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A REVIEW FOR EVALUATING THE INFLUENCE OF WASTE MATERIALS ON THE STRUCTURAL PERFORMANCE OF BITUMINOUS MIX

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Abstract: On the basis of past studies, several methods were identified for utilizing different waste materials i.e. plastic waste, industrial waste, agricultural waste and many more in road construction resultant in a sustainable environment. Use of different waste materials as the replacement of bituminous was found appropriate for the road construction (flexible pavement) as different properties of bitumen were found to be increased or within the limit as specified by Indian standards. Therefore, waste material can be utilized in the construction of low volume roads (i.e. traffic movement will be minimum) which will be beneficial and economical. The main problem which hinders the development of such technologies is the absence of proper guideline of mix design procedures regarding the same. From the present study, it is revealed that the waste materials can be utilized to create a sustainable environment without compromising the actual requirements (i.e. strength). From the future point of view, a study can be extended by proposing an alternative of bitumen (based on waste material) for construction of flexible pavement or maximum utilization of waste material by mixing these wastes in the combined manner (by looking at their chemical properties) in order to replace the bitumen partially or fully.
Keywords: Bituminous Mix, Flexible Pavement, Sustainable construction

1. INTRODUCTION

According to present scenario, Population is increasing day by day and people are using moreplastic polymers, automobiles etc. and due to this pollution is also increasing day by day with waste polymers. There are different challenges coming in day-to-day life for decomposition of waste polymers. There are need of disposal of these waste materials because if these waste materials will not have decomposed then they will remain same on earth for hundreds of years which can increase environmental pollution. There is a solution of decomposing this material is recycling or reusing the waste materials into useful way.

There are new advance researches into new and innovative techniques for utilizing waste materials. There are many private companies and highway agencies completed many advance researches and projects for utilising the waste polymers for road construction which are environmentally suitable and by using it performance will also increase. These studies are done for trying to match safe and economical disposal of waste material or for more cost efficiency in road construction. These studies mainly show the waste materials which is having substitute for conventional construction material. In the researches there is main focus on new and innovative invention for utilizing waste materials.

2. Previous Research Review on Bituminous Mix

Reddy et al. (2017) performed a study on the properties of pavement using waste plastic in Road Construction. The materials used in the study were bitumen, waste polyethylene terephthalate, crushed granite (coarse aggregate). Marshall test was conducted to obtain a crushing value, impact value, los angeles abrasion value, flakiness index, Elongation index, the specific gravity of coarse aggregates, the specific gravity of fine aggregates, water absorption test values of aggregate. Similarly, physical properties of bitumen like penetration, softening point, ductility, flash point and fire point, specific gravity, and viscosity were also recorded. The optimum binder content was found to be 5.5% for

80/100 grade of bitumen with the stability value of 1190 kg. The flow value along with Maximum stability was 3. 6mm. Gm was found to be maximum of 2.394 gm/cc at 5.5% of bitumen. Percent air void (Vv) varied from 2.5% to 4% by different % from 5% to 6%. Vv was found to be 3.5% with the bitumen content of 5.5%. Plastic was added to the hot aggregate mix with a varying range of 0-12%.
The results showed that with the increase in the % of plastic waste the optimum stability was found to be in the range from 1930 to 1950 kg. The flow values varied from 4.0 to 4.5mm at 8% of plastic waste. The bulk density was found to be maximum b/w 2.29 to 2.35 gm/cc at 8% of waste plastic, and there was a decrease from 2.14 gm/cc at 12% plastic. The study concluded that the Vv was found to be 4.9%to 4.6% at 8% of plastic waste. The properties of bitumen were increased by adding 12%-14% plastic waste as compared to unmodified bitumen. This study also approached towards preserving our environment.

