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Eco-Friendly Roads: An Experimental Investigation into The Use of Steel Slag in Flexible Pavement Construction

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Abstract- ***Large quantities of natural materials are traditionally used in road construction. Concurrently the world faces the problem of management of an increasing quantity of waste, so that linking the two problems leads to a simple solution: a growing and more diverse application of waste materials in road building and other areas of civil engineering alike. Road pavement can be considered to be one of the fundamental elements of the transportation system. Significant amounts of bitumen and natural aggregates are used in the construction of asphalt concrete pavements. Waste materials whose application is possible in road construction are divided into three basic groups: re- usable construction materials, industry by-products and natural construction materials of a lower usability value. The first group includes the materials that were used one or more times, such as materials from unbound base courses (gravel, sand, and rock) and materials from bitumen and hydraulically bound layers. Slag is the group of industry by- products, whereas the group of natural construction materials with lower usability value is primarily represented by excavation materials.***

Index Terms- ***Bitumen, Re-Usable Construction Materials, Unbound Base Courses (Gravel, Sand, And Rock)***

I. INTRODUCTION

In this present era the technology in advanced construction has developed to a very large extent. Some parts of construction are still in improving stage which includes road construction. In this chapter, we are going to deal with metal and bitumen tests in Brief. The design is done by manual analysis. And various tests has been conducted in the replaced of dust by steel slag.

SCOPE

The basic Marshall test consists essentially of crushing a cylinder of bituminous material between two semi- circular test heads and recording the maximum load achieved and the deflection at which the maximum load occurs.

MATERIALS USED

Materials used for the pavements are

- Bitumen
- Steel Slag
- Metal

BITUMEN

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water prolongs properties and relatively low cost.[1] Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar. Bitumen is the residue or by-product when the crude petroleum is refined.

STEEL SLAG

Steel slag, a by-product of steel making, is produced during the separation of the molten steel from impurities in steel-making furnaces. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling. Steel slag used as a bituminous material. Moisture absorption value of Steel Slag was obtainedas 10%. It is feasible to use metal slag as a binder material in the bituminous mix design. Steel Slag sample was collected from workshop. It was selected from different locations of the heap and mixed thoroughly before using it for laboratory Study. Aggregates collected from crusher industry. Use of local soil should be collected and different layers in field to check Geotechnical properties of Local soil and steel slag in various percentage mixes.

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II. UTILIZATION OF STEEL SLAG

Utilization of steel slag in industrial projects is a valuable approach for technical, economical and environmental reasons. Steel slag aggregates are highly angular in shape and have a rough surface texture. Processed steel slag has favorable mechanical properties for aggregate use, including good abrasion resistance, hardness and high bearing strength. Steel slag has been successfully used as aggregate in surface layers of pavement. The effectiveness of steel slag aggregates in asphalt mixtures. They conducted Marshall Stability test on the flexible pavement. The result indicated the use of steel slag with bitumen efficiency.

Steel Slag Aggregate Advantages and Disadvantages

The advantages and disadvantages of bituminous applications, as noted in the literature reviewed, are as follows:

Advantages when used in bituminous pavements

1. High skid resistance
2. Resistant to wear
3. High stability
4. Resistant to rutting
5. Higher stiffness
6. Fatigue resistant
7. Resistant to permanent deformation
8. High cohesive strength
9. Electrically conductive
10. Compatible with typical asphalt binders

Disadvantages when used in bituminous pavements

1. High volume expansion potential in the presence of moisture
2. Increased binder demand (24% to 30%) due to its porous structure
3. High specific gravity results in lower volumes of pavement mix and higher transportation costs
4. Overall higher cost of applications

TESTS CONDUCTED IN PAVEMENT
SPECIFIC GRAVITY TEST

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TESTS CONDUCTED IN PAVEMENT
SPECIFIC GRAVITY TEST

Specific gravity test was carried out as per IS 2720 Part 3 (1980).Specific gravity of steel slag and local soil was observed to be 4.28 and 2.10 respectively. Grain Size Analysis Grain size analysis was carried out of slag and local soil as per IS 2720 part 4 (1985). Slag and local soil samples were observed to be coarse grained materials. Slag was crushed by roller and grain size analysis was also carried out.

DUCTILITY TEST

Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square.

The bitumen sample is heated and poured in the mound assembly placed on a plate. These samples with molds are cooled in the air and then in water bath at 27^0 C temperature.

S.NO	INITIAL READING (cm)	FINAL READING (cm)	DUCTILITY VALUE (cm)
1	0	25.2	25.2
2	0	46.8	46.8

DUCTILITY VALUE = FINAL READING – INITIAL READING CM

= 25.2-0 = 25.2

= 46.8-0 = 46.8

Ductility value = 46.8 + 25.2 = 72/2 = 36

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Ductility value of bitumen is 36 cm.

SOFTENING POINT TEST

Softening point denotes the temperature at which the bitumen attains a particular degree of softening under thespecifications of test.

