International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 07 | July - 2021 ISSN: 2582-3930

A COMPARATIVE INVESTIGATION ON THE IMPACT OF INDUSTRIAL WASTE USED AS FILLER IN BITUMINOUS MIXES

Sandeep Kumar[1], Pardeep[2]

[1]Sandeep Kumar Dept of civil Engineering, Sat Priya Institute of Engineering & Technology, Haryana, India
[2]Pardeep Dept of civil Engineering, Sat Priya Institute of Engineering & Technology, Haryana, India

---***---

Abstract- Construction of highway involves huge outlay of investment. 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. Fillers paly vital role in the filling of voids. 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 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. . 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 mixes, Marshall Method, Morth, Mineral 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. Keeping in mind the need for bulk use of these solid wastes in India, it was thought convenient to test these materials and to develop specifications to enhance the use of these industrial wastes in road making, in which higher rate of returns may be possible. The pollution and disposal problems can be minimized by properly utilizing these materials in highway construction. Using waste materials in road construction have great economic and environmental benefits. Energy consumption can be reduced by reuse of waste materials instead of natural materials. In addition, the environmental risk can be reduced by the use of waste materials instead of stockpiling them. High performance and environment friendly roads can be constructed by the use of many waste materials in bituminous paving mixes. In recent years, industrial wastes have been utilized in road construction in developing countries. The use of these materials in road making is based on technical, economic and ecological criteria. The lack of traditional road materials and the protection of the environment make it imperative to investigate the possible use of these materials carefully. Traditionally soil, stone aggregates, sand, bitumen, cement etc. are used for road construction. Natural materials being exhaustible in nature, its quantity is declining gradually. In addition, cost of extracting good quality of natural material is increasing. Concerned about this, the scientists are looking for alternative materials for highway construction, and industrial wastes product is one such category. It is important to test these materials and to develop a methodology and specifications to enhance the use of these industrial wastes for their effective utilization in road construction in India.

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 mix design is to produce a bituminous mix by proportioning various components so as to have-

- Sufficient bitumen to ensure a durable pavement.
- Sufficient strength to resist shear deformation under traffic at higher temperature.
- Sufficient air voids in the compacted bitumen to allow for additional compaction by traffic.
- Sufficient workability to permit easy placement without segregation.
- Sufficient resistance to avoid premature cracking due to repeated bending by traffic.
- Sufficient resistance at low temperature to prevent shrinkage cracks.

.

2. LITERATURE REVIEW

Various studies, which have been carried out for determining the adequacy of industrial waste used as filler in bituminous mixes in the pavement construction, are discussed in this section.

Ishai et al. (1980) investigated six types of fillers with a wide range of properties and two types of : sand asphalt and bituminous concrete. They performed rheological tests on filler-bitumen mastic samples and mechanical tests on different sets of bituminous concrete samples. A basic model was adopted in which the bituminous mixture is composed of two components: an aggregate bitumen system and a filler-bitumen system (mastic). The model was analyzed through weight-volume relationship, and the optimum mastic needed to obtain the optimal mechanical behavior of the mixture was determined. **Giri et al.** (2018) investigated the performance of recycled concrete aggregates (RCA) in dense bituminous macadam (DBM) after modification with waste polyethylene. RCA were used in the mixes as coarse aggregate fraction before and after pre-treatment with bitumen emulsions. Various performance tests such as indirect tensile strength test, retained stability test, repeatedload triaxial tests, wheel tracking rut test, flow number test, dynamic modulus tests, were conducted on the prepared DBM specimens. Experimental results concluded that the performance of mixes with pre-treated RCA was better than the other mixes.

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.

