Hydraulic conductivity and strength analysis of granular sub-base using steel slag

Ravindra Dashrath Dharankar
M.Tech Transportation Engineering. & Planning, School of Engineering & Technology, Sandip university, Nashik
Abhishek Loya
Assistant Professor, Civil engineering department, Sandip University, Nashik

Abstract

Granular sub base is layer lies immediately below the base layer and above the subgrade. Granular sub base (GSB) is the provide drainage and stability to achieve longer life of pavement. For the GSB layer both strength as well as permeability is major criteria of performance.

MORT&H current guidelines suggest using natural sand, crushed gravel/stone or slag or their combinations for GSB layer. Due to the scarcity of natural aggregate, present trends is to use the industrials waste in the road construction. Using of iron and steel slag is now a day becomes popular due as low-cost material compared to the natural aggregate.

Steel slag in solidifies form also known as Electric arc furnace (EAF).Electric arc furnace slag, which is one of the form of steel slag, is produced during the manufacture of crude steel by the electric arc furnace (EAF) process. Steel Slag in solidified form also fulfilling the criteria of the GSB layer as suggest by MORT&H.

For current study, an attempt is made to use the steel slag in crystalline form in the GSB layer with the combination recommended by MORT&H. This slag is obtained from the ESSAR steel plant, Hazira is used for the study purpose. EAF slag is available in both coarse and fine form. In this study, an attempt is made to find out that how much percentage of natural aggregate can be replaced by EAF slag without affecting the basic criteria required to fulfill the requirements of GSB layer. For the study constant head hydraulic conductivity and CBR test along with modified proctor test are conducted to check the strength as well as drainability criteria of GSB. The durability of EAF slag is checked using soundness test. The results are showing that 30%-50% natural aggregate can be replaced by EAF slag with improved value of all parameters.

Keywords: Granular sub-base, electric arc furnace slag, hydraulic conductivity, CBR test, durability test, soundness test.

Objective

1. To determine the hydraulic conductivity of different gradation used for GSB layer.
2. To compare the Hydraulic conductivity characteristics of GSB gradations prepared with a different combination of steel slag (electric arc furnace) in order to assess their ability to drain, which is based on the Hydraulic conductivity criteria.
3. To investigate California bearing ratio to check strength characteristic for the same mix.
4. To check the weathering action on sub-base layer after using slag material based on soundness criteria.
5. To figure out the economic analysis for using the steel slag as a secondary material for the sub-base layer.

Scope of work

Due to less availability of natural aggregate and hazardness of industrial waste for the environment, use of slag in road construction gets the popularity.

Scope of work are as follows:-

1. The iron and steel slag that is generated as a byproduct of iron and steel manufacturing processes but Presently, this electric arc furnace slag is not utilized and is dumped on the costly land available near the plants
2. India has series of steel plant clusters located along its length and breadth of the territory. Essar Steel is one of India's leading integrated steel producers with an annual production capability of 10 million tons annually. Along with the production of steel, waste material like steel slag (EAF) is also producing which is nearly 517100 ton annual.

Methodology:

Step 1: Selection of gradation for the testing

Table 1Gradation of granular sub-base as per MORT&H, 5th Revision

IS Sieve Percent by Weight Passing the IS Sieve	Grading III	Grading IV	Grading V	Grading VI
75.00mm	-	-	100	-
53.00mm	100	100	80-100	100
26.5 mm	55-75	50-80	55-90	75-100
9.50 mm	-	-	35-65	55-75
4.75 mm	10-30	15-35	25-50	30-55
2.36 mm	-	-	10-20	10-25
.85 mm	-	-	2-10	-
.425 mm	-	-	0-5	0-8
.075 mm	<5	<5	-	0-3

