Effects of Steel Slag on Soil used in Subgrade Construction.

Mr. Sushil V. Kale[1], Prof. A. R. Bijwe[2,] Prof. Sneha M. Jadhal[3] Dr. B. S. Shete[4],
[1] *M.E Student, Dr. Rajendra Gode Institute of Technology and Research, Amravati (MS), India.*
[2,3]*Professor, Dr. Rajendra Gode Institute of Technology and Research, Amravati (MS), India*
[4]*Professor, Takshashila Institute of Engineering and Technology, Darapur (MS), India.*

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ABSTRACT

The life of the road mainly depends upon the type of material used during construction. It is being well known that, Roads are built up in several layers, consisting of sub-grade, sub-base, base and surface layer. The pavement can be constructed from a wide variety of materials and mixtures of materials consisting of gravel, stone, bitumen, concrete or improved soils. The selection of materials and thickness of the pavement layers are determined by the expected traffic density. The construction of Sub grade layer with suitable material plays an important role in road construction. Depending upon the easily availability of good quality material in permissible leads, the subgrade layer is constructed with suitable soil available in nearby area. In absence of availability of suitable material in nearby area, it becomes difficult to maintain the quality of work and consequences to failure the road. Under such situations, the bearing capacity of available soil to sustain the permissible load can be improved by adding the Steel Slag. The steel slag shows good technical and ecological properties, thus being used forthe road construction.

***Keyword** – Sub grade, Steel slag, Standard Proctor test, California bearing ratio, Road pavement.*

1. INTRODUCTION:

Roads are built up in several layers, consisting of sub-grade, sub-base, base and surface layer. These layers together constitute the pavement. Pavements made from good quality construction materials spread the forces caused by the traffic so that the loads exerted on to the road foundation is protected from overloading and deformation. The pavement can be constructed from a wide variety of materials and mixtures of materials consisting of gravel, stone, bitumen, concrete or improved soils. The choice of materials and thickness of the pavement layers are determined by the expected traffic density.
Subgrade soil is an integral part of the road pavement structure as it provides the pavement from beneath. The subgrade soil and its properties are important in the design of pavement structure. The main function of subgrade is to adequate support to the pavement and for this the subgrade should possess sufficient stability under adverse climate and loading conditions. The formation of waves, corrugations, rutting and shoving in blacked topped pavements and the phenomena of pumping, blowing and consequent cracking of cement concrete pavements are generally attributed due to poor subgrade condition.

2.OBJECTIVES:

2.1 To study the utilization of steel slag in road construction as sub-grade material along with black cotton soil.
2.2 To study the effect of addition of steel slag on bearing capacity of soil and its variation according to percentage of steel slag.
2.3 To check if the steel slag replaces natural materials, thereby resulting in protection of natural, non-renewable resources and a reduction in energy requirements.
2.4 To reduce environmental pollution due to changes in current practice.

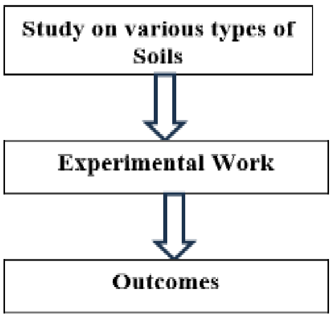
3. LITERATURE REVIEW:

3.1. In the study done by Karthik S. in the publication for IOSR journal of Mechanical and Civil engineering in the year 2014, The objective of this study was to evaluate the effect of Fly Ash derived from combustion of sub-bituminous coal at electric power plants in stabilization of soft fine-grained red soils. California bearing ratio (CBR) and other strength property tests were conducted on soil. Soil stabilization is widely used in connection with road, pavement and foundation construction. It improves the engineering properties of the soil, e.g: Strength - to increase the strength and bearing capacity, Volume stability - to control the swell-shrink characteristics caused by moisture changes, durability - to increase the resistance to erosion, weathering or traffic loading. To reduce the pavement thickness as well as cost.
Based on the data accumulated from above research following conclusions have been made.
The borrowed red soil has bearing capacity of 10 kg/mm^2.
The stabilized red soil with 6 percentage of Fly Ash achieves bearing capacity of 35kg/mm^2

The CBR value of borrowed red soil is 3.1. From design curve in „A" type traffic, pavement thickness for Corre flying soil is 12 inches.
CBR value of stabilized soil is 4.82. Pavement thickness Corre flying to this value is 8.5inches.
3.2 In the study done by Oormila T. R. and T. V. Preethi in the publication for effect of stabilization using fly ash and GGBS in soil characteristics in the year 2014. Utilization of industrial waste materials in the improvement of soils is a cost efficient and environment friendly method. Stabilization of the soil is studied by using fly ash and ground granulated blast furnace slag. This paper includes the evaluation of soil properties like unconfined compressive strength test and California bearing ratio test. The soil sample was collected from Palur, Tamil Nadu and addition to that, different percentages of fly ash (5, 10%, 15% and 20%) and GGBS (15%, 20%, 25%) was added to find the variation in its original strength. Based on these results CBR test was performed with the optimum fly ash, optimum GGBS and combination of optimum fly ash with varying GGBS percentages (15%, 20%, and 25%). From these results, it was found that optimum GGBS (20%) gives the maximum increment in the CBR value compared with all the other combinations.
From the result of this study, the following conclusions can be made.
The CBR test was performed with optimum fly ash (10%), optimum GGBS (20%) and also for combination of optimum fly ash with varing GGBS percentage (15%, 20%, 25%) and it was found that, among the combination of optimum fly ash with varing GGBS percentage (15%, 20%, 25%), 10% fly ash with 25% of GGBS gives an increment of 78.29% in the CBR value with curing period of 10 days when with the CBR value of the virgin soil.

4. METHODOLOGY:

Flow Chart



The scope of work for this research is to develop the subgrade compatible by using a combination of steel slag and black cotton soil for subgrade. We have taken the different samples of different proportions of steel slag and black cotton soil in different proportions as given below.

4.1 Sample Proportions

Table -1 – Sample proportion for testing

Sr. No.	Description
Sample 1	0% steel slag & 100% black cotton soil
Sample 2	10% steel slag & 90% black cotton soil
Sample 3	20% steel slag & 80% black cotton soil
Sample 4	30% steel slag & 70% black cotton soil
Sample 5	40% steel slag & 60% black cotton soil
Sample 6	50% steel slag & 50% black cotton soil

4.2 Materials:
The material used is natural soil and steel slag.

4.3 Subgrade soil:
For the determination of properties of soil samples, tests have been conducted on the different samples of different proportions of steel slag and black cotton soil.

4.5.1 Liquid limit and plastic limit.
The apparatus to determine liquid limit of soil are Casagrande's liquid limit device, grooving tools Casagrande type, evaporating dish, spatula, 425-micron sieve etc. Gauge block, balance, oven sample containers, and distilled water.
Plastic limit is defined in general term as the minimum moisture content at which soil remains in plastic state.

4.5.2 Specific gravity of subgrade soil:

The specific gravity of solid particles (G) is defined as the ratio of the mass of given volume of solids to the mass of equal volume of distilled water. Both weights are taken in air.

4.5.3 Fineness test on Steel Slag.

Grain-size distribution is one of the most important characteristics of granular materials that affect their mechanical properties. As steel slag is generated as a by- product of the steelmaking process, its generation cannot be controlled precisely. Moltenslag solidifies in the slag pits and, subsequently, breaks down into smaller size particles during the cooling process. During this natural particle break down process, steel slag particles of varying dimensions - from as large as boulder size to as small as silt-size aregenerated.

4.5.4 Standard Proctor test for obtained Maximum dry density and optimummoisture content.

To obtain the relation between moisture content and dry density of soil using lightcompaction and hence to find out the value of maximum dry density (M.D.D.) and optimum moisture content (O.M.C.)**.** Compaction is the process by which soil particles are artificially rearranged and packed together in to a closer state of contact by mechanical process in order to decrease the porosity of the soil and thus cause increase inits dry density.

Bulk density = ρb= M/V

Dry density = ρd= ρb/ (1+w) Where, M = mass of soil,

V = volume of mould

w = water content

4.5.5 California Bearing Ratio test (CBR)

The C.B.R. values are calculated using the relation:

$$C.B.R = \frac{Load\ sustained\ by\ the\ specimen\ at\ 2.5\ or\ 5.00mm\ penetration}{Load\ sustained\ by\ standard\ aggregates\ at\ the\ corresponding\ penetration\ level} \text{x100}$$

Normally the CBR value at 2.5 mm penetration which is higher than that at 5.00 mm is reported as the CBR value of the material. However, if the CBR value obtained from the test at 5.0 mm penetration is higher than that at 2.5 mm, then the test is to be repeated for checking. If the check test again gives similar results, the higher value obtained at 5.0 mm penetration is reported as the CBR value.

4.6 STEEL SLAG:

Table -2 Engineering properties of steel slag

Engineering properties of steel slag	Values
Specific Gravity gm/cc	3.1-3.6
Angle of Internal Friction	40° - 50°
Los Angeles Abrasion	20 – 25 %
Maximum Dry Unit Weight (kN/m3)	15.7-18.9
Porosity (%)	up to 3
Water Absorption (%)	0.2-2

5. RESULT AND DISCUSSION:

The scope of work for this research is to develop the subgrade compatible or out performing existing conventional subgrade, using a combination of % steel slag and % black cotton soil for subgrade. We have taken the different samples of different proportions of steel slag and black cotton soil.

5.1 Consistency Limit:

Consistency limit determined by using IS code and result obtained as follows

Table -3 Observation table liquid limit.

