IDENTIFICATION OF SUITABLE SELF HEALING MATERIAL FOR THE ASPHALT PAVEMENTS

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Abstract-*The pavement losses its strength, durability and required level of performance due to fatigue failure of the asphaltic layers under the repeated cycles of heavy traffic loading ,extreme temperature, environmental factors such as moisture, rainfall etc. The self-healing technology used in pavements eliminates the crack, ageing and failure of the pavements and hence reduces the need of the frequent and costly maintenance of the pavements lowering the life cycle cost. The basic principle behind the self-healing is using the material property to detect the cause for damage and repair the damage (itself or by external intervention). Asphaltic mixes are self-healing materials since they have the capacity to close micro-cracks at higher temperatures or under external force. To improve their self-healing, asphalt mixes are modified with inductive agents that can be heated and in that way healed through applying alternating magnetic fields with the help of an induction coil or material and this is named induction healing.*

Keywords: **Bitumen, Steel slag, Marshall Stability, Induction heating.**

1. INTRODUCTION

Self-healing is the process where an asphalt can partially recover from damage and produce an increase in lifetime of roads and can reduce the need for maintenance. It also reduce road disruption and reduce economic and environmental impact. Anyway this process occurs naturally in absence of traffic loads and in ideal conditions of temperature, which helps in melting and flow of bitumen filling the cracks. The different types of additives added in asphalt mixtures helps in overcoming and improving their healing capacity. These additives include encapsulated rejuvenators, nano particles and metallic particles, and they are heated by electromagnetic induction or microwaves. There are numerous publications in which steel fibres and steel slag from waste materials are replaced in aggregates for their modification, to produce as good healing pavement material. Other types of wastes where used in coarse aggregates such as steel grits , and nano particles like micro capsule are used assuring equal or even enhanced performance .The steel slag is replaced as aggregates in pavement. When cracks are caused due to various loads it affects the quality of road .So with the help of self-healing process the crack are repaired by producing magnetic induction. This helps the steel slag to fill the cracks. This helps in an increase in lifetime and reduction in maintenance cost.

2.AIM & OBJECTIVE

1. To study the effect of aggregate gradation on the design of flexible pavement (dense graded aggregate) and replacement of steel slag as coarse aggregates for pavement construction.
2. To conduct basic tests on aggregate and bitumen.
3. To identify the proper gradation for pavement mixtures.
4. To identify the suitable material to reduce and heal the crack formation on pavement.
5. To recommend a suitable and cost efficient material for self-healing.

3. RELATED WORKS

Q.Liu et al (2013). According to their study it indicates that the healing potential of porous asphalt are enormously increased with induction heating because of the reinforcement of steel wool and these results indicates that the healing potential of porous asphalt are enormously increased with induction heating because of the reinforcement of steel wool.

Miss. Gauri et al (2017). Their study helps to find and study the different technologies like induction heating, nano particles and rejuvenators. The different technologies used in self-healing pavement produce increment in lifetime, less energy consumption and cost reduction.

Erkut Yalcin et al (2018). Their journal is used to study about self-healing asphalt by induction using electrically conductive fibres. The results provide increase in healing potential, decrease in raveling and improving the durability of the pavement.

Yahya Agzenai et al (2014). Their study deals with the methodologies used for self-healing paying particular attention to embedded micro capsules, nano - fibres and microwave and induction heating and also used in outlining different technologies, nanotechnologies and methodologies used for self-healing paying particular attention to embedded micro capsules, nano - fibres and microwave and induction heating.

Ali Azhar Butt et al (2012). Their study deals about the healing capacity of bitumen could have significant impact on a lifetime of asphalt highways and as such have significant effect on the energy consumption and the overall environmental impact and bitumen self-healing capacity can be significant reduction in greenhouse gas and energy usage.

Quantao Liu et al (2012). Their study deals about reducing rutting and raveling in pavements, as it causes high damage to layer and hence the layer has to be replaced. As the result they reduced raveling by inducing steel fibres to trigger the induction healing process.

Pradip kandel (2014). Their study were used in findings regarding the study of the self-healing mechanism in the bituminous binder with importance on its implication the durability of the asphalt pavement. By inducing micro capsules they state that the maintenance cost is reduced and increase in life cycle.

4. PAVEMENT MATERIALS

4.1 AGGREGATE

The aggregates are classified into two types. The two types of aggregates are coarse aggregates and fine aggregates. The aggregates retained up to 4.75 mm sieve are called as coarse aggregates. Fine aggregates along with stone crusher dusts were collected from a local crusher with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. Whose specific gravity has been found to be 2.78.Aggregate passing through 0.075 mm IS sieve is called as filler.

Figure -1: Different sizes of aggregate sample.

4.2 BITUMEN

Bitumen is defined as a tar like mixture of hydrocarbons derived from petroleum naturally or by distillation and used for road surfacing and roofing. Bitumen is a, black and highly viscous liquid or semi-solid form of petroleum. Viscosity grade bitumen VG 30 used as a binder in this project for preparation of mix.

