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UTILIZATION OF STEEL SLAG IN PAVEMENT SUB-BASE

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ABSTRACT

Now-a-days, the natural resources are depleting which is a major issue in the construction sector from which the road segment cannot be excluded. Aggregate materials are depleting very fast and in short supply because of extensive road construction process. Also the energy consumption is very high for blasting, quarrying, crushing and transportation activities. On the other hand, bye-products, industrial wastes, and locally available unused materials which are causing environmental and dumping problems, but they can be used for the construction of roads. In the present study, an attempt has been made to utilize ***Steel Slag****. By using suitable tests and techniques, its gradation and other physical properties are studied. Conventional crushed aggregates are also used simultaneously with the slag to satisfy the desired grading for using it in a particular layer as per the specifications given by MORTH. The optimum percentage of slag is 80% that can be used in sub-base layers. Physical properties have also been studied. From the observations, it is seen that slag have excellent properties as road aggregates and hence can be used for application in road base and sub-base pavement layer.*

Keywords: Steel Slag, California Bearing Ratio, Impact test, etc.

1. INTRODUCTION:-

Generally, flexible or rigid pavements are used for the construction of roads. A flexible pavement consist of four components:- soil subgrade, sub-base course, base course and surface course from which the transmission of vertical load takes place i.e. from top (surface course) to the bottom (soil subgrade). A good flexible pavement which transfers the compressive stresses through a wide area consists of well graded aggregates which are well compacted. The base layer which lies immediately below the surface layer provides support to the pavement and transmits the load to the layers below. The sub-base layer which is below to the base layer not just only provides the support to the pavement structure and transmit traffic load to the subgrade but also provides drainage and frost action. The sub-base mainly consists of two layers, the lower (filter) layer and upper (drainage) layer. The filter layer forms the separation and preventing the intrusion of subgrade soil into the upper layer and the drainage layer is composed of granular sub-base (i.e. GSB) materials that drains the water away which enters through surface cracks. [**Yoder & witczak, principles of pavement design**].

A rigid pavement generally consists of a cement concrete slab, with a granular base or sub-base course which is provided below for the purpose of drainage, to control frost action, to control pumping and to control shrinkage & swelling of the subgrade. Rigid pavement and flexible pavements are different because of their low distribution phenomenon. In the rigid pavement, critical condition occurs due to flexural stress which is maximum in the slab because of wheel load and the variation of temperature whereas, in flexible pavement compressive stresses are distributed throughout. As compared to flexible pavement, rigid pavements have noteworthy flexural strength or flexural rigidity but still flexible pavement is widely used in the construction due to its smooth riding surface and low cost of construction. [**Yoder &witczak**]**.**

However, in semi-rigid pavements bonded materials are utilized in the base course or sub-base course of pavement layer, which gives them higher flexural strength as compared to conventional flexible pavement layers. The materials for bound base or sub-base layer may consist of aggregate, soil or combination of modification with stabilizers such as lime, cement, fly-ash or commercial stabilizers to give the desired strength.

1.1. Statement of the problem

Traditionally, the high way construction materials are also used in other activities of construction (like dams, buildings, power house, industrial setups etc.). Aggregates for the base & sub-base course used or composed of crushed aggregates, sand, gravel or natural materials that provide the necessary strength and durability. To meet the enormous demand of the construction the above natural aggregates are heavily consumed for the road construction. The aggregates are extracted from hills through quarrying operations, crushing & transportation etc. which are not only the major cause of environmental degradation in the form of loss of forest land, dust, pollution hazards, vibrations, noise, etc. But also consumes a high amount of energy which depletes the sources of energy. [**Indian Highways, May 2011**].