Sultana and Prasad (2012) performed a study on the use of waste plastic as a strength modifier in the surface course rigid and flexible pavement. The materials used in the study were waste polymer low-density polyethylene, High-density polyethylene and polypropylene (PP), bitumen 80/100 penetration grade, cement concrete and water. Plastic coated aggregates, polymer modified bitumen, and concrete cubes were prepared. Aggregate tests, Rheological tests, Performance tests were done on modified mix and unmodified mix.
The results showed, increase in properties of aggregates like impact value, abrasion value, and los-angeles abrasion value. On the basis of result, penetration and ductility value decreases and softening point value increases. Marshall stability test was conducted both on plastic coated aggregates and modified bitumen with waste material and marshall stability value increased by addition of waste material in mix. Loss of stability test resulted that mixes with an index of more than 75% were approved. On the basis of test report, properties of aggregates were improved by using waste material with aggregates. The rheological properties were also improved by adding waste plastic material to unmodified bitumen mix. Penetration and ductility value decreases and softening point value increases. The marshall stability test concluded that low-density polyethylene (LDPE) showed better values as compare to polypropylene (PP). The optimum value for low density poly ethylene was noted 8% for sample made with waste plastic material. On the basis of performance test there was an improvement in flexible pavements than rigid pavements.
Shedame and Pitale (2014) performed a study on bituminous concrete containing plastic waste material. The materials used in the study were aggregates of size (20mm, 10mm), bitumen (60/70grade), stone dust and cement as filler, waste plastic in shredded form. The penetration test, Ductility test, Specific gravity test, and Softening point test were performed on bitumen. On Aggregates Specific gravity, Water Absorption Test, Impact value test, Abrasion test, crushing value test, stripping value Test were conducted. Marshall stability test was carried out to determine the Optimum Binder content for bitumen content (BC) mixes. The properties that were checked in this test included stability, flow value, Bulk specific gravity, Air voids, Voids filled with bitumen and Voids in mineral aggregate. The Plastic Waste was added to 0% to 1% by the increment of 0.25%. Marshall specimen with varying waste plastic content was tested for Bulk density and Stability. The average Optimum Waste Plastic Content value was 0.76%.
The study concluded that when 0.76% plastic by wt. of aggregate and 3% filler was used, it improved the volumetric properties of bituminous mixes which resulted in better performance of BC with plastic waste. Addition of plastic increased the melting point of bitumen. Plastic roads idea was eco-friendly and also increased the road life along with being eco-friendly.

Sutradhar et al. (2015) utilized stone dust, waste concrete, and brick dust as filler material in the bituminous mix design. In this study coarse aggregate of size 2.36 mm, bitumen of grade 85/100, fine aggregates which were kept in 0.075mm sieve and waste filler material like fine sand and stone dust mix, waste concrete dust and brick dust was used as a material. For testing purpose, the marshal test was conducted. According to the test result, the optimum bitumen content for brick dust and waste concrete dust was found similar to the conventional filler material. It was concluded that the waste

concrete dust and brick dust is having the same properties as compared to conventional one and can be used as filler materials.

Somani et al. (2016) conducted a study on strengthening of the flexible pavement by using waste plastic and Rubber. The materials that were used in the study were low-density polyethylene (LDPE), CRMB, aggregate, and bitumen. For aggregate, the tests that were carried out were aggregate impact value test, aggregate crushing value test, flakiness, and elongation index test. For bitumen the tests that were carried out were penetration test, softening point test, ductility test, and viscosity test. Semi-dense bituminous concrete was prepared by adding conventional bitumen with different %s of LDPE and bitumen with the addition of different %s of CRMB.

The results depicted that the Marshall stability and the density will be increased with the addition of vitamin content was up to 6 %. All the other parameters or properties were found as per the specification of MORT&H. It was observed that the mixing of 8% LDPE and 6% bitumen content will result in the higher Marshall stability value (i.e. 945 kg with 3. 26 mm flow value).