4.3 STEEL SLAG

Steel slag is a by-product of steel making. It 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 slags are utilized in roads as construction and paving materials, since its physical properties are similar to gravel.

Figure -2*:* Steel slag of 1mm diameter

5. SELF HEALING

Self-healing is defined as the process of recovering of pavement by itself using an external additive. The steel used as additive in asphaltic mixtures helps in the process of self healing.as the ageing of roads occurs it causes cracks, so the steel slag mixed with pavement are heated with alternate magnetic field and induction heating .This process helps to melt the steel slag and it decreases the viscosity of the bitumen, and hence the melted steel slag along with bitumen helps to fill the cracks. This process of self-healing helps in reducing maintenance cost, reduce ageing of roads and produce good quality roads. The Fig. No. 3 given below shows the self-healing process.

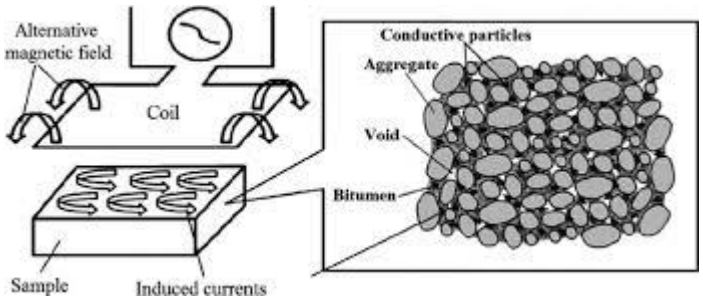

Figure -3: healing process

6. METHODOLOGY

The required samples are collected. The required laboratory tests are done for aggregate and bitumen. For aggregates the following tests are done. They are impact value test, crushing value test, Los Angeles test and shape test. For bitumen the following tests are done. They are viscosity test, softening test, penetration test and flash point test. Then the additives are added and Marshall Molds are prepared for Marshall Stability test. The bulk density, Marshall Flow and Marshall Stability is found from Marshall Stability test. The obtained values are checked with the interpretation values for good result and according to the values graphs are plotted. From the graph the result is obtain. The conclusion and recommendations are given according to the result obtained.

7. EXPERIMENTAL TESTING AND ANALYSIS

Pavement material analysis is an important factor for cost efficient, durable and safe transportation system. Through the analysis process only we came to know about the characteristics of the pavement materials in terms of quality.

7.1 Test on aggregate

The method used for testing the aggregate is IS-2386 (PI – PIV). The following tests are done and the results are obtained. The impact value test – 17.66%,The flakiness and elongation index test – 9.3%& 12%,The specific gravity test – 2.64,The water absorption test – 0.195%,.Aggregate test results are shown in Table No. 1.

Table -1: Aggregate test results

Sl. No.	Description of Test	Specification As Per MORTH Table-500-18	Test Method	Test Result
1	Impact Value Test	Max – 24%	IS – 2386 (Part 4)	17.66%
2	Flakiness & Elongation index	Max – 35%	IS – 2386 (Part 1)	9.3% & 12.5%
3	Specific Gravity Test	1.5 – 3	IS – 2386 (Part 3)	2.64
4	Water Absorption Test	Max – 2%	IS – 2386 (Part 3)	0.195 %

7.2 Test on bitumen

The method used for testing the bitumen IS: 1203-1209-1978. The following tests are done and the results are obtained. The penetration value of bitumen is 54.95 mm, the softening point of bitumen and modified bitumen is 47.5 ºC and the specific gravity of bitumen is 1.006 respectively, Bitumen test result shown in Table No. 2.

Table -2: Bitumen test results

Sl. No.	Description of Test	Unit	Result obtained for Bitumen
1	Penetration Test	mm	54.95
2	Softening Point Test	ºC	47.5
3	Specific Gravity Test	-	1.006

8. Marshall Stability

Marshall Stability test is mostly used for pavements. This test is conducted to find the optimum binder content of the aggregate mix. Marshall Stability is used to measure the maximum load sustained by the bituminous material. It is also tested to find the resistance of bituminous material against stresses, like rutting and shearing.

8.1 Marshall Values

The Marshall Stability values obtained for the 25%, 50% and 75% of steel slag are shown in Table No. 3.

Table -3: values obtained from Marshall Stability

Steel slag (%)	Maximum Stability(KN)	Flow (mm)	Air voids (%)	Voids filled with bitumen (%)	Optimum binder content (%)
25	19.45	2.84	4.84	72.53	5.56
50	23.69	2.84	4.72	73.13	5.62
75	17.52	3.45	4.34	73.32	5.70

The Marshall Stability, flow and bulk density values obtained are represented in graph below. The graphs are plotted and compared with conventional mix. The graphs are plotted for 25%, 50%, 75% replacement of aggregates with steel slag and compared with values of conventional mix as shown in Fig. No. 4, Fig. No. 5 and Fig. No. 6.

