A Brief Study on Industrial Waste used in Bituminous Mixes

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Abstract— Highway construction involves huge investment. A precise engineering design may save considerable investment, as well as reliable performance of the in-service highway can be achieved. Two major consideration are taken – pavement design and the mix design. This study emphasizes on the mix design considerations. A good bituminous mix design is result in a mix which is adequately strong, durable and resistive to fatigue and permanent deformation and environment friendly and economical. Due to the problems related to excessive waste generation, the need of recycling and reusing of waste material is arising for achieving the sustainability in construction activities. The present study focuses on the utilization of industrial waste as a filler material in flexible pavement. Fillers are very important in engineering properties of bituminous paving mixes. An attempt has been made in this investigation to assess the influence of mineral fillers such as ceramic dust, stone dust, crumb rubber and marble dust in bitumen paving mixes. The fillers used in this study are likely to solve partially the solid waste disposal of the environment. Four types of fillers was taken from different industries i.e. Ceramic Dust (CD) from ceramic industry, Crumb Rubber (CR) from automobile industry, Marble Dust (MD) from marble industry and Stone Dust (SD) from stone crusher. To check the suitability of these industrial wastes as filler in bituminous concrete, Marshall Specimens were prepared by adding filler in different doses i.e. 2%, 5% and 8%.

Keywords: Bituminous mix, stone dust, crumb rubber, ceramic dust, marble dust aggregates

I. Introduction

Industrial waste is the waste produced by industrial activities, which includes any material that is rendered useless during a manufacturing process such as that of industries, factories and mining operations. Most of the industrial wastes such as fly ash, stone dust, marble dust, end of life tires, granite dust, ceramic dust, blast furnace slag, construction waste etc. are non-combustible and non-biodegradable. The common method adopted for the disposal of industrial waste is landfilling. Lesser available space and shortage of landfills leads to the disposal problems and promotes the illegal dumping of waste in water bodies, on hill slopes, in roadside areas etc. Due to the problems related to excessive waste generation, the need of recycling and reusing of waste material is arising for achieving the sustainability in construction activities. The present study focuses on the utilization of industrial waste as a filler material in flexible pavement.

The pollution and disposal problems can be minimized by properly utilizing these materials in highway construction. In road construction, waste materials' use have great economic and environmental benefits. High performance and environment friendly roads can be constructed by the use of many waste materials in bituminous paving mixes.

II. Ingredients of Bituminous Mix

A. Bitumen

Bitumen acts as a binding agent to the aggregates, fines and stabilizers in bituminous mixtures. Bitumen must be treated as a visco-elastic material as it exhibits both viscous as well as elastic properties at the normal pavement temperature.

B. Coarse aggregate

Coarse aggregate should have crushed rocks retained on 4.75 mm sieve. The coarse aggregates must possess a cubic shape and rough texture to resist rutting and movements. It offers compressive and shear strength and shows good interlocking properties.

C. Fine aggregate

Fine aggregates are those particles that passes through 4.75 mm sieve and retain on 0.075 mm sieve. Fine aggregates usually have 35% to 45% by mass or volume of total aggregate. It fills the voids in the coarse aggregate and stiffens the binder.

D. Mineral filler

The materials passing through 0.075mm (No. 200) sieve known as fillers. Filler plays an important role in properties of bituminous mixture particularly in terms of air voids and voids in mineral aggregate. The main function of filler is that of filling voids in coarser aggregates, which increases the density, stability and toughness of a conventional bituminous paving mixture.

III. Application of Filler in Bituminous Mixes

Materials that can be used in highway construction as filler are Fly ash, stone dust, marble dust, waste tires, brick dust, concrete dust, granite dust, ceramic dust, blast furnace slag, construction and demolition waste etc. Industrial wastes can be used as filler in bituminous mixes. Fillers have a significant effect on the performance of asphalt paving mixtures in terms of permanent deformation, fatigue cracking, and moisture susceptibility. According to the Ministry of Road Transport & Highways (MORTH), filler content should lie between 2 to 8 % of the total weight of the given aggregates.