Step 2: Selection of material

Table 2 Physical Requirements for Materials for Granular Sub-base as per MORT&H

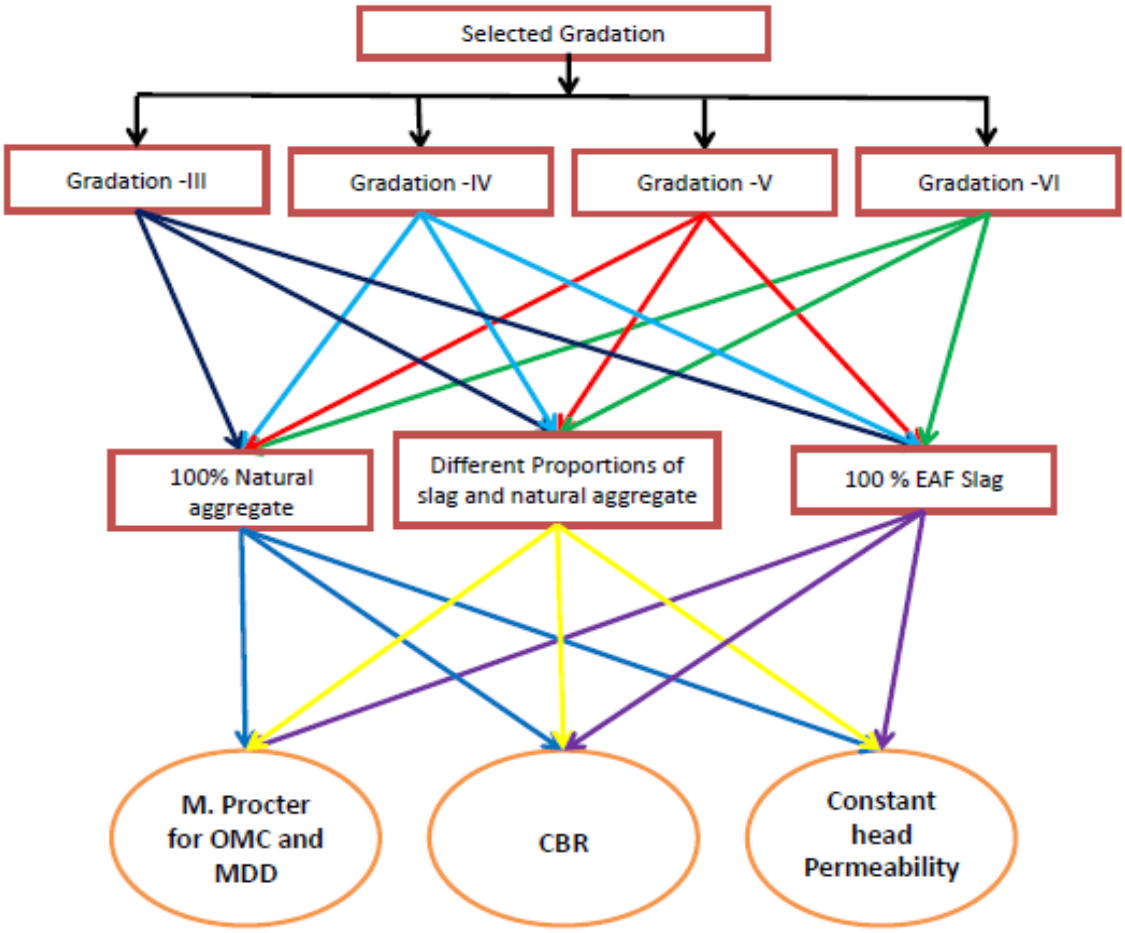
Aggregate Impact Value (AIV)	IS:2386 (Part 4) or IS:5640	40 maximum
Plasticity Index	IS:2720 (Part 5)	Maximum 6
CBR at 98% dry density	IS:2720 (Part 5)	Minimum 30 unless specified in the Contract

Step 3: testing of different mix gradation of material

Step 4: find out the different parameter under given limit

Step 5: validation of relations and result

Step 6: conclusion and final report preparation



Experimental work:

Table 3 Physical properties test and specifications

Property of Aggregate	Type of Test	Test Method
Crushing strength	Crushing test	IS : 2386 (part 4)
Toughness	Aggregate impact test	IS : 2386 (Part 4)
Durability	Soundness test	IS : 2386 (Part 5)
Specific gravity and porosity	Specific gravity test and water absorption test	IS : 2386 (Part 3)
Optimum moisture content and maximum dry density	Modified proctor test	IS : 2720 (Part 8)
Strength test	California bearing ratio test	IS : 2720 (Part 16)
Permeability test	Constant head Permeability test	IS : 2720 (Part 17) & ASTM D-2434-68