Huge quantity of waste materials are generated from industries like coal, iron, steel, etc. which causes a shortage of dumping space and thereby it creates severe environmental pollution. Solid waste from steel industries such as power plant flyash, tar sludge, acid sludge from by-product plant, steel flag, B.F. slag, steel scrap, coke breeze, dolomite & calcined lime, etc. are generated in huge quantity that causes environmental degradation [**Viswanathan &Gangadharan (1996)].**

1.2. Slag obtained from steel plants

As of 2017, India is the world's 3rd largest producer of crude steel (up from 8th in 2003), pig iron, sponge iron, alloy & non-alloy steel. Slag is generated as a by-product during the manufacturing of pig iron & steel. During the process of making of pig iron (in the blast furnace) and production of steel (in steel melting shop), slag is produced as a by-product by the action of fluxes upon gangue materials with the iron ore. The slag primarily consists of silicon, calcium, aluminium, iron, magnesium & manganese in various combinations. Under controlled cooling slag becomes hard and dense, which can achieve the required strength to sustain heavy loads thus making it especially suitable for use in road construction. [**Indian minerals yearbook 2012**].

The slag amount generated is so huge that dumping problem arises which can be hazardous for the environment. So due to rapid growth in the construction industry and sufficient slag availability, it can be used as a partial substitute for the natural aggregate materials in the base & sub-base course application in pavement. Slag is a cheaper material than natural aggregate materials and also its availability is sufficient. When the slag is used in bounded form in road sub-base then its hazardous effects can be decreased making it environmentally sheltered. So because of the above factors slag can be used in road base & sub-base layer due to its cost effectiveness & economic point of view in construction and by using slag in the construction industry environmental issues can also be resolved.

2. METHODOLOGY

Before the application of whether natural aggregates or locally available material or industrial wastes/by-products, they must satisfy the strength parameters and desired physical properties for using it in the base or sub-base pavement layer. Apart from these tests, the materials which could harm the environment are also subjected to the chemical test and characterization to check whether they are suitable for the environment or not. In this work chemical composition and characterization of the slag were undertaken. As per the respective codes, specifications, literature, the physical properties of slag and natural crushed aggregate were determined. The methods of the tests carried out in the work are presented below.

2.1. Physical Properties

In the present work, an attempt has been made on the utilization of slag in the sub-base layer of flexible pavement. As per the specifications given by MoRTH (2013), for lower sub-base layer (i.e. filter layer) a closed grading (i.e. Grading II for Grannular sub-base material) and for the upper layer (i.e. drainage layer) a uniform grading (i.e. GSB Grading IV) was used. For the usage in the drainage layer of the sub-base using GSB Grading IV, the stabilization of crushed aggregates was done by using cement. The desired gradation of GSB Grading II & IV as per the specifications given by MoRTH (2013) corresponding to the Indian Standards (IS)Sieve size are given in the table 1 :-

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IS Sieve Size (in mm)	%age passing the IS Sieve	
	GSB Grading-II	GSB Grading-IV
53	100	100
26.5	75 – 100	55 – 80
9.5	55 – 80	-
4.75	40 – 60	15 – 40
2.36	30 – 45	-
0.425	15 – 20	-
0.075	0 – 5	0 - 5

Table 1 Grading Granular sub-base materials

2.1.1. Gradation

By sieve size analysis, gradation of the materials was determined by taking IS sieve. For 24 hrs., the materials were stored in Oven and then cooled before sieve analysis. Wet sieving was done for finding the gradation of the finer materials (i.e. finer than 4.75 mm) by washing the materials on 75µm IS sieve (until all the finer materials were passed), retained materials dried in Oven (for 24 hrs.) and then after cooling sieving the dried materials in the designated IS sieves which are finer than 4.75mm. Sieve size analysis of the 15 samples of slag, 5 samples each of 40, 20, 10, 6 mm crushed aggregates was done and after that the gradation results are shown in the graphical forms by taking sieve size (in mm) along X-axis (log scale) and percentage passing corresponding to it along Y-axis.

2.1.2. Blending of the Aggregates

After obtaining the gradation results of slag and crushed aggregates blending was done by different proportions of crushed aggregates and also with slag to meet the desired gradation (either by using GSB grading II & IV as specified in Table 1) on the basis of trial & error and the blend of aggregates for which the percentage passing was within the desired limits was used for test & analysis.