Shaikh et al. (2017) conducted a study on the Use of Plastic Waste in Road Construction. The materials used in the study were bitumen 60/70, aggregates, cement, and shredded plastic waste of 2.36mm size. Marshall stability test was performed on both the modified and unmodified bituminous mix. On aggregate the tests performed were aggregate impact value, los angeles abrasion test, water absorption test, specific gravity test, stripping value test. On bitumen the tests performed were penetration value test, ductility test, flashpoint test, fire point test, Softening point test. Marshall stability test was then performed by adding plastic waste. The specific gravity increased from 2.5 to 2.66 and 2.77 on the addition of 10% and 15% plastic content respectively. Aggregate impact value decreased from 10.79% to 8.94% on addition of 15% plastic. Los Angeles abrasion value declined from 12.85% to 10.65% on addition of 15% plastic waste. Water absorption value decreased to 1.1% at the plastic waste of 15% and stripping value was decreased to nil by adding 15% plastic waste. On addition of 15%, plastic waste by wt. of bitumen the marshall stability value increased from 950kg to 1980kg, and the flow value increased from 3.1mm to 5mm at plastic waste of15% by wt. of bitumen. Thus, the study conducted that modified mix improved the marshall characteristics. With the addition of plastic waste marshall stability value increased, flow value decreased, thus it could withstand heavy loads, hence, increasing the durability of roads and also preserving the environment. Recently,

Sharma et al. (2018) examined the performance of bituminous paving mix containing waste plastic. The material used was crushed basalt type of course aggregate 20 mm, crushed basalt type of fine aggregate 2.36 and down,80/100 penetration grade bitumen, basalt stone dust, and cement as a mineral filler. While the waste plastics namely polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), low-density polyethylene (LDPE), high-density polyethylene (HDPE) was used in the shredded form. Marshall Stability test was carried out with varying % of plastic waste in order to check the stability of the mix. Later, a comparison b/w the results of BC (Bituminous concrete) mix with waste plastic and plain BC mix was made. Consequently, the stability value of optimum plastic content OPC (optimum plastic content) was found to be 30.1, which was much higher than the optimum bitumen content OBC (optimum bitumen content). The volume of voids in BC mix containing plastic waste was found lower than the plain BC mix. These results were within the parameters of MORT&H-2001 specifications. The test concluded that the OPC mix showed higher stability as compared to OBC mix and intermolecular binding b/w bitumen and waste plastic enhances the strength, durability, and life of roads.

Sarma and Srikanth (2018) utilised waste polythene in the bituminous paving mix design. The materials used in the study were bitumen, aggregate and waste plastic. Marshall stability test was performed and carried out in two parts to determine optimum bitumen content (OBC) and optimum plastic content (OPC). Different samples were made with different ratio of bitumen, aggregates, and plastic. After that test was conducted at the temperature of 60°c to check the OBC which was found to be 5.8%. Later, disposed milk packets were used to determine OPC. In this. The specific gravity and softening point were taken from the report of milk packets manufacturer and report specified the