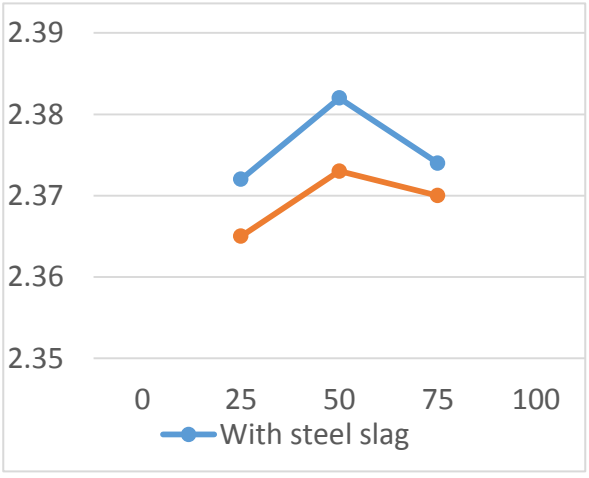

Chart -1*:* Comparison of bulk density with and with and without steel slag.

Chart -2: Comparison of Marshall Stability with and without steel slag

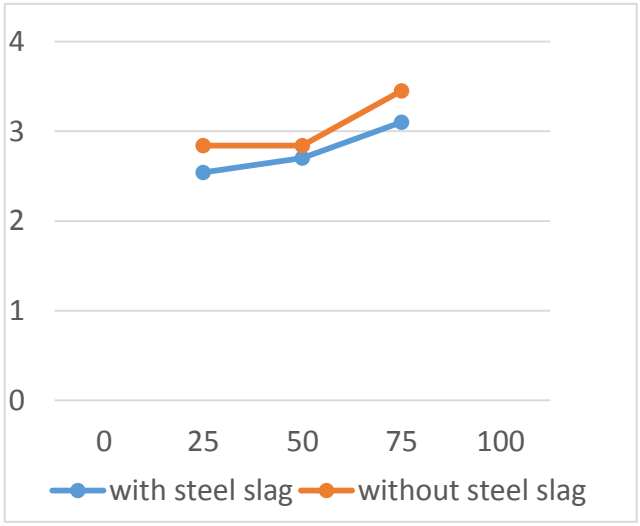

Chart -3*:* Comparison of Marshall Flow with and without steel slag

The graphs are plotted for 25%, 50%, 75% replacement of aggregates with steel slag and compared with values of conventional mix.

By comparing the above graphs it is found that 50% steel slag gives the best result, because when compared 25% and 75%, 50% slag used has higher stability than the other two slags. So it is concluded that 50% steel slag is better for self-healing

Pavement and it is found that steel slag has lower flow value, it's because the steel slag has porous and dense characteristics.

9. Self-Healing Process

This process is conducted to find the healing ratio (HR) of the specimens. The samples are freezed for two days, until the core of the specimen are freezed. The freezing process is done to make the specimen fragile and easy to break. The specimen is then breaked with the help of three point bending machine. After testing the specimen the resistance before healing is noted (Rbh). After breaking the specimen is stored in room temperature of 25ºC for two hours. Then the specimen is placed on the induction heating for healing the specimen. The specimen was placed at a distance of 3cm from the coil. The specimen was

kept at room temperature for 24 hours and the freezed for 24 hours. Then the specimen is breaked again with three point bending apparatus and the resistance is noted as resistance after healing (Rah).

HR = Rah / Rbh

10. Result Analysis

The specimens are heated for 3 minutes by induction. The time the specimen was in induction (s) and the Intensity applied in during that time (A) is noted. Each specimen of steel slag with percentages 25, 50 and 75 are taken.

The specimen with 25% steel slag was heated for 180s at an intensity of 500A. The healing ratio obtained was 37% and the surface temperature of the specimen was 65ºC. For 50% steel slag, the specimen was heated for 180s at intensity of 500A. The healing ratio of the specimen obtained was 52% and the surface temperature was 81% and for 75% steel slag the specimen was heated for 180s at an intensity of 500A. The healing ratio obtained was 56% and the surface temperature was noted to be 110ºC.

Conclusions

In Analysis from the laboratory test data combined with literature search and field investigation of asphalt mixtures it is conclude that 50% steel slags are better when compared to 25% and 75%. As 50% steel slag has better stability, healing ratio and surface temperature. The Marshall stability is increased in addition of steel slag when compared to the conventional. The flow rate is higher because the steel slag are porous in nature and this also helps in the cooling speed of bitumen. The porous nature of steel slag also increase the percentage of voids From the economic point of view, use of steel slag in roads may reduce the cost of extracting natural aggregates. The steel industries may also reduce the cost for disposing the steel slags.So it is economical and it also reduces CO2 emissions. So steel slag can be used as self-healing material as it is waste thrown out of industries, so it costs low and help in reduction of maintenance cost.

From the above analysis, the strength of the material is obtained through Marshall Stability. Beyond that for a design of asphalt pavement the traffic data as well as the CBR data plays a major role in it. In order to enhance the asphalt pavement design and to reduce the pavement composition as well as the base coarse and sub base coarse can be reduced and result can be made economical without compromising the strength.

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