2.2 TEST CONDUCTED ON MATERIAL

In the present work, different types of tests are conducted on the blended mixture obtained after the blending. Various physical properties are measured by using these tests. The various test conducted on material are listed below:

- Determination of Water Absorption & Specific Gravity
- Determination of Plasticity Index (I_P)

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- Impact Test
- Combined flakiness index test
- Modified proctor test
- California Bearing Ratio (CBR) Determination

3. RESULT

3.1. Gradation

The sieve size analysis for slag & crushed aggregate, samples are presented in graph shown in Fig.1

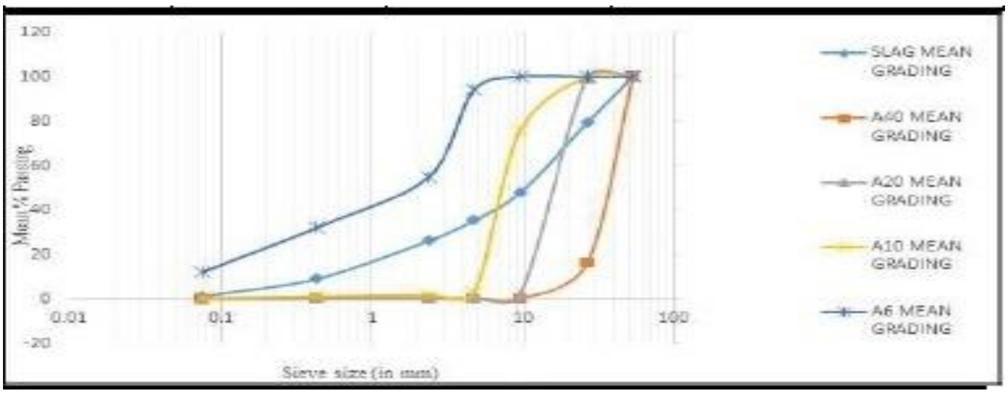

Fig.1: Graph which represents size V/s mean %age passing of slag & crushed aggregate

3.2. Blending:

3.2.1. Blending of slag with crushed Aggregates:

It is done to make the requirements of GSB Grading-II and GSB Grading-IV as per the specifications given by MoRTH. The final proportion of aggregates were determined and it was given in table 2 & 3 after so many trials.

Grading II Limits			BLENDING
Sieve Size	%passing (L)	%passing (U)	Slag=76%+A6=24%
53	100	100	100.00
26.5	70	100	83.42
9.5	50	80	59.98
4.75	40	65	49.14
2.36	30	50	32.87
0.425	10	15	14.39
0.075	0	5	3.60

Table 2:- Blending of slag with crushed aggregates to satisfy the desired gradation for GSB Grading-II

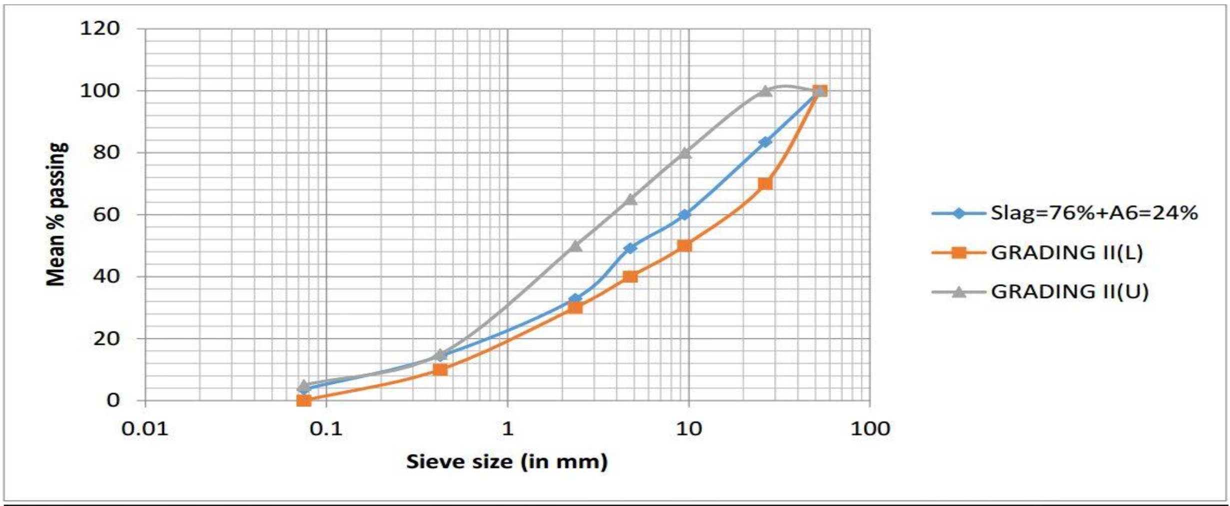

Fig.2:- Blending of the slag with crushed aggregate to satisfy the desired gradation for GSB Grading-II

Grading IV Limits			BLENDING
Sieve Size	%passing (L)	%passing (U)	Slag=80%+A40=20%
53	100	100	100.00
26.5	50	80	65.64
4.75	15	35	28.00
0.075	0	5	0.81

Table 3:-Blending of slag with crushed aggregates to satisfy the desired gradation for GSB Grading-IV

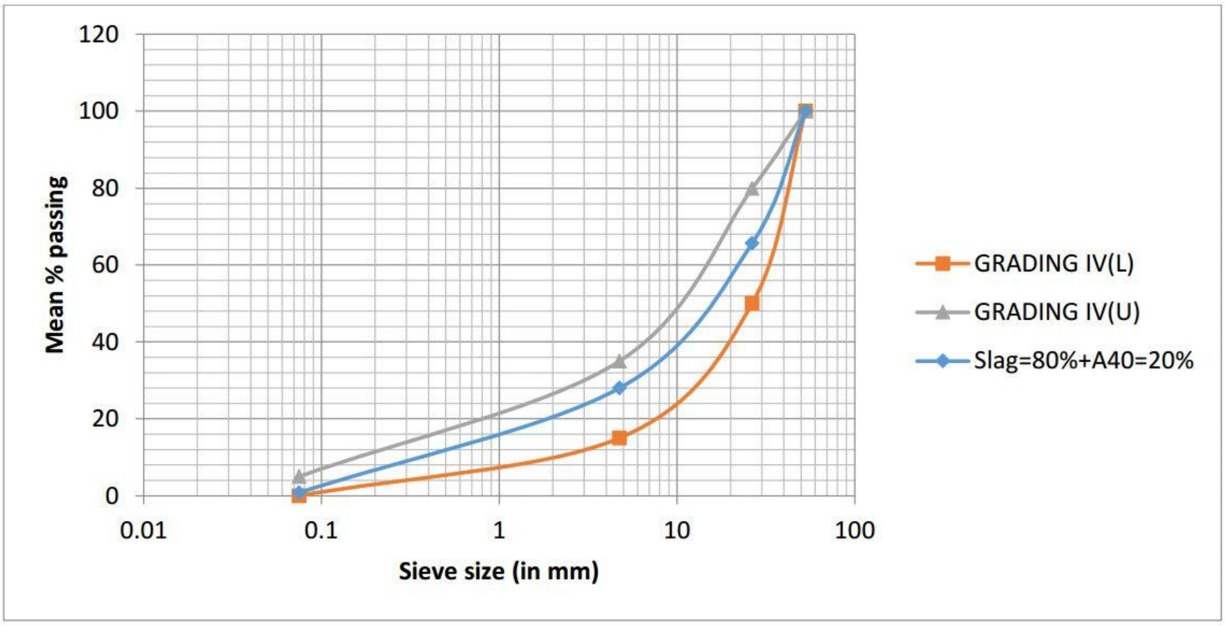

Fig. 3:- Blending of the slag with crushed aggregates to satisfy the desired gradation for GSB Grading-IV

3.2.2.Blending of Crushed Aggregates

As per specifications given by MoRTH, to meet the requirements of GSB Grading-IV, the blending of different size crushed aggregate was done by trial & error method.

