
3.	Category – C	Soil (60%) + Copper slag (40%)	2.84
4	Category – D	Soil (40%) + Copper slag (60%)	2.90
5.	Category – E	Soil (20%) + Copper slag (80%)	3.31

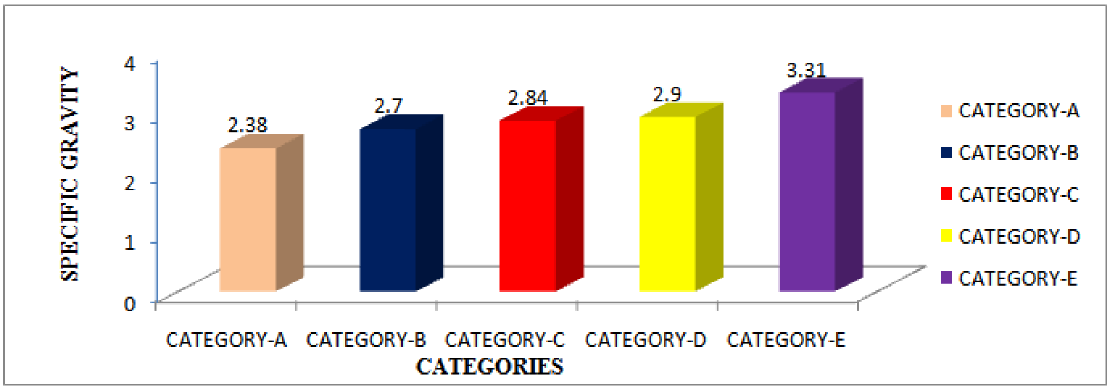

Fig 3.1Specific Gravity for different Categories

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

3.3 Proctor Compaction Test

The results of proctor compaction test conducted for various categories of stabilization material are given in Table 3.2 and shown in Fig 3.2.

Table 3.2 Result of Proctor Compaction Test for Category

DRY DENSITY (g/cc)					
MOISTURE CONTENT(%)	4	7	10	13	16
CATEGORY-A	2.12	2.1	1.97	1.89	1.8
CATEGORY-B	2.24	2.29	2.14	2.01	1.9
CATEGORY-C	2.3	2.34	2.28	2.12	2.02
CATEGORY-D	2.37	2.4	2.40	2.3	2.15
CATEGORY-E	2.37	2.38	2.39	2.29	2.21

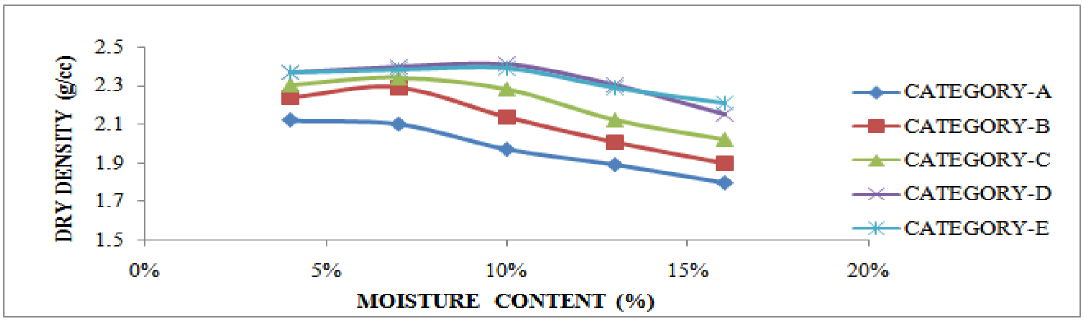

Fig 3.2 Effect on OMC & MDD for different Categories

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 increased from 2.24 to 2.29 g/cc for a moisture content upto 7% and then decreased with increase in percentage of moisture content. Hence for Category – B, the optimum moisture content and its corresponding dry density was 7% and 2.29 g/cc respectively.
In Category – C, the dry density increased from 2.30 to 2.34 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 8% and 2.34 g/cc respectively.
In Category – D, the dry density increased from 2.37 to 2.4 g/cc for a moisture content upto 9% and then decreased with increase in percentage of moisture content. Hence for Category – D, the optimum moisture content and its corresponding dry density was 9% and 2.4 g/cc respectively.
In Category – E, the dry density increased from 2.39 to 2.39 g/cc for a moisture content upto 10% and then decreased with increase in percentage of moisture content. Hence for Category – E, the optimum moisture content and its corresponding dry density was 10% and 2.39 g/cc respectively.