The test is conducted by using Ring and Ball apparatus.

A brass ring containing test Sample of bitumen is suspended in liquid like water or glycerin at a given temperature. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5 ^{0} C per minute. Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates.

S.NO	TEMPERATURE WHEN THE BALL TOUCHESBOTTOM, (^{O}C)	AVERAGE	SOFTENING POINTOF BITUMEN
1	44.5	44.5	44.5
2	44		
3	45		

Softening value of bitumen= 44.5 ^{O}C

VISCOSITY TEST

Viscosity denotes the fluid property of bituminous material and it is a measure of resistance to flow. At the application temperature, this characteristic greatly influences the strength of resulting paving mixes. Low or high viscosity during compaction has been observed to result in lower stability values. At high viscosity, it resists the compactive effort and thereby resulting mix is heterogeneous, hence low stability values. Viscosity of a cutback can be measured with either 4.0 mm orifice at 25 ^{O}C or 10 mm orifice at 25 or 40 ^{O}C.

S.NO	TEMPERATURE, ^{O}C	TIME TAKEN IN SEC	VISCOSITY IN SEC
1	50	84	
2	70	56	70

The viscosity value of given bitumen is = 70 sec

AGGREGATE

Aggregate is a collective term for the mineral materials such as sand, gravel, and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as bituminous concrete and Portland cement concrete).

DESIRABLE PROPERTIES

- Strength
- Hardness
- Shape Of Aggregate
- Durability

STRENGTH

The aggregates used in top layers are subjected to

(i) Stress action due to traffic wheel load,

(ii) Wear and tear,

(iii) Crushing. For a high quality pavement, the aggregates should posse's high resistance to crushing, and to withstand the stresses due totraffic wheel load.

SHAPE OF AGGREGATE

Aggregates which happen to fall in a particular size range may have rounded cubical, angular, flaky or elongated particles. It is evident that the flaky and elongated particles will have less strength and durability when compared with cubical, angular or rounded particles of the same aggregate. Hence too flaky and too much elongated aggregates should be avoided as far as possible.

HARDNESS

The aggregates used in the surface course are subjected to constant rubbing or abrasion due to movingtraffic. The aggregates should be hard enough to resist the abrasive action caused by the movements of traffic. The abrasive action is severe when steel tyre vehicles moves over the aggregates exposed at the top surface.

ABRASION TEST

Abrasion test is carried out to test the hardness

property of aggregates and to decide whether they are suitable for different pavement construction works. Los Angeles abrasion test is a preferred one for carrying out the hardness property and has been standardized in India (IS:2386 part-IV).

SOUNDNESS TEST

Soundness test is intended to study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycles. The Porous aggregates subjected to freezing and thawing is likely to disintegrate prematurely. To ascertain the durability of such aggregates, they are subjected to an accelerated soundness test as specified in IS: 2386 part-V.

MARSHALL STABILITY TEST

State Highway Department formulated Marshall Stability test – flow test on bitumen and is applicable to hot mix design of bitumen and aggregates of maximum size 2.5 cm. Bituminous concrete mix is commonly designed by Marshall Method. This test is extensively used in routine test programmed for the paving jobs.

USE OF STEEL SLAG IN FLEXIBLE PAVEMENT

A steel slag is produced as a byproduct during the oxidation of steel pellets in electric furnace.This by-product that mainly consists of calcium carbonate is broken down to smaller sizes to be used as aggregates in pavement layers. They are particularly useful in areas where a good quality aggregate

MARSHALL MIX DESIGN

The Marshall Stability and Flow test provides the performance prediction measure for the Marshall Mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute.

Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to the loading. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded. The important steps involved in marshal mix design are summarized next. Approximately 1000gm of aggregates and filler is heated to a temperature of 90-150oC. Bitumen is heated to a temperature of 121−125oC with the first trial percentage of bitumen the heated aggregates and bitumen are thoroughly mixed at a temperature of 140−150oC. The mix is placed in a preheated mound and compacted by a rammer with 50 blows on either side at temperature of 138oC to 149oC. The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-3 mm. Vary the bitumen content in the next trial by +0.5% and repeat the above procedure

IMPACT TEST

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal diameter 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine

AGGREGATE

IMPACT VALUE (%)1 =

W2 *100

W1

= 0.1 *100 = 15.15 %
0.60

2 = 0.11 *100

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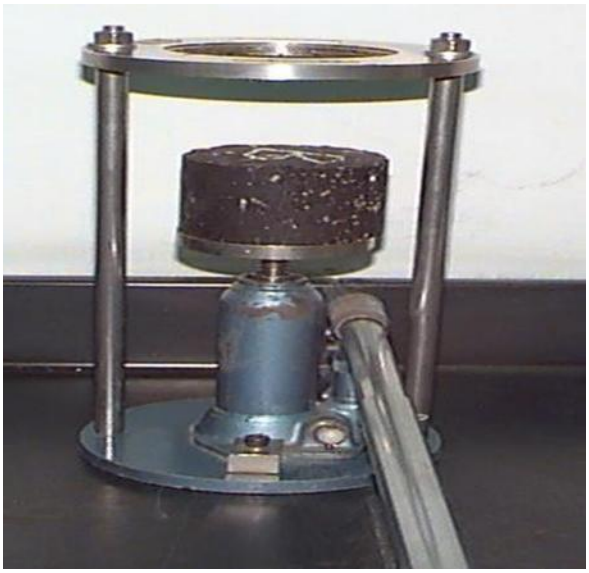
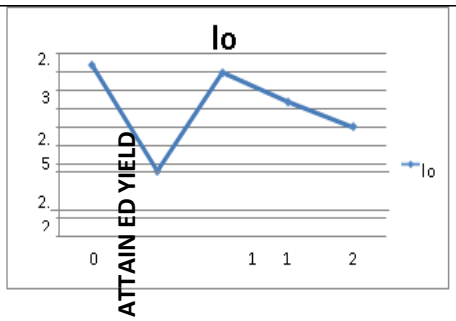
S.NO	WEIGHT OF SURFACEDRY SAMPLE(W1)	WEIGHT OF FRACTION PASSING 2.36 mm SIEVE(W2)	AGGREGATE IMPACT VALUE
1	0.66	0.1	15.15
2	0.64	0.11	17.18
3	0.64	0.1	15.62

MARSHALL STABILITY FLOW

The results of the Marshall test are the average of the specimen which is prepared in optimum bitumen content. The results indicated that the use of steel slag is maximum average stability valve of the mixture prepared with the combination of steel slag. Use of steel slag in preparation of Marshall Bitumen specimen resulted as increase the valve of Marshall Stability. The reason could be due to the hardness of the slag aggregates. It gives high stiffness mixture with the great ability to resist creep deformation. A mixture provides a positive contribution to the overall performance of flexible pavement.



S.NO	SIZE OF AGGREGATE	WEIGHT OF AGGREGATE	SPECIMEN 1 (gm)	SPECIMEN 2 (gm)	SPECIMEN 3 (gm)	SPECIMEN 4 (gm)	SPECIMEN 5 (gm)
1	12.5	72	72	72	72	72	72
2	10	310	310	310	310	310	310
3	4.7	84	84	84	84	84	84
4	2.6	254	254	254	254	254	254
5	FILLER	480	480	430	380	330	280
6	STEEL SLAG		0	50	100	150	200



III. RESULTS

The following features concluded from this

experimentation of steel slag replacement of filler are

- The partially replacement of filler by steel slag will increases the strength and also load carrying capacity.
- Based on the Marshall stability Test results replacing the coarse portion of the aggregate in mixture with the coarse portion of the aggregate leads to a concurrent increase in the Marshall Stability and Flow with an improvement.
- Based on other tests results of this research study the advantageous of using steel slag Better adhesive properties, better resistance to moisture damage and hence a more durable mixture. Better aggregate interlocking, higher cohesive property and hence better resistance to permanent deformation.
- When compared to normal road pavement of capacity Load is of 8KN, but 10% - 15% of steel slag added in a road pavement gives an optimum result. This specimen carrying a 7KN – 8KN into a deflection of 2.12 mm .So it can reduce a less usage of course aggregate used in a road pavement. Huge amount of steel slag is available in workshop, steel industry, etc…
- Steel slag is added only on 10 – 15 % ,Because more than 15 % of steel slag is added for this road pavement is suddenly deflected and cannot carrying a load .

REFERENCES

[1] Ahmed Ebrahim Abu El-Maaty Behiry(2012) "Evaluation of steel slag and crushed limestone mixtures as subbase material in flexible pavement" Ain Shams Engineering Journal Vol .4(2012), pp 43–53.

[2] C.N.V. Satyanarayana Reddy and K. Durga Rani (2013) Potential of Shredded Scrap Tyres In Flexible Pavement Construction, IndianHighways, October 2013 pp 7-12.

[3] Dr. D S V Prasad, Dr. G V R Prasada Raju, M Anjan Kumar(2009),Utilization of Industrial Waste in Flexible Pavement Construction.EJGEJournal Vol. 13, Bund. D,pp.1- 12.

[4] Hassan Ziari & Mohammad M. Khabiri(2007),Preventive maintenance of flexible pavement and mechanical properties of steel slag asphalt.Journal Of Environmental Engineering And LandscapeManagement, 2007, Vol. XV, No 3,pp. 188– 192.

[5] K V Subrahmanyam, U Arun Kumar, Dr. PVV Satyanarayana,(2014) A Comparative Study on Utilization of Waste Materials in GSB Layer,SSRG International Journal of Civil Engineering (SSRG-IJCE) – Vol.1.Issue3 Aug. 2014 ISSN: 2348 – 8352,pp.10-14.