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# A STUDY ON THE INFLUENCE OF INDUSTRIAL WASTE USED AS FILLER IN BITUMINOUS MIXES

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**Abstract-** Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment, as well as reliable performance of the in-service highway can be achieved. Two things are of major considerations in this regard – pavement design and the mix design. This study emphasizes on the mix design considerations. A good design of bituminous mix is expected to result in a mix which is adequately strong, durable and resistive to fatigue and permanent deformation and at the same time environment friendly and economical. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions of material combinations and finalizes the best one. Bitumen mix design is a delicate balancing act among the proportions of various aggregate sizes and bitumen contents. For a given aggregate gradation, the optimum bitumen content is estimated by satisfying a number of mix design parameters. Due to the problems related to excessive waste generationFillers play an important role 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%. Marshall tests were conducted on prepared specimens and optimum filler content (OFC) and optimum bitumen content (OBC) for a particular filler was obtained by comparing various Marshall parameters. Retained stability tests were also performed on samples prepared on obtained OFC and OBC for a particular filler. The results indicates that marble dust and ceramic dust have good potential for their use as filler in bituminous mixes. The OFC of the ceramic dust, marble dust and stone dust comes out to be 5 %. The crumb rubber does not perform satisfactorily when used as a filler in bituminous mixes as the stability and flow value does not meet the specified criteria as set by Ministry of Roadsx Transportation and Highways (MORTH). The wheel rutting test was performed on samples prepared for bituminous mixes. The results shows that the minimum rut depth was observed for mixes with marble dust and stone dust as filler followed marginally by ceramic dust as filler. Rut depths were found to be in the same order for marble dust and ceramic dust.

***Key Words*:** Bituminous concrete, Asphalt, Marshall Method, Morth, Fillers

## 1.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. India has a vast network of industries located in different parts of the country and many more are to come in the near future. Million metric tonsindustrial wastes are produced every year. Excessive generation of Industrial waste is creating various environmental and economic problems. The amount of waste generated from industrial waste is estimated to be 12 to 14.7 million tonnes per annum in India. Pavements or highways are regarded as country's backbone, upon which its upswing and progress depend on. All countries normally have a series of programs for building a new road infrastructures or emerging the existing one. Construction of both flexible and rigid pavement include a gross amount of investment to reach better performance oriented and smooth quality of pavement that will endure for long time. In India, where highways are considered as the primary function of transportation, Government of India have been investing a huge amount of money for developing the pavement construction and maintenance. A detailed engineering study may retain significant amount of investment and pavement materials, which in turn achieve a reliable performance of the in-service highway. Hence, to suppress the wretched effect of these materials, a detailed study is necessary to utilize them in bituminous mixes as filler material in a productive way.

### 1.1 History of Bituminous Pavement Mix Designs

A huge outlay of investment is involved in the construction of highway. Considerable investment can be saved by having a precise engineering design. A good performance of the in-service highway can also be achieved by the same. Pavement design and the mix design are the two things of major consideration in this regard. The present section emphasizes on the mix design considerations. During 1900"s, the bituminous paving technique was first used on rural roads – so as to handle rapid removal of fine particles in the form of dust, from Water Bound Macadam, which was caused due to rapid growth of automobiles [Roberts et al. 2002]. At initial stage, heavy oils were used as dust palliative. An eye estimation process, called pat test, was used to estimate the requisite quantity of the heavy oil in the mix. Hveem used the surface area calculation concept (which already existed at that time for cement concrete mix design), to estimate the quantity of bitumen required

[Hveem 1942]. Moisture susceptibility and sand equivalent tests were added to the Hveem test in 1946 and 1954 respectively [Roberts et al. 2002]. Bruce Marshall developed the Marshall testing machine just before the World War-II. It was adopted in the US Army Corpes of Engineers in 1930"s and subsequently modified in 1940"s and 50"s.

### 1.2 Objectives of Bituminous Pavement Mix

The objective of the design bituminous pavement mix is to prepare an economical mixture of sand, stone aggregates and fillers such Fly ash, stone dust, marble dust, waste tires that produces a mix having

1. Sufficient bitumen so as to make sure that pavement is stationary or stable.
2. Sufficient stability to withstand shear deformation under traffic at higher temperature.
3. Sufficient workability for placement as well as to avoids segregation.
4. Sufficient flexibility to prevent early cracks due to deformation by traffic.
5. Sufficient flexibility at low temperatures to avoid shrinkage cracks.
6. Sufficient mix stability the demand of traffic without dislocation or deformation.