specific gravity and softening point value around 0.92 and 115°C respectively. So according to the result, the value for plastic content corresponding to maximum stability was equal to 10%. The value of binder content corresponding to maximum bulk specific gravity was found to be equal to 7.5%. Average of the above values came out to be 8.75%.
The results from the test stated that, the OBC was 5.8% and the OPC was concluded to be 8.75%. Thus, it was concluded that addition of plastic waste material content in bitumen increases the stability as comparison to conventional bituminous mix.
Tiwari et al. (2018) conducted a study on modified bituminous binder using plastic waste. The materials utilized in the study were bitumen 60/70 grade, plastic waste (LDPE) shredded into the size of 2.36mm. Bitumen was modified by melting at a temperature of 150°c and adding shredded pieces of low-density polyethylene (LDPE) ranging b/w 2.36mm to 4.75mm. Different tests like penetration test, softening point test, ductility test were performed on modified bitumen. The results showed that penetration value of plastic modified bitumen was reduced by 19.4% for LPDE waste. By adding 2% and 4% plastic the penetration values were 65mm and 62mm, this led to an increase in strength and load-bearing capacity. Ductility value was decreased by about 21.79% for plastic modified bitumen. For 2% to 10% addition of plastic ductility value decreased from 75cm to 61cm. Softening point value increased by 18.6% when plastic was added. The results showed that on the addition of 2% and 4% plastic the softening point in increased to 49°c and 52°c respectively. The study concluded that use of plastic waste in the proportion of 2% -4% gave penetration values and softening point under the IS code (IS-1203-1978) specifications. Adding 2%-4% plastic higher softening value of 52°c was obtained which helped in withstanding higher temperature susceptibility. In the same way decrease in penetration value gave higher load-bearing capacity. Addition of plastic waste to the bituminous mix also reduced its aging. Thus, it was proved that using plastic waste modified bituminous mix in road construction increased the durability of roads.
Wayal and Wagle (2013) investigated a study on the use of waste plastic rubber in aggregate and bitumen for road materials. The material used in this study was aggregate, bitumen, plastic, and rubber. Different tests were performed to calibrate different properties i.e. crushing values, impact value, abrasion value, the specific gravity of aggregate and bitumen penetration value, ductility, softening point. For checking moisture absorption and void measurement hot stone aggregates (150°c) is mixed with hot bitumen (170°c) and coated with rubber and plastic. This showed a decrease in porosity and improve in quality with respect to soundness, voids and moisture absorption. The soundness test confirmed that the plastic and rubber-coated aggregate didn't show any wt. loss. To study the aggregate impact value, the aggregate was coated with 1%and 2% plastics and rubber by wt. and then subjected to aggregate impact value test. It was seen that the coating of plastic and rubber on aggregate improves the quality. Los Angeles abrasion test found out that there was less wear and tear values of 1% and 2% plastic and rubber-coated aggregate as compared to conventional aggregates. Softening point, ductility and penetration point of bitumen was studied by heating bitumen 10-140 degrees, to this 10% and 20% plastic and crumbled rubber (split in 5%and 10%) was taken in proportion by wt.. Then these values were compared with the conventional values and found better. Hence proving that use of waste rubber and plastic increased the durability and life of roads lastly, Marshall stability test was performed to determine the stability of bituminous mix. For this 1200 GM's of mix was taken with thickness 63.5 mm, approximately 1200 GM's of filler and aggregate was heated at 180-200°C, the values were compared with the conventional mix. This study concludes that on adding 8% polymer and crumbled rubber in the blended mix, the Marshall test, flow(mm), Gmb(gm/cm3), AV (%), VMA (%)VFB (%) increases compared to conventional mix.
Vashisht and Saini (2017) utilized waste plastic and CRMB in the flexible pavement. In this study, the wet and dry process was adopted for preparing the modified bitumen. Samples were prepared according to the ministry of road transport and highway (MORT&H) specification. In the wet process, first bitumen was heated at the temperature of 160°C and temperature was recorded at the time of softening of material. Later, waste material was added in the mix for avoiding agglomeration in the

material. In this % of modified agent vary from 1% to 16 %. In the dry process, it was only done with plastic waste by cutting it into small size of around 3mm- 6mm and mixed with the aggregate at the temperature of 165°C. On the other hand, bitumen was heated at a temperature of 160°C for having good binding strength. After that sample was made with 8% of plastic waste and 16% of plastic waste. In the present study, CRMB was not utilized in order to make the sample because of the poor bonding quality (i.e. b/w CRMB and aggregates).
As per the result, impact value was found to be increased up to 10% due to the addition of plastic waste (i.e. worked as a coating material for aggregate). The specific gravity of plain and modified aggregates was found to be same while penetration value and ductility value of modified bitumen was lower than the conventional one.

3. CONCLUSION

The reviewed studies demonstrate the significant potential of incorporating waste materials, particularly plastics and rubber, in bituminous mixes to improve pavement performance and durability. Research by Reddy et al. (2017) and Sultana and Prasad (2012) found that using plastic waste in road construction enhances the stability, density, and volumetric properties of bituminous mixtures. Similarly, Shedame and Pitale (2014) observed improvements in the bulk density and stability of bituminous concrete with the addition of shredded plastic. The studies also highlight the environmental benefits of utilizing waste plastics in road construction, as seen in Sharma et al. (2018), who reported higher stability and enhanced durability of bituminous mixtures containing polyethylene terephthalate (PET) and other plastic materials. Research by Somani et al. (2016) and Shaikh et al. (2017) confirmed that modified bitumen with added plastic waste results in better Marshall stability, lower air voids, and reduced wear and tear, thus increasing the load-bearing capacity and lifespan of pavements. Additionally, investigations into the use of rubber waste by Wayal and Wagle (2013) showed improvements in moisture resistance, aggregate quality, and durability. Overall, the reviewed studies suggest that incorporating waste materials in bituminous mixes can significantly enhance road performance while promoting environmental sustainability.

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