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# TO ENHANCE MARSHALL PROPERTIES OF BITUMINOUS MIXES BY USING CONCRETE DUST AND BRICK DUST AS FILLER

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**Abstract-** Asphalt concrete familiarly known as bituminous concrete is a petroleum product. It is used for driveways, roadways, walking paths, curbs and for any project that requires smooth surface. The aim of bituminous mix design is to determine the proportion of its ingredients in order to produce a mix which is strong, durable, workable and economical. In bituminous mixes ingredients used are aggregates, fillers and bitumen. Voids remain in coarse aggregates which are filled by fine aggregates. But all the voids are not filled by fine aggregates. Some of the voids still remain there which are filled by fillers. On adding fillers physical and chemical properties of mix changes and gets improved considerably. Thus it is necessary to find the stability and behavior of bituminous mixes when filler is added in it. Asphalt institute in India, has recommended usage of 4-8% of filler in bituminous mixes. The present study deals with the effect on Marshall Properties of Bituminous mixes using brick dust and concrete dust as filler is studied. For both the bituminous mixes containing brick dust as filler and concrete dust as filler properties were studied and compared with each other. Marshall Method of mix design was used for the purpose or comparison. In this study also tests were carried out on aggregates and bitumen. The results obtained were compared with the specifications laid down by BIS, MORTH and IRC in order to find whether the materials were within the specified limits. Samples were prepared with varying bitumen content using brick dust and concrete dust as filler. Those samples were then tested through Marshall Method. The results revealed that physical characteristics of bitumen improved on adding the fillers. Also stability and flow value of bitumen mix improved. Adding filler also helps in reducing the problem of waste disposal.

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

## 1.INTRODUCTION

The total road network in India has increased from 2 million km in 1990s to 5.4 million km now which in deed is the second largest around the world. Under the new program Indian government plans to develop a total of 66,117 km of roads under different programs such as National highway development project (NHDP), special accelerated road development programme in North east (SARDP-NE) and left wing Extremism(LWE). Under PradhanMantri Gram SadakYojna (PMGSY), Government has planned to spend Rs 1 lakh crore during financial year 2018-20. Further over the next five years Government has decided to invest Rs. 7 trillion for construction of new roads and highways. During the financial year 2017 highway length in India was recorded as 103, 9333 kms. The largest ongoing highway project in India under NHDP is North-south-East-west corridor. It is managed by National Highway authority of India (NHAI) under the ministry of road transport and highways. It consists of building 7300 kms of four lane Expressways connecting Srinagar, Kanyakumari, Kochi, Porbandar and Silchar. 93.5% of the proposed work has been completed till date. North-South corridor is 4000 kms and is via NH 44. East-west corridor is 3300 kms and is via NH 27.

### 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 establish an economical mixture of sand, stone aggregates and fillers such as brick dust and concrete dust that produces a mix having

1. Sufficient bitumen so as to make sure that pavement is durable.
2. Sufficient stability to withstand shear deformation under traffic at higher temperature.
3. Sufficient workability for easy placement. Sufficient workability not only enhances easy placement but also avoids segregation.
4. Sufficient flexibility to avoid early cracks due to repeated deformation by traffic.
5. Sufficient flexibility at low temperatures to intercept shrinkage cracks.
6. Sufficient mix stability to fulfill the demand of traffic

without displacement 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.

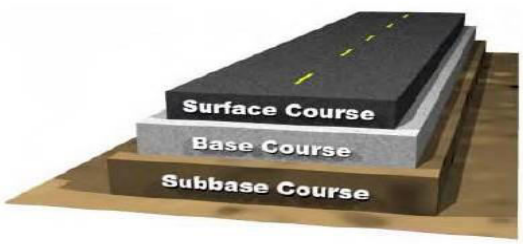


**Fig -1**: Basic flexible pavement structure

### 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. Unsatisfactory performance of traditional road materials exposed to remarkable increase and changes in traffic patterns promoted transportation industry for introducing this technology. Since then, various types of modifiers for bituminous mixtures like polymers and fibers are considered. With the help of various types of stabilizing additives, it has been made possible to improve the operation of bituminous mixes used in the surfacing course of road pavements. The additives such as carbon black, fibers, rubbers, polymers, fly ash, artificial silica, and brick dust or a combination of these materials are used to harden the mastic at high temperatures during production and placement, and to obtain even higher binder contents for increase in durability (Pierce, 2000). Since effect of fillers on bituminous mixes is the focus of the present study, the literature related to that has been presented as a separate session after this.

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.


**Fig-1**: Ring and Ball Appartus

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 Crushing Test

A test is standardized by IS:2386 part-IV and used to determine the crushing strength of aggregates. The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied crushing load. The test consists of subjecting the specimen of aggregate in standard mould to a compression test under standard load conditions. Dry aggregates passing through 12.5 mm sieves and retained 10 mm sieves were filled in a cylindrical measure of 11.5 mm diameter and 18 cm height in three layers. Each layer was tampered 25 times with at standard tamping rod. The test sample was weighed and placed in the test cylinder in three layers each layer being tampered again. The specimen was subjected to a compressive load of 40 tonnes gradually applied at the rate of 4 tonnes per minute. Then crushed aggregates were then sieved through 2.36 mm sieve and weight of passing material (W2) is expressed as percentage of the weight of the total sample (W1) which is the aggregate crushing value.

