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Experimental Study on Asphalt Mixture using Steel Slag (Partial Replacement)

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Abstract *Natural coarse aggregates are extracted from quarries and as a result of this quarries will be soon depleted, if the rate of their use continuous at this pace. Hence there was a need of permanent solution to this perpetual problem. Keeping this in view the feasibility of use of steel slag as replacement of coarse aggregate in road construction has been experimentally assessed in this project. The increasing demand of steel industry leads to the increased production of steel slag enormously through steel plant. Instead of disposing steel slag into environment, it can be reused in flexible pavement as it has asphalt properties. So it can be used in road construction as a partial replacement for coarse aggregate. Addition of quarry dust in flexible pavement reduces the effect of steel slag in the environment. In this experimental work of 0%, 5%, 10%, 15%, 20%25% of aggregates were partially replaced by steel slag and also 10% of the filler material is replaced by quarry dust. Various test like specific gravity, penetration test, viscosity, binder content, water absorption, impact value, and Marshall Stability test were conducted on the obtained asphalt mix and the results are compared with the conventional mix. From the results it is obtained that the asphalt mix with steel slag performs better than the conventional mix.*

KEY WORDS: Steel slag, asphalt, quarry dust, partial replacement, flexible pavement.

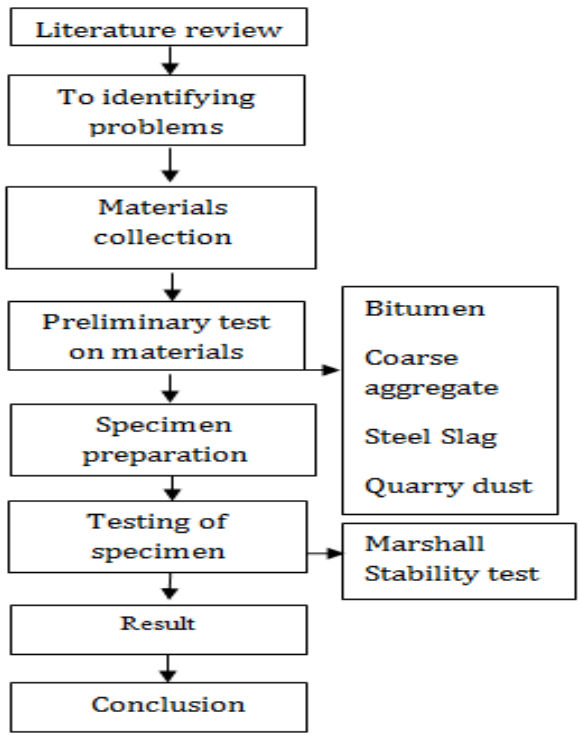
1. INTRODUCTION

The development of the highway the aggregate resources in India are becoming depleted, construction is increasing rapidly. Consequently and the land is being sacrificed to obtain raw materials. Thus it is necessary to to find a recycled material that can replace aggregates in highway construction. Much research has been done to improve and upgrade the materials used for preparing asphalt .The utilization of waste material as a replacement for aggregates in the production of hot mix asphalt (HMA) could have many benefits to mankind. Waste materials can be categorized broadly as follows: industrial waste (e.g., fly ash, bottom ash, slag, lignin's), municipal waste (e.g., incinerator residue, scrap rubber, glass) and mining waste (e.g., coal mine refuse).

Steel slag is a by-product of steel industry and is reported to exhibit great potential as a partial replacement for natural aggregate in road construction. Steel slag is a waste material that can be recycled as a road construction material. Steel slag aggregate have been reported to retain heat considerably longer than natural aggregates. The heat retention characteristics of steel slag aggregates can be advantageous for HMA construction, as less gas (energy) is used during the execution of asphaltic concrete work. Based on high frictional and abrasion resistance, steel slag is used widely in industrial roads, intersections and parking areas where high wear resistance is required.

The waste material is neutral and nonorganic hazardous is natural as per chemical analysis report of central pollution control board India (CPCB).the quantity of generation of this steel slag is around 24 lakhs metric ton per year from different steel industries in India CRRI 2010.the steel slag is a non-metallic ceramic material formed from the reaction of flux such as calcium oxide with the inorganic non-metallic components present in the steel scrap. Work done by various researchers has found that the addition of steel slag in HMA enhances the performance characteristics of pavement. Since it is rough, the material improves the skid resistance of pavement.

2. ORGANIZATION OF THE PROJECT



3. PROJECT SIGNIFICANCE

Use of steel slag in the road construction reduces the coarse aggregate demand. It also gives the same strength compared to normal aggregate. The use of quarry dust as a filler material will reduces the effect of steel slag in the environment. Various test has been conducted to check the performance of steel slag with bitumen as a partial replacement compared to normal aggregate. Use of steel slag in road construction protects the environment from disposal.