Table 3.3 Result of Maximum Dry Density for different Categories

Category	Category-A	Category-B	Category-C	Category-D	Category-E
OMC (%)	4	7	7	9	10
Dry density (g/cc)	2.12	2.29	2.34	2.40	2.39

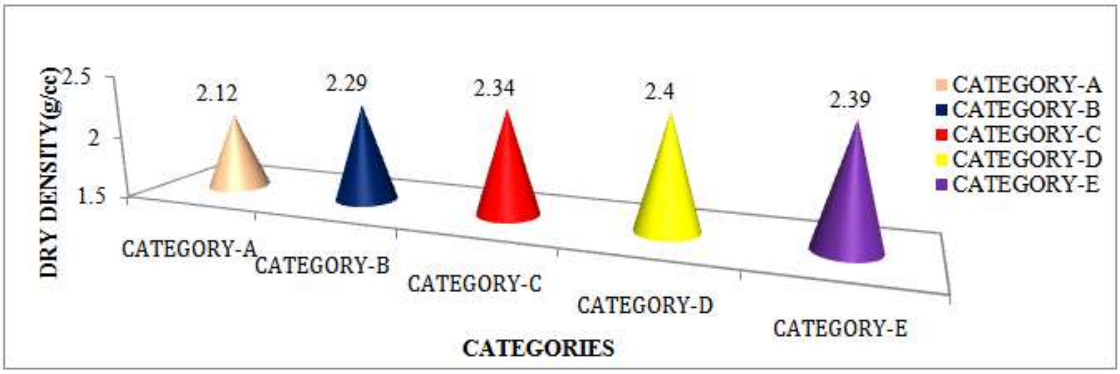

Fig 3.3Maximum Dry Density for different Categories

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

3.4 California Bearing Ratio (CBR) Test

The results of CBR including bearing capacity for different categories of stabilization materials are given in Table 3.4 and shown in Figs 3.4. and 3.5.

Table 3.4 Results of CBR Test and Bearing Capacity for different Categories

S.No	**Category**	**Bearing Capacity (kN/m^2)**	**CBR Value (%)**
1	Category-A	134.4	6.54
2	Category-B	257.6	12.53
3	Category-C	290.7	14.14
4	Category-D	392.0	19.07
5	Category-E	352.8	17.16

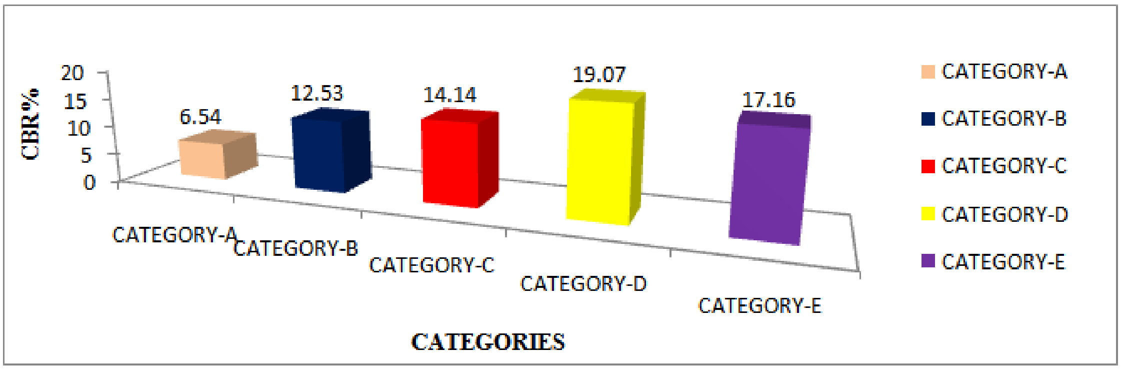

Fig 3.4 CBR for different Categories

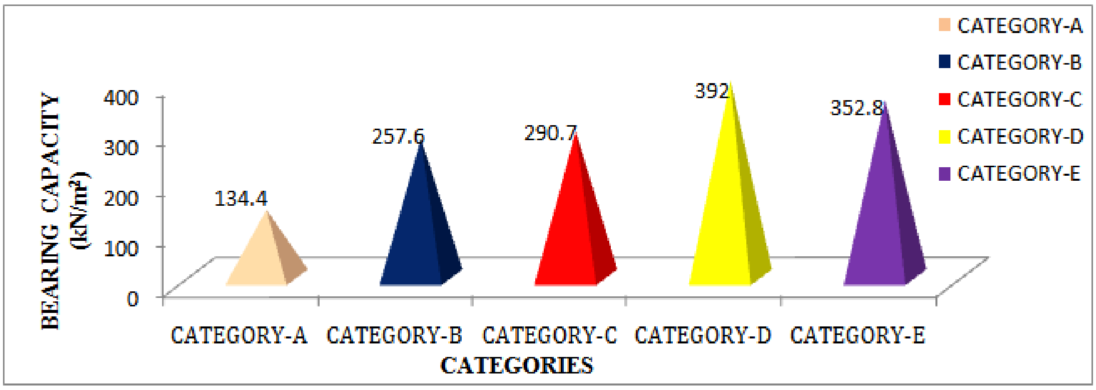

Fig 3.5Bearing Capacity for different Categories

The percentage variation in CBR for different categories of stabilization 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, Category-D and Category-E increased to 91.59%, 116.20%, 191.59% and 162.38% respectively, when compared to natural soil Category-A.