**Fig -4:** Crushing Strength Apparatus

### 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**: Los Angles 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 Concrete Dust.

| Bitumen content % | Unit weight kg/m$^3$ | Stability kn | Flow value mm | Air void % | VMA % |
|---|---|---|---|---|---|
| 5 | 2365 | 10.9 | 3.20 | 5.9 | 18.35 |
| 5.5 | 2375 | 11.3 | 3.40 | 5.6 | 17.85 |
| 6 | 2390 | 11.9 | 3.65 | 4.3 | 17.20 |
| 6.5 | 2400 | 12.7 | 3.95 | 4.1 | 16.85 |

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

| Bitumen content % | Unit weight kg/m$^3$ | Stability kn | Flow value mm | Air void % | VMA % |
|---|---|---|---|---|---|
| 5 | 2320 | 14.21 | 2.5 | 7.95 | 18.28 |
| 5.5 | 2335 | 15.12 | 2.33 | 7.35 | 17.95 |
| 6 | 2348 | 16.65 | 3.45 | 6.35 | 17.35 |
| 6.5 | 2361 | 17.95 | 4.10 | 5.5. | 16.63 |

### 4.2 Comparison of Concrete Dust and Brick 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$^3$.

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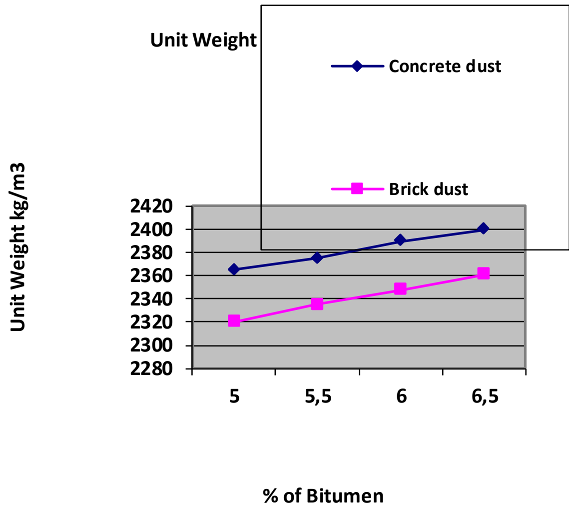


**Chart -1**: Variation of Unit Weight With %age of Bitumen

### 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.

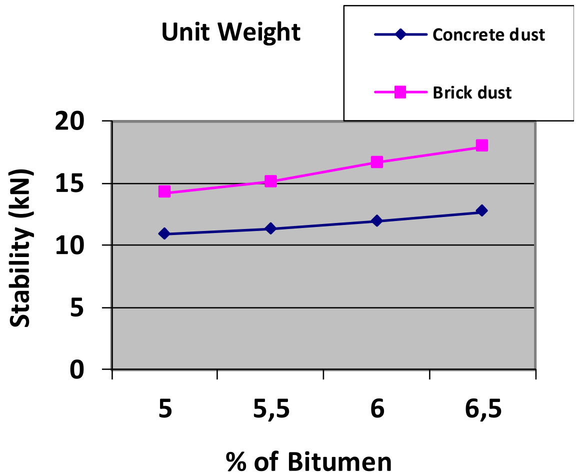


**Chart -2:** Variation of Stability With %age of Bitumen.

## 5 CONCLUSIONS AND FUTURE SCOPE

After performing all the necessary tests and plotting of results on graphs, conclusions drawn are listed below

1. The specimen with brick dust as filler is found to have nearly same Marshall Properties as that of the specimen with filler concrete dust.
2. The specimen with concrete dust as filler is found to have maximum unit weight at bitumen content of 6.5%. Unit weight of that particular sample at 6.5% bitumen content is found to be 2400 kg/m$^3$. Further it is shown that with the increase in bitumen content unit weight goes on increasing.
3. For the specimen with brick dust as filler it is found to have maximum unit weight at bitumen content of 6.5%. Unit weight of that particular sample at 6.5% bitumen content is found to be 2361 kg/m$^3$. Further it is shown that with the increase in bitumen content unit weight goes on increasing.
4. The specimen with concrete dust as filler is found to have maximum stability at bitumen content of 6.5%. Stability of that particular sample at 6.5% bitumen content is found to be 12.7 KN. Further it is shown that with the increase in bitumen content Stability goes on increasing.
5. For the specimen with brick dust as filler it is also found to have maximum Stability at bitumen content of 6.5%. Stability of that particular sample at 6.5% bitumen content is found to be 17.95 KN. Further it is shown that with the increase in bitumen content Stability goes on increasing.
6. The specimen with concrete dust as filler is found to have maximum flow value at bitumen content of 6.5%. Flow value of that particular sample at 6.5% bitumen content is found to be 3.95 mm. Further it is shown that with the increase in bitumen content flow value goes on increasing.

### 5.1 Future Scope

- In order to improve the quality of pavement mixes Stone dust, cement, fly ash, can also be used as fillers.
- The tensile strength of the bituminous mixes can be studied through Creep test and indirect tensile strength test.
- In bituminous mixes we can also use various types of binders and additives like rubber, plastic waste, polymer etc in order to improve the various properties of mixes.
- Quality of pavement mixes can also be improved by using various types of fibers like synthetic and natural fibre.

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