4. MATERIALS REQUIRED

4.1 AGGREGATE

The aggregates are bound together either by bituminous materials or by cement. In a few cases, rock dust is mixed with waste and forms the slurry which acts as binding medium. The aggregates may be classified into natural and artificial aggregates. The natural aggregates again are classified as coarse aggregates consisting of crushed rock aggregates or gravel and fine aggregates or sand. The blast furnace slag obtained as a by- product from blast furnaces is the one extensively used as road construction material.

Fig.1.Coarse aggregate

4.2 BITUMEN

Bitumen also known as asphalt in the united states, is a substance that forms through the distillation of crude oil. It has waterproofing and adhesive properties. Bitumen production through distillation removes lighter crude oil components such as gasoline and diesel, leaving the heavier bitumen behind.

Fig.2. Bitumen

4.3 STEEL SLAG

Steel Slag aggregate is a byproduct of the production of steel in an electric arc furnace. The high iron oxide content of the aggregate results in an aggregate that is very hard and very dense(SSA is 20-30% heavier than naturally occurring aggregates such as basalt and granite)

Fig.3. Steel Slag

4.4 FILLER MATERIAL

Quarry dust is a byproduct o the crushing process which is concentrated material to use as aggregates for concreting purpose, especially as fine aggregate. In quarrying activities, the rock has been crushed into various sizes, during the process the dust generated is called quarry dust and it is formed as waste.

Fig.4. Quarry Dust

5. TESTING OF MATERIALS

5.1 SPECIFIC GRAVITY TEST ON AGGREGATE

Specific Gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. Water, at temperature of 73.4°F (23°C) has a specific gravity of 1 Specific Gravity is important for several reasons. Some deleterious particles are lighter than the good aggregates.

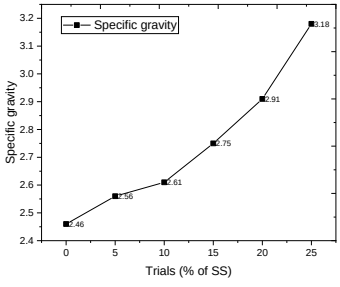


Chart.1. Specific Gravity test on aggregate

5.2 WATER ABSORPTION TEST ON AGGREGATE

Specific gravity test of aggregate is done to measure the strength or quality of the material while water

absorption test determines the water holding capacity of the coarse aggregate. The main objective of these tests is to measure the strength or quality of the material

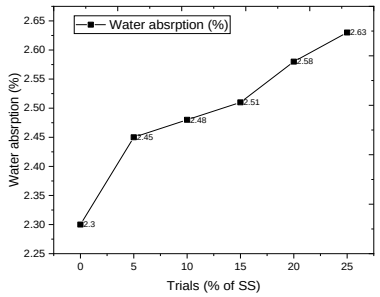


Chart.2.water absorption test on aggregate

5.3 IMPACT TEST ON AGGREGATE

The property of a material to resist impact is known as toughness of coarse aggregate. This characteristic is measured by impact value test. The aggregate impact value is measures the resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

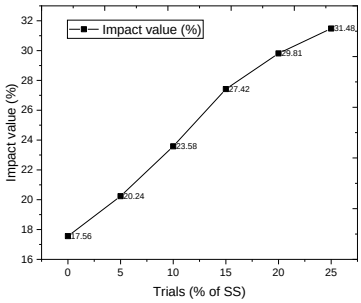


Chart.3. Impact test on aggregate

5.4 CRUSHING STRENGTH TEST ON AGGREGATE

The strength of coarse aggregate is assessed by aggregate crushing test. The aggregate crushing value provides a relative measure of resistance to crushing under a gradually applied compressive load. To achieve a high quality of pavement, aggregate possessing low aggregate crushing value should be preferred.

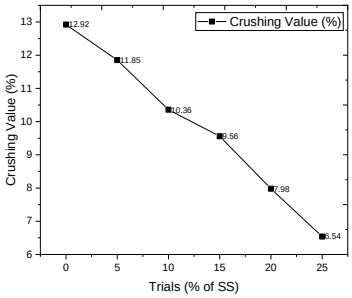


Chart.4.Crushing strength test on aggregate

5.5 SPECIFC GRAVITY TEST ON BITUMEN

This test is done to determine the specific gravity of semi-solid bitumen road tar. the principles is that it is the ratio of mass of a given volume of bitumen to the mass of an equal volume of water, both are recorded as specified temperature

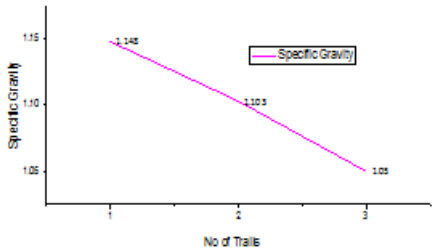


Chart.5.Specific gravity test on Bitumen

5.6 SOFTENING PONT TEST ON BITUMEN

Temperature is noted when the softened bitumen touches the metal plate which is at a specific distance below. Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates.

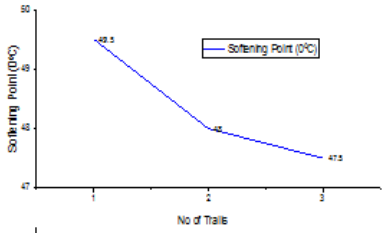


Chart.6.Softening point test on bitumen

5.7 DUCTILITY TEST ON BITUMEN

Ductility of a bitumen material is measured by the distance in centimeters to which it will elongate before braking when two ends of standard briquette specimen of material are pulled apart at a specified speed and specified temperature.

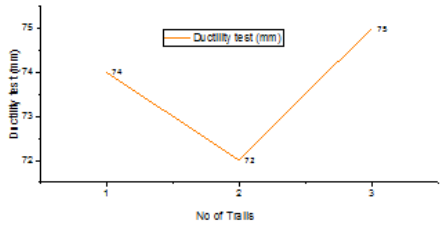


Chart.7.Ductility test on bitumen

5.8 VISCOSITY TEST ON BITUMEN

Say bolt Furl viscosity test is used to determine the viscosity of liquid bitumen's. In this test, time in seconds is noted for 60 ml of the liquid bitumen at specified temperature to flow through an office of a specific size. The higher viscosity of bitumen requires more time for a quality to flow out.

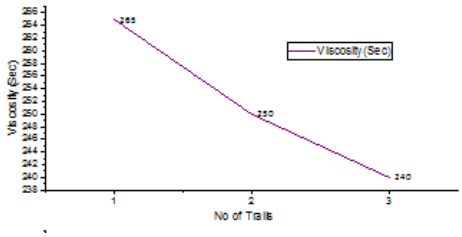


Chart.8. Viscosity test on bitumen

5.9 PENETRATION TEST ON BITUMEN

The penetration test of bitumen is a test where a standard penetration needle [Carrying 100 gm super imposed load] is allowed to penetrate a standard bitumen sample for a standard time period [5 seconds], at standard test temperature [25°C] and the value of penetration is expressed as $1/10^{th}$ of mm.

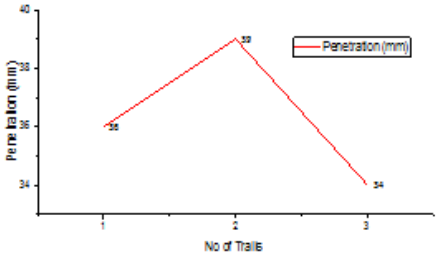


Chart.9.Penetration test on bitumen

5.10 BINDER CONTENT TEST ON BITUMEN

The determination of binder content of bituminous mixture is one of the major properties that affect pavement performance. The binder content affects the pavement's tendency to permanent deformation, fatigue cracking and moisture damage. The binder content can be determined by ignition method and hot/cold extraction.

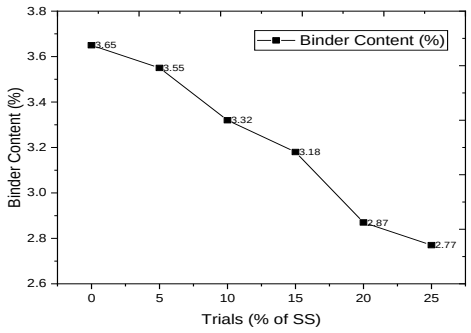


Chart.10.Binder content test on bitumen

5.11 MATERIAL TEST RESULTS AND DISCUSIONS

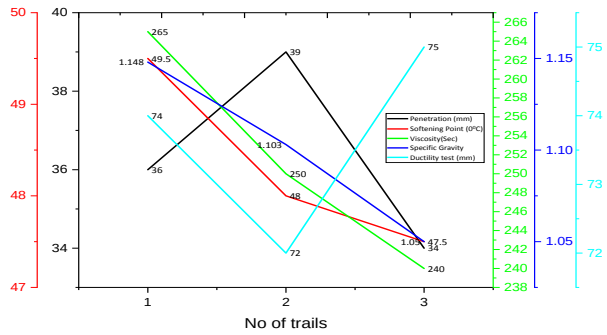


Chart.11. Combined Graph of Bituminous Tests Results

Discussion

Bitumen is a low cost thermoplastic material which is widely used in roofing, road and pavement applications. However it is brittle in cold environments and softens in warm environment.