IV. Objectives of the Study

The present study is undertaken to explore the possibility of using the industrial wastes as filler in bituminous concrete (BC) mix and to study their effect on strength and performance parameters of the mix. Industrial wastes such as crumb rubber, ceramic dust, and marble dust was used as filler in this study. Conventionally used stone dust was included to prepare control mixes for comparison of results.

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- To study the impact of different types of fillers on the Marshall mix design parameters at their different percentages.
- To calculate the optimum filler content (OFC) for different types of filler.
- To study the impact of the fillers on the moisture susceptibility of the Marshall Mix samples using Retained Stability Test.
- To study the impact of the fillers on the rut resistance of the mix and evaluate their performance by using Wheel Tracking Test.

V. Literature Review

Chari et al. (1984) studied the influence of lime and stone dust fillers on fatigue performance of bituminous concrete mixes. Of the two fillers, lime had a substantial influence on fatigue properties, although static strength remained more or less the same for both fillers.

Katamine (2000) tested three wearing course mixes with three different samples of oil shale fillers, which contained three different oil contents, and a standard mixture containing limestone filler. The Marshall test results indicated that the incorporation of oil shale filler instead of limestone filler does not alter the optimum binder content of the mixes nor increase the stability or the Marshall quotients of the mixes.

Karasahin and Terzi (2007) used marble dust as filler in asphalt concrete mixes. The Marshall and plastic deformation tests showed that limestone and marble dust gave almost the same results. Marble dust possess high plastic deformation and so it is for low traffic volume roads.

Sharma et al. (2010) have shown that the presence of high calcium oxide in fly ash is an important parameter governing the strength characteristics of bituminous mixes, and up to 7% fly ash can be used as filler in BC mixes. Panda et al. (2018) evaluated the performance of recycled concrete aggregates (RCA) in dense bituminous macadam (DBM) with two different types of fillers i.e., cement dust and stone dust. RCA were used in the mixes as coarse aggregates fraction before and after pre-treatment with bitumen emulsions. Various performance tests such as Marshall, indirect tensile strength, moisture susceptibility, dynamic modulus, and wheel-tracking tests were conducted on prepared DBM mixes. This study concluded that the performance of mixes with pre-treated RCA was better than the other mixes and mixes with cement dust as filler produce better engineering properties as compared to the mixes with stone dust as filler.

VI. Methodology

- Collection and characterisation of aggregates, bitumen and fillers were done. The required gradation of aggregates for different percentages of fillers for BC mixes was obtained from MORTH criteria.
- Marshall test was conducted on BC mixes using different types of fillers and by varying different percentages of filler content. Optimum bitumen contents (OBC) and optimum filler contents (OFC) were obtained for different filler.
- For determining the moisture susceptibility of bituminous mixes, retained stability tests were conducted on Marshall specimens containing SD, CD, CR and MD as filler, prepared at optimum bitumen contents, corresponding to optimum filler contents.
- For determining the rut resistance of the mix, the wheel-tracking test was performed at optimum bitumen contents of the filler used.
- After the laboratory experimentation, analysis of the test results was carried out for comparing the impact of utilization of SD, CR, CD and MD as filler in flexible pavement construction.

VII. Material Characterization

Normally, the composition of bituminous mixture is aggregate and bitumin. Aggregates are divided into coarse, fine and filler fractions. The characterization of natural virgin aggregates and bitumen were carried out.

A. Tests on aggregates

Characterization of aggregates and fillers were carried out by conducting the aggregate impact value test, Los Angeles abrasion test, aggregate crushing test, shape test, wet aggregate impact value test, water absorption and specific gravity test.

B. Tests on bitumen

Bitumen fills the voids, cause particle adhesion and offers impermeability. The following properties of bitumen were determined such as Specific Gravity, Penetration value, Ductility Value, Softening Point, Flash and fire point.

VIII. Composition of Aggregates with BC Mixes

The natural aggregates were sieved into individual fractions and recombined them to produce the gradation as specified by MORTH for bituminous concrete. Grading 1 was adopted for preparing bituminous concrete mixes for 50mm thick wearing course as per the MORTH 17 specifications for roads and bridges.