Sr. No.	Determination Number	1	2	3
1	Number of blows	39	29	27
2	Container No.	1	2	3
3	Mass of container (g) M1	25.15	25.00	25.10
4	Mass of container + wet soil (g) M2	36.93	39.23	41.36
5	Mass of container + Dry soil (g) M3	33.81	35.35	36.29
6	Mass of water (g) M2- M3	3.12	3.88	5.07
7	Mass of oven dry soil (g) M3- M1	8.66	10.35	11.19
8	Water content	36.02	37.48	45.30

Liquid limit = 39.60

5.2 Plastic limit:

Table - 4 Observation table plastic limit

Sr. No.	Determination Number	1	2	3
1	Container No	1	2	3
2	Mass of container (g) M1	24.12	23.50	24.24
3	Mass of container + wet soil (g) M2	30.28	30.10	31.06
4	Mass of container + Dry soil (g) M3	29.12	29.06	30.20
5	Mass of water (g) M2- M3	1.16	1.04	0.84
6	Mass of oven dry soil (g) M3- M1	5.00	5.46	5.96
7	Water content	23.2	19.04	14.09

Plastic limit =18.78

5.3 Specific gravity of subgrade soil:

The specific gravity of solid particles (G) is defined as the ratio of the mass of given volume of solids to the mass of equal volume of distilled water. Both weights are taken in air.

Table - 5 Observation table specific gravity of subgrade soil

Sr. No.	Particulars	SAMPLE – 1 (gm)
1	Pycnometer No.	1
2	Mass of empty pycnometer (M1) gm	485
3	Mass of pycnometer + soil (M2) gm	910
4	Mass of pycnometer + soil + distilled water (M3) gm	1540
5	Mass of Pycnometer + distilled water (M4) gm	1325
6	Specific Gravity	2.023

Specific gravity G = 2.023

5.4 Specific gravity of steel slag:

Table - 6 Observation table specific gravity of steel slag

Sr. No.	Particulars	SAMPLE – 1
1	Pycnometer No.	1
2	Mass of empty pycnometer (M1) gm	485
3	Mass of pycnometer + soil (M2) gm	1065
4	Mass of pycnometer + soil + distilled water (M3) gm	1740
5	Mass of Pycnometer + distilled water (M4) gm	1325
6	Specific Gravity	3.51

Specific gravity of steel slag G =3.51

5.5 MDD, OMC and CBR Values:

Table-7 Observation table MDD, OMC, CBR

Sr. No.	Description	MDD	OMC	CBR@5 cm	CBR@10 cm
Sample 1	0% steel slag & 100% black cotton soil	1.71	16.51	1.75	1.69
Sample 2	10% steel slag & 90% black cotton soil	1.86	11.05	2.17	2.07
Sample 3	20% steel slag & 80% black cotton soil	1.89	18.00	2.35	2.29
Sample 4	30% steel slag & 70% black cotton soil	2.13	18.67	3.56	3.43
Sample 5	40% steel slag & 60% black cotton soil	2.24	13.02	4.71	4.66
Sample 6	50% steel slag & 50% black cotton soil	2.30	11.35	5.91	5.85

5.6 Effect of steel slag addition on California bearing ratio for subgrade soil.

The main aim of the project is to study the utilization of steel slag in road construction as sub-grade material along with black cotton soil. Different tests on soil were performed like specific gravity, liquid limit, plastic limit, proctor test, CBR test. Tests performed on steel slag were specific gravity, fineness test. Test performed on soil and Steel slag with different percentage were proctor test and CBR test. The combinations of steel slag soil were 0% - 100%, 10% - 90%, 20 % - 80%, 30 % - 70%, 40% - 60 % and 50 % - 50 %.

It can be seen from the test results that as we increase the percentage of steel slag in the soil, the CBR ratio is increasing. That means as we increase percentage of steel slag in soil, the bearing capacity of soil goes on increasing. Moreover, the graph plotted % of steel slags to CBR %also shows that the bearing capacity goes on increasing.

Fig. - 1 Effect of steel slag addition on California bearing ratio for subgrade soil

6. CONCLUSIONS:

It is observed from the tests carried out and the reports studied that the steel slag can be effectively used for increasing the bearing capacity of soil. It is effective method that can be adopted for construction of road pavement in a area having low bearing capacity like black cotton soilregion, marshy land etc. Also, by using this method effective use of waste product can be achieved.

From the results of this study following conclusions can be made.

1. Steel slag can be mixed with natural soil to enhance the strength effectively.
2. The maximum dry density of soil increases with increase in steel slag content which can be used for road pavement as per the required design CBR.
3. The cost of project increases as we increase the percentage of steel slag in soil as compared to other methods of soil stabilization.
4. By utilizing the industrial waste product i.e. steel slag, wastage of good cultivable land can be avoided where large quantity accumulated slag is dumped.

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