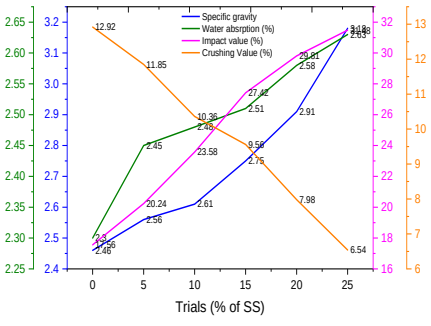


Chart.12.Combined graph on aggregate replacement test results

Discussions

Aggregate is the natural material and it is used for construction purpose, pavement etc. In pavement it used as subgrade material. For that it will be partially replaced by steel slag. Steel slag performs with bitumen better than normal conventional mix.

6. MARSHALL STABILITY TEST ON SAMPLES

Marshall Method is applied with penetration bitumen or viscosity grade bitumen. It requires the preparation and evaluation of a series of tests with different bitumen content of each other. The Marshall test uses the standard cylindrical test specimens that are 10 cm diameter by about 7.5cm high. The specimens are prepared by using a prescribed procedure for heating, mixing and compacting the bitumen-aggregate mixtures. The two principle features of the Marshall method of mix design are a density-voids analysis and a stability-flow test of the compacted test specimens. The stability test is a type of unconfined compressive strength The Marshall stability of each test specimen is the maximum load resistance in Newton that the specimen develops, whilst the Marshall Flow value is the total movement or strain occurring in the specimen between no load and maximum load during the stability test.

Particulars	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5	Sample-6
Percentage of waste materials added	0%	5%	10%	15%	20%	25%
Weight of core in air	1572g	1585g	1593g	1623g	1691g	1625g
Weight of core in water	1056g	1082g	1193g	1150g	1191g	1125g
Weight of saturated surface dry core	1576g	1590g	1628g	1650g	1698g	1627g
Volume of core	495cc	500cc	504cc	503cc	507cc	502cc
Density of core	3.03g/cc	3.10g/cc	3.16g/cc	3.37g/cc	3.33g/cc	3.23g/cc
Marshall stability	4.5kN	4.7kN	4kN	6.2kN	10.5kN	9.8kN
Flow value	1.860mm	1.920mm	1.970mm	2.500mm	2.070mm	2.020mm
Marshall quotient	2.30	2.50	2.03	3.80	5.07	4.85
Bitumen content	4.60%	4.75%	5%	5.30%	5.78%	5.43%

The specified gradation of mineral aggregates and bitumen as per IRC 29-1968.The aggregate and Stone dust are mixed together in the desired proportion as per the design requirements and fulfilling the specified gradation. The required quantity of the mix is taken so as to produce the compacted bituminous mix specimen of thickness 63.5 approximately.

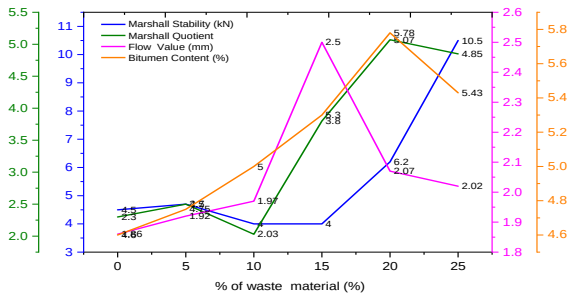


Chart.13.Marshall Stability Test

7. CONCLUSION

It is feasible to use steel slag as a binder material in the bituminous mix design. The following points were observed. 5-25% addition of steel slag gives the maximum value for ductility test.

- Hence 5-25% is the optimum value.
- The water absorption of steel slag is slightly increased when compared with coarse aggregate; it is because of presence of voids in steel slag.
- The aggregate is a material having specific gravity of 2.46 and steel slag having a specific gravity of 3.16.
- The Steel Slag Aggregate improved the porous surface in comparison to the natural aggregate.
- Under these conditions, Steel Slag Aggregate appears to be especially beneficial for aggregate substitution for road paving applications.
- The physical properties of Steel Slag Aggregate basically satisfy the requirements of Marshall Specification for design of Asphalt. Based on laboratory test results, Steel Slag Aggregate appears to be especially beneficial for the use in road construction to reduce the dependent on naturally occurring aggregate.

Finally it is concluded that, the use of natural aggregate in the Asphalt layer of road pavement is seen as a wasteful use of a finite natural resource. Therefore, the use of waste (secondary) materials is recognized as being of benefit to both environment and society. Of the various waste materials, the steel

slag can be considered reasonable alternative sources of aggregate for asphalt mixture productions.

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BIOGRAPHIES

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