The percentage variation in bearing capacity for different categories of stabilization 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, Category-D and Category-E increased to 105.05%, 116.29%, 191.66% and 162.5% respectively, when compared to natural soil Category-A.

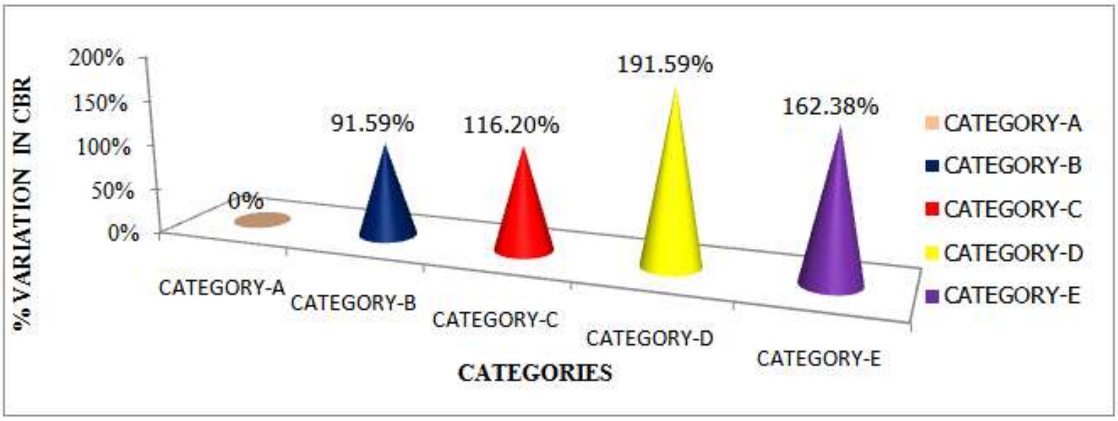

Fig 3.6 Percentage variation in CBR for different Categories compared to Category-A

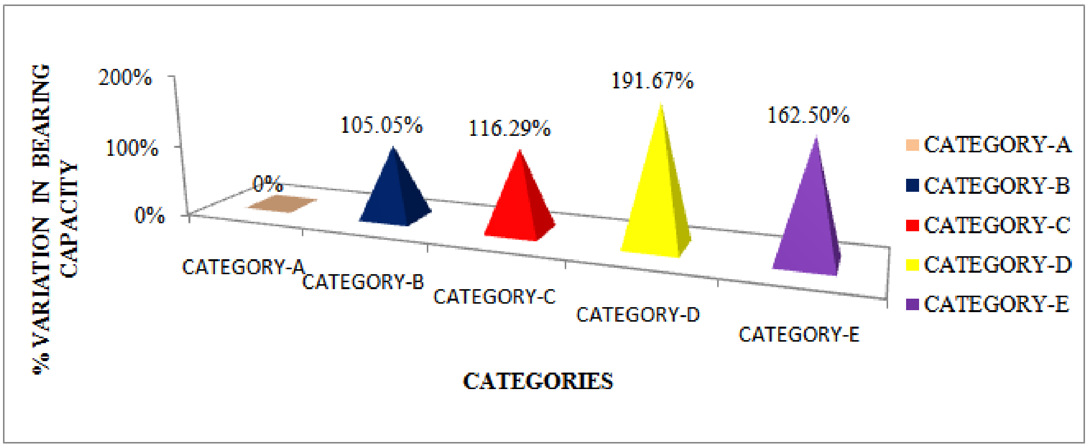

Fig 3.7 Percentage variation in Bearing Capacity for different Categories compared to Category-A

IV. Conclusions

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

- The CBR of Category-B stabilization material was 91.59% higher than Category-A. The bearing capacity of Category-B stabilization material was 105.05 % higher than Category-A.
- The CBR of Category-C stabilization material was116.20% higher than Category-A. The bearing capacity of Category-C stabilization material was 116.29 % higher than Category-A.
- The CBR of Category-D stabilization material was191.59% higher than Category-A. The bearing capacity of Category-D stabilization material was 191.67 % higher than Category-A.
- The CBR of Category-E stabilization material was162.38% higher than Category-A. The bearing capacity of Category-E stabilization material was 162.50 % higher than Category-A.

From the over all analysis of the test results, it was observed that the optimum percentage of copper slag required to strengthen the poor subgrade of soil was 60%(Category-D).

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