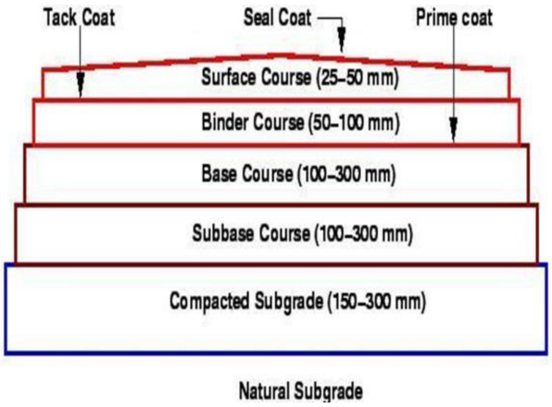


Fig -1: Basic flexible pavement structure

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

Materials passing 0.075 mm IS sieve was used as filler material. In this study, four types of mineral fillers: crumb rubber, stone dust, ceramic dust and marble dust were used as shown in Fig. . The crumb rubber was obtained from Publix India Incorporation, Ludhiana, India. The Ceramic Dust and Marble Dust was obtained from Shri Sai Cutting Edge, Sultanpur, Delhi. The stone dust was obtained from local stone crusher. Marshall mix design was conducted for investigating the effect of ceramic dust as filler in bituminous concrete at different filler contents. Marshall specimens were prepared at different bitumen contents for 2%, 5% and 8% ceramic dust used as filler in BC. The sample for bituminous mix containing marble dust was prepared at 5.22% bitumen content and 5% optimum filler content. The rut depth of mix was found to be 5.721 mm.

Fig -2: ***Different filler as stone dust***

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 $5^{o}C$ per minute. The temperature at which the softened bitumen touched the metal plate was recorded as softening point of bitumen.

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. 3 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.

3.3 Marshall Mix Design

Marshall Method of mix design has been adopted in this project 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.

3.4 Mixing of Materials

The mixes were prepared according to the Marshall procedure specified in ASTM D1559. For BC mixes, the coarse aggregates, fine aggregates and filler were mixed with bitumen in specified proportion. Here Optimum Binder Content (OBC) and optimum filler content (OFC) was found by Marshall Test. The mixing of ingredients was done as per the following procedure;

- Required quantities of coarse aggregate, fine aggregate & mineral fillers were taken in an iron pan as shown in Fig. 3.3. Then aggregates are kept in an oven at temperature 160 for 2 hours. Preheating is required because the aggregates and bitumen are to be mixed in heatedstate.
- The required amount of fillers were weighed and kept in a separate container.
- The aggregates in the pan were heated in oven for a few minutes maintaining the above temperature. Then the fillers were added to the aggregate and was mixed for 2 minutes.
- Bitumen was added to this mix and the whole mix was stirred uniformly and homogenously. This was continued for 15-20 minutes till they were properly mixed which was evident from the uniform colour throughout the mix.
- Then, the mix was placed in a preheated mould and compacted by giving 75 blows on each face with a 4.54 kg weight of hammer using a free fall height of 457 mm (18 in.), representing heavy traffic conditions. After compacting, Specimens were removed from the mold and each sample was marked and kept separately for 24 hours. Samples were immersed in a water bath at 60°C for 30±5 minutes.

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 Marble Dust.

Filler content %	Unit weight kg/m^3	Stability kn		Flow value mm	Air void %	VMA %
2	1036.03	15.48		1.54	7.58	16.56
5	1996.45	13.18		1.85	6.29	15.48
8	1565.6	9.74		1.68	5.92	17.26

Table 2 Marshall Properties of Specimens with Filler used as Crumb rubber

Bitumen content	Unit weight	Stability kg	Flow value	Air void	VMA %

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 07 | July - 2021 ISSN: 2582-3930

%	kg/m^3		mm	%	
2	1036.03	389.3	1.524	6.124	15
5	1996.45	743.47	1.575	5.026	13.52
8	1565.6	101.2	2.98	4.0616	12.17

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 2% to 8% 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 marble dust as filler maximum unit weight is observed at 8% bitumen content. Unit weight of specimen with marbledust as filler is 2400 kg/m^3. Also in case of the specimen with crumble rubber as filler maximum Unit weight is observed at 8 bitumen content. Unit weight of specimen with crumble dust as filler is 2361 kg/m^3.