IX. Marshall Test

Laboratory investigations were made by performing Marshall test on bituminous concrete mixes. The standard size of Marshall Specimen were 63.5 mm height by a 101.6 mm diameter. Approximately 1200 g of aggregates and filler required for each test specimen. The aggregates and bitumen were blended together after heated separately at their corresponding mixing temperatures.

X. Retained Stability Test

Retained stability tests were conducted in accordance with ASTM D1075 (ASTM, 2011) specifications to examine the performance of bituminous mixes against the moisture-induced damage. In this test, Marshall stability values of specimens prepared at optimum bitumen contents, are determined before and after the moisture conditioning process. The Marshall specimens were considered conditioned when they have been immersed in water at 60°C for 24 h, and are unconditioned when they have been

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immersed in water at 60°C for a half hour. Retained stability was calculated by taking the ratio of Marshall stability of conditioned specimen to the Marshall stability of unconditioned specimen. For determining the resistance of mixes to moisture damage, the retained stability was obtained by using the equation.

XI. Wheel Tracking Test

Wheel tracking test is used to assess the liability of a bituminous mix to deform plastically at high temperatures under pressure caused by traffic. The susceptibility of bituminous material to deformation is determined by the rut formed by repeated passes of a loaded wheel at a constant temperature of 60°C on a test specimen. The wheel-tracking test was conducted according to the procedure given in EN 12697-22 (BSI 2003). The apparatus consists of a loaded wheel that bears on a sample held on a moving table. The table moves backward and forward with respect to the center of the top surface of the specimen. The total distance of travel is 220 mm. The wheel has an outside diameter of 200 mm and is fitted with a solid rubber tire. Bituminous concrete slabs (specimens) of size 300 × 300 × 50 mm were fabricated by a tire-roller machine. The tests were carried out at 60°C with back-and-forth frequency of 42 passes/min. One new device is the wheel rut tester which is a temperature-controlled wheel tracking device. It measures the rutting which is occurs in laboratory-compacted specimens. The details of apparatus used in for preparation of compacted specimen and carrying out rutting test have been discussed below.

XII. Wheel Rut Shaper

Wheel rut shaper is used to prepare the specimen for wheel rut testing used in research, road construction and highway and airport runway projects. The apparatus employs a rolling wheel of radius 500mm and width 300mm. The specimen is prepared in a mould of size 300mm*300mm*50mm. The weight of the machine is 400 Kg with bearing car moving speed 6 times/minute.

XIII. Wheel Rut Tester

The wheel rut tester is used to determine the resistance of bituminous pavements to rutting at different temperatures and speeds. It can also be used to conduct an ancillary test for bitumen combined material mix proportion design. The wheel rut assembly moves back and forth by a cranked rod mechanism through a link rod connected to a gear box and motor. The vehicle speed is run at 42 rpm by a link rod. The pressure between trial vehicle and specimen is ensured at 0.7MPa due to direct weight of the wheel rut assembly. A displacement sensor is used for measuring the displacement value or the rut depth and the value is acquired from computer in real time.

XIV. Conclusion

- Ceramic dust (CD), stone dust (SD) and marble dust (MD) used as filler in the study shows the improvement in Marshall Stability and density values as compared to crumb rubber. The higher values of Marshall Stability were achieved by using CD and SD.
- In case of crumb rubber (CR), the Marshall parameter showed inferior results as the minimum stability value was achieved only at 5% CR that was marginally above than the required value. Decrease in the stability values occurs due to increase of the rubber particles in the mix because of the softening of agglomerate.
- Higher value of voids filled with bitumen (VFB) in case of CD and SD could be used in normal traffic flow conditions.
- Though the experimental results concluded that MD, SD and CD can be effectively utilized as fillers in bituminous concrete for provision in wearing course, it is recommended that other mix characteristics such as durability, cracking resistance etc. needs to be investigated so as to obtain satisfactory performance of wearing course during its service life.
- Utilization of waste materials such as CD, MD etc. is not only beneficial to decrease environmental problems such as air pollution, disposal problems etc., but there are indirect benefits such as reduction in land wastage etc.

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