## 2. LITERATURE REVIEW

Because of the limitation and lack of available natural resources there has been a significant increase in the demand for using recycled materials. Thus, for the construction of road a number of industrial and domestic waste products are being used. Roads in which bitumen is used as a binder are generally termed as bituminous roads. It is a mixture of aggregates and bitumen. Filler is generally added in it to fill the voids. Fillers modify the properties, improve the performance and thus increase the durability of pavement. Among all the sectors of construction, it is found that waste materials can only be used effectively in road construction provided the laboratory and field performances show satisfactory results. Using waste materials as fillers reduces environmental risk as they get utilized instead of stock piling.

### 2.1 Flexible Pavements

Flexible pavements are those pavements which a have a low flexural strength. Flexible pavements are flexible in their structural action under the loads. Wheel load stresses in flexible pavements are transmitted to the lower layer by grain to grain transfer. Thus, the wheel load which acts on the pavement gets distributed to the wider area and thus there is decrease in the stress with depth. Hence, concept of layered system in used in the design of flexible pavements.

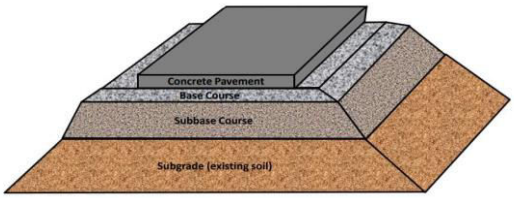


**Fig -1**: Basic flexible pavement structure

### 2.2 Classification of Bituminous Mixes

A combination of bituminous materials, properly graded aggregates and additives forms a bituminous mixture. Classification of Bituminous mixtures used in pavement applications is done on the basis of:-

1. Method of production
2. Composition and Characteristics.

Further on the basis of method of production bituminous mixes are further classified as: -

1. Hot mix Asphalt(HMA)
2. Cold-laid Plant mix
3. Mixed in Place road mix
4. Penetration macadam

### 2.3 Fillers in Bituminous Mixes

Considerable attention has received for bitumen modification reinforcement as viable solutions to enhance flexible pavement performance. 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. Fillers could improve the temperature susceptibility and durability of the asphalt binder and asphalt-concrete mixture. It helps in maintaining adequate amount of void in mix. 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. In 2016 performance of hot mix asphalt concrete when missed with waste material was studied. Materials used in the study were carbonized wood saw dust and PET. On all the samples Marshall Test was carried out. The study revealed that wood saw dust can be used as filler and gave satisfactory results. The study also revealed that PET when used show increase in the Marshall Properties trend. [1]

In 2015 fly-ash was used as filler to determine Marshall Properties of samples containing varying percentage of bitumen content. The study revealed that Maximum stability and unit weight was observed when fly ash was used as filler.

The study further revealed that using high calcium fly ash is good solution for disposal of waste products. [2]

In 2015 stone dust and fly ash were used as fillers and compare with each other. It was observed that Marshall Stability was higher for the sample containing stone dust as filler. Further with the increase in the percentage of bitumen content **flow** value also increased. In case of fly ash it was observed that with increase in percentage of bitumen content volume of voids decreased.[3]

## 3. EXPERIMENTAL PROGRAM

This chapter describes the experimental works carried out in this present investigation. This chapter is divided into two parts. First part deals with the experiments carried outon bitumen tests and second part deals with the tests carried out on aggregates.

### 3.1 Bitumen Tests

Various tests pertaining to bitumen were performed. Softening point test, penetration test, specific gravity test, ductility test and viscosity test were carried out and compared with the specifications laid down by BIS, IRC and MORTH. All the tests were carried out in laboratory and results were calculated. Procedure and Results along with the specifications laid down by BIS, IRC and MORTH are described in the below section

### 3.1.1 Softening Point Test

Bitumen does not change its state suddenly but with increase in temperature it gradually becomes softer. The temperature at which substance attains a particular degree of softening under specified conditions of test is known as softening point. Softening Point for bitumen is determined by Ring and ball apparatus. Apparatus consists of Steel balls (2 in number each having diameter 9.5 mm and weight 2.5g), Brass rings (2 in number each having Depth 6.4mm, Inside diameter at bottom 15.9mm, Inside diameter at top 17.5mm and outside diameter 20.6mm), metallic support for placing pair of rings, heat resistant glass container of 85 mm diameter and 120 mm depth and mechanical stirrer. In this test a brass ring containing test sample of bitumen was suspended in a beaker with liquid bath (water was used as liquid bath). After that a steel ball was placed upon the sample and the medium was heated at a rate of 5°C per minute. The temperature at which the softened bitumen touched the metal plate was recorded as softening point of bitumen.