Results and discussion:

Table 4 Result of physical properties of natural aggregate and EAF slag

Properties	Natural aggregate	Electric arc furnace(EAF) slag	Requirement as per MORT&H 5th revision
Aggregate Impact value(AIV)	7.91	16.13	Maximum 40
Aggregate Crushing value(ACV)	18.37	28.34	Maximum 45
Liquid Limit and Plastic Limit	Non-plastic	Non-plastic	LL Maximum 25 PI Maximum 6
Specific Gravity	2.79	3.09	2.5-3.5
Water absorption	1.60	2.89	1-3

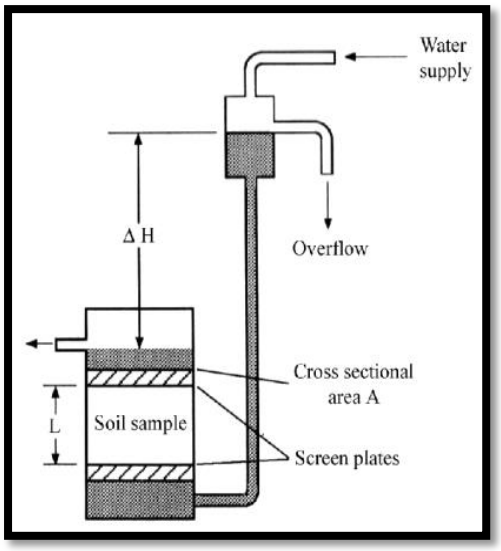


Table 5 Chemical composition of EAF slag

S.N.	Type of test	Test method standard	Result obtained(% by mass)
1.	Silica;Sio2	IS-4032	13.54
2.	Ferric oxide ; Fe2O3	IS-4032	25.70
3.	Alumina ;Al2O3	IS-4032	21.18
4.	Calcium oxide;CaO	IS-4032	27.59
5.	Magnesium Oxide MgO	IS-4032	1.03
6.	Sulphuric anhydrides :SO3	IS-4032	1.23
7.	Insoluble Residue	IS-4032	10.33
8.	Loss on Ignition	IS-4032	9.00