Grading IV Limits			BLENDING
Sieve Size	%passing (L)	%passing (U)	A40=35%+A10=50%+A6=15%
53	100	100	100.00
26.5	50	80	70.41
4.75	15	35	15.64
0.075	0	5	1.95

Table 4:- Blending of crushed aggregates to satisfy the desired gradation for GSB Grading-IV

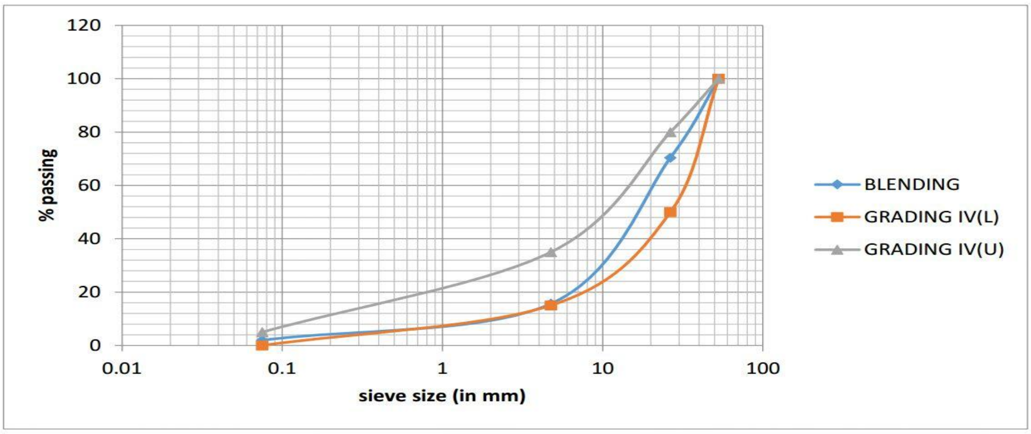

Fig. 4:- Blending of crushed aggregates to have the desired gradation for GSB Grading-IV

3.3. Other Properties

The physical properties of individual aggregates were determined as presented in table 5. The physical properties of combination of aggregates were determined for their use in different layers by taking the optimum proportion as obtained in the blending.

Property		Slag	A40	A20	A10	A6
Plasticity Index (PI)	Liquid Limit (LL)	30.00	-	-	-	17.60
	Plastic Limit (PL)	-	-	-	-	-
	PI=LL-PL	NP	NP	NP	NP	NP
Water Absorption (%)	Coarse	1.95	0.22	0.30	0.41	0.76
	Fine	6.94				
Specific Gravity (Bulk)	Coarse	3.10	2.76	2.75	2.74	2.65
	Fine	2.66				
Specific Gravity (Apparent)	Coarse	3.33	2.78	2.78	2.77	2.66
	Fine	2.94				
Combined Flakiness Index		17.59	54.68	65.65	92.03	-
Impact Value		14.72	12.93	19.76	22.98	-
Optimum Moisture Content (%)		-	-	-	-	-
Max. Dry Density (g/cc)		-	-	-	-	-

Table 5:- Physical Properties of slag and crushed aggregates individually

CONCLUSIONS

From the experiments conducted on the slag samples, and from the analysis of results, the conclusions drawn are summarized below:.

- The slag samples are well graded which require less amount of crushed (conventional) aggregates for blending to meet the desired grading for use in different layers of sub-base.
- Not more than 76% & 78% slag should be used for filter layer & drainage layer respectively.
- Impact value of slag, crushed aggregates are within prescribed limits.
- Specific gravity is much higher for slag as compared tocrushed aggregates. MDD and CBR values are very high.

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