**Fig -2:** Ring and Ball Apparatus

### 3.1.2 Penetration Test

The consistency of paving grade bitumen is determined by Penetration Test. Bitumen can be classified into different grades with the help of Penetration Test. Penetration test is used to measures the hardness or softness of bitumen. The depth in tenth of millimeter to which a standard loaded needle will penetrate vertically in 5 seconds give the penetration value of Bitumen. The equipment and test procedure have been standardized by BIS. Penetrometer is the apparatus that is used for measuring of penetration value. Apparatus consists of a container (55 mm diameter and 57 mm height), needle with shank, water bath and an assembly attached to calibrated dial). In this test bitumen was softened to a pouring consistency and then was poured into the container.


**Fig -3:** Penetration Test Apparatus

### 3.2 Aggregate Tests

Various tests pertaining to aggregates were performed. Crushing test, Abrasion test, specific gravity test, elongation test, flakiness test, impact values test and water absorption test were carried out and compared with the specifications laid down by BIS, IRC and MORTH. All the tests were carried out in laboratory and results were calculated. Procedure and Results along with the specifications laid down by BIS, IRC and MORTH are described in the below section.

### 3.2.1 . 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 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.

### 3.2.2 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). The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge. Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated.

**Fig -5**: Marshall Machine Test

### 3.3 Marshall Mix Design

Marshall Method of mix design has been adopted in this project. Accordingly aggregates with the grading 2 of IRC and bitumen 80/100 having properties as described in the preceding paragraphs have been used. The objective of bituminous paving mix design is to develop an economical blend of aggregates and bitumen. In the developing of this blend the designer needs to consider both the first cost and the life cycle cost of the project.

### 3.4 Mixing of Materials

Take about 1200 gm of aggregate sample from design Gradation and kept in oven until dried. The aggregate should be heated to 135°C temperature before addition of bitumen. For BC mix bitumen should be added in the aggregate varying from 4.5-6% at an increment of 0.5% by weight of total mix and also mix the fillers concrete dust and brick dust as per the design mix. Three samples should be prepared for each binder contents by compacting 75 blows on both side of sample in Marshall Compactor after 24 hrs. Sample should be de-molded and noted down the weight of sample in Air and in water to determine the bulk density of mix. The sample should be immersed in water bath at 60°C for 40 minutes prior of testing and tested on Marshall Apparatus which gives the Stability and Flow value for each sample.

## 4 RESULTS AND DISCUSSIONS

This chapter includes the test results obtained after the laboratory testing of the bituminous mixes with modified Marshall Method by using of fillers with different percentage of bitumen content. The results were obtained to determine the Optimum Binder Content (OBC) by performing the Stability-Flow analysis and Volumetric analysis for the prepared samples.

### 4.1 Test Results of Marshall Bitumen Mixes

The results of the Marshall test of individual specimens and average Marshall Properties of specimens prepared with concrete dust and brick dust as filler for varying bitumen contents have been presented in tables 1 and 2 respectively.

**Table 1** Marshall Properties of Specimens with Filler Stone Dust.

| Filler content % | Unit weight kg/m$^3$ | Stability kn | | Flow value mm | Air void % | VMA % |
|---|---|---|---|---|---|---|
| 2 | 1036.03 | 10.9 | | 1.67 | 6.67 | 15.91 |
| 5 | 1996.45 | 11.3 | | 2.03 | 7.73 | 16.77 |
| 8 | 1565.6 | 11.9 | | 1.55 | 7.16 | 17.65 |

**Table 2** Marshall Properties of Specimens with Filler Ceramic Dust

| Bitumen content % | Unit weight kg/m$^3$ | Stability kn | Flow value mm | Air void % | VMA % |
|---|---|---|---|---|---|
| 2 | 1036.03 | 17.12 | 1.50 | 6.61 | 15.82 |
| 5 | 1996.45 | 14.70 | 1.33 | 5.86 | 15.95 |
| 8 | 1565.6 | 17.38 | 3.45 | 5.98 | 15.25 |

### 4.2 Comparison of Stone Dust and Ceramic Dust Specimens Results

Comparison for both the specimens is done through graphs below. Further the results have been explained also

#### 4.2.1 Marshall Unit Weigh Curves(kg/m$^3$)

The graphical representation of unit weights for variation in bitumen content from 5% to 6.5% for samples containing brick dust and concrete dust as filler is shown in Fig 1. From the graphs it is observed that both the samples containing brick dust and concrete dust as filler show somewhat equal unit weight. In case of the specimen with concrete dust as filler maximum unit weight is observed at 6.5% bitumen content. Unit weight of specimen with concrete dust as filler is 2400 kg/m$^3$. Also in case of the specimen with brick dust as filler maximum Unit weight is observed at 6.5% bitumen content. Unit weight of specimen with brick dust as filler is 2361 kg/m$^3$.

**Chart -1**: Variation of Unit Weight With %age of Bitumen

### 4.2.1 Marshall Stability Curves

The graphical representation of stability for variation in bitumen content from 5% to 6.5% for samples containing brick dust and concrete dust as filler is shown in Fig 2. From the graph it is seen that with the increase in the bitumen content stability increases. It is seen that specimen with concrete dust as filler has lesser stability than specimen with brick dust as filler. In case of the specimen with concrete dust as filler maximum stability is observed at 6.5% bitumen content. Stability of specimen with concrete dust as filler is 12.7 KN. Also in case of the specimen with brick dust as filler maximum stability is observed at 6.5% bitumen content. Stability of specimen with brick dust as filler is 17.95KN.

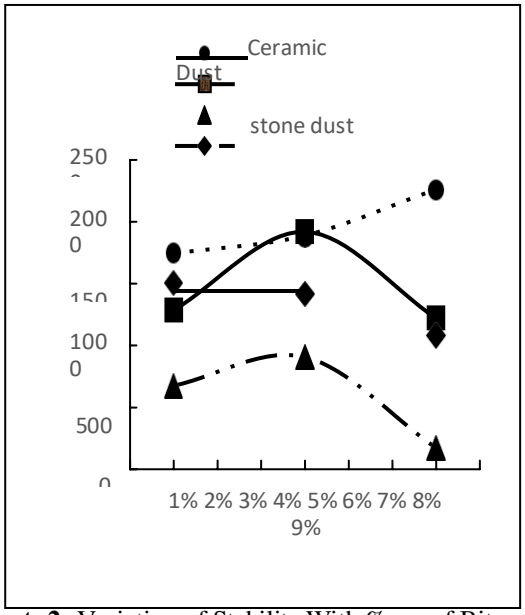


**Chart -2:** Variation of Stability With %age of Bitumen.

## 5 CONCLUSIONS AND FUTURE SCOPE

From the laboratory investigation carried out for determining the suitability of different types of fillers in bituminous concrete, the following conclusions have been made.

a. 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. Marshall stabilityof a mix at OBC with 2% ceramic filler was 1744.8 kg and increased to 2261.5 at 8% ceramic filler.

b. 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 rubberparticles in the mix because of the softening of agglomerate. A decrease in the density and VMA of the mix was observed with the addition of rubber in the mix because of low density of rubber.

c. Higher value of voids filled with bitumen (VFB) in case of CD and SD could be used in normal traffic flow conditions.

d. The highest retained stability value was obtained by marble dust (MD) filler i.e. 87.19%. In case of CR, the retained stability value was lesser than the specified limit, so the use of CR may be restricted to normal rainfall regions with effective drainage or it may be used with anti-stripping compounds in high rainfall regions.

### 5.1 Future Scope

Based upon this research, following recommendations for future studies has been made.

- The present study concluded that the crumb rubber used as filler shows the inferior results as compared to other fillers. More research on the use of crumb rubber as filler in bituminous mixes needs to be carried out.
- Many properties of BC mixes such as Marshall Properties, retained stability and rut susceptibility characteristics have been studied in this investigation. However, some of the properties such as fatigue properties, dynamic indirect tensile strength characteristics and dynamic creep behavior needed to be investigated in future.
- In future, performance of fillers with other grades of bitumen can also be tested and seen whether it can be used successfully or not.

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