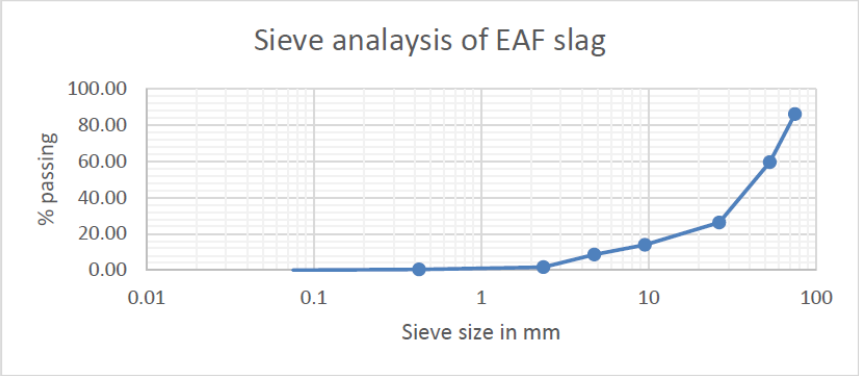
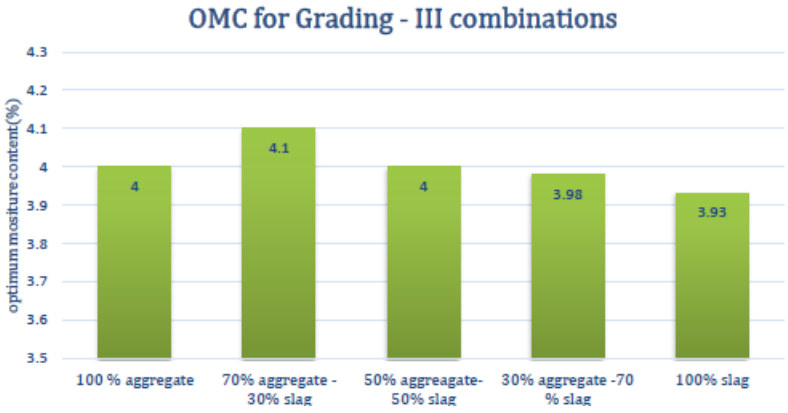
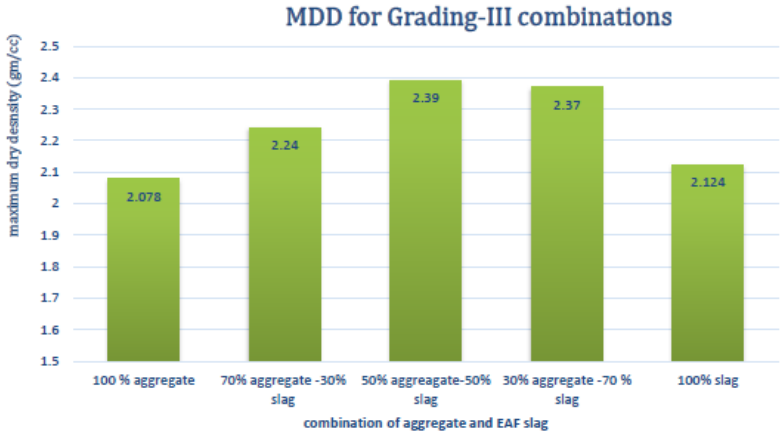
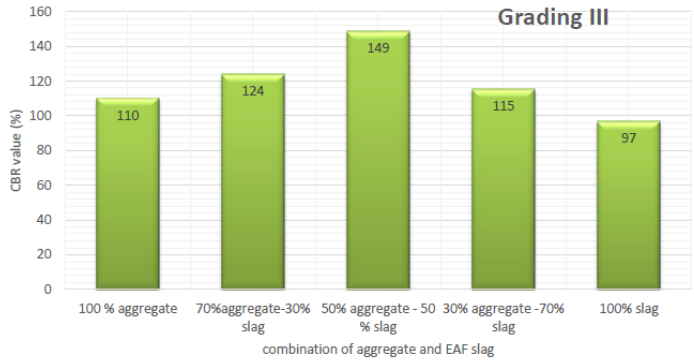


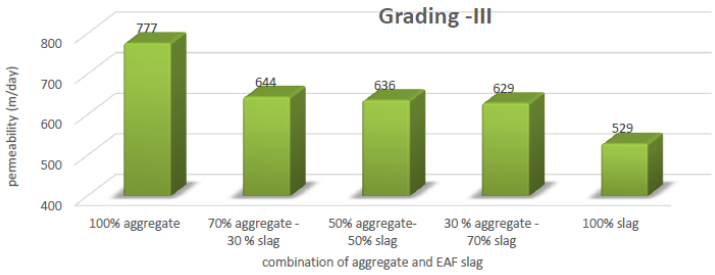
Table 6 Soundness test specification according to IS 2386-part V

Sieve size		Grading of original sample	Weight of test fraction before test	Weight of test fraction after test	% passing finer sieve after test(actual %loss)	Weighted average (corrected % loss)
Passing	Retain					
63	40	22	3025	3008.5	0.545	0.12
40	20	38	1510.5	1496	0.960	0.36
20	10	23	1000	986	1.400	0.32
10	4.75	17	300	293.5	2.167	0.37
		Sum	5835.5	5784	5.072<18%	1.18 < 18%









Conclusion

1. Optimum percentage of EAF slag, which can replace the natural aggregate in GSB for Grading-III to Grading -VI suggested by MORT&H, is 30% to 50%. This optimum percentage is based on Strength and drainability criteria.
2. For the 30% and 50% slag in aggregate – slag combination, CBR value comes out to be maximum for all Grading, as a strength point of view aggregate – slag combination are giving good result, CBR of which vary from 124 to 161 for these two combinations.
3. All the combinations are also satisfying drainability criteria (300m/day) required for Granular – sub-base layer combinations, which vary from 382m/day to 636 m/day.

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