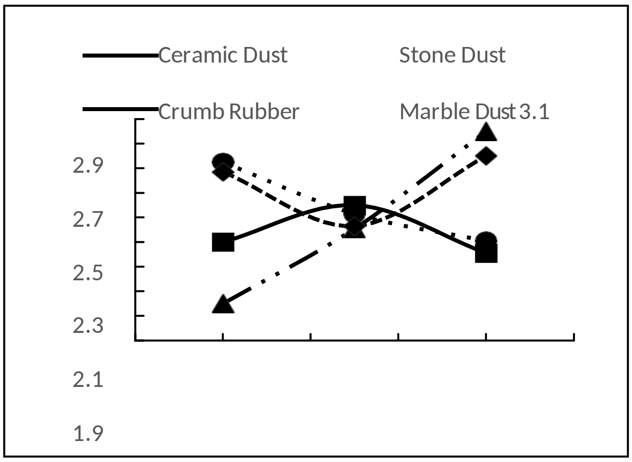


Chart -1: Graphs of Marshall mix design parameters with different fillers at different filler contents at their OBC values

4.2.1 Marshall Stability Curves

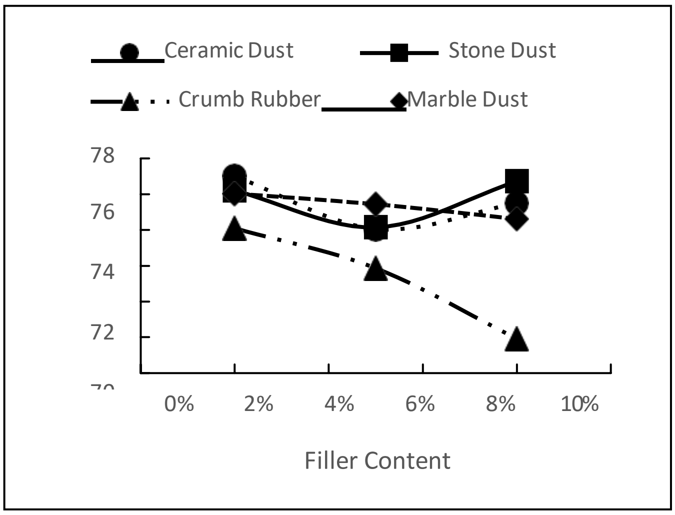
The graphical representation of stability for variation in bitumen content from 2% to 8% for samples containing marble dust and crumble rubber as filler is shown in Fig 2. From the graph it is seen that with the increase in the bitumen content stability increases. It is seen that specimen with marble dust as filler has lesser stability than specimen with crumble rubber as filler. In case of the specimen with marbledust as filler maximum stability is observed at 8% bitumen content. Stability of specimen with marble dust as filler is 12.7 KN. Also in case of the specimen with marble dust as filler maximum stability is observed at 8% bitumen content. Stability of specimen with marble dust as filler is 17.95KN.

Chart -2: Effect of different type of filler and filler content

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. 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.



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

c. 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.

References

Giri J.P., Panda M. and Sahoo U.C., (2018), Performance of Bituminous Mixes Containing Treated Recycled Concrete Aggregates and Modified by Waste Polyethylene, *Journal of Materials in Civil Engineering*, Vol. 30, No. 8, pp. 04018184-1.

Giri J.P., Panda M. and Sahoo U.C., (2018), Performance of Bituminous Mixes Containing Emulsion-Treated Recycled Concrete Aggregates, *Journal of Materials in Civil Engineering*, Vol. 30, No. 4, pp. 04018052-1.

IRC 37, 2012, Guidelines for the design of flexible pavements, *Indian Roads Congress*, New Delhi, India.

IS 383, 2016, Coarse and fine aggregate for concrete – Specifications, *Bureau of Indian Standards*, New Delhi, India.

Ishai, I., Craus, J., and Sides, A. (1980). "A model for relating filler properties to optimal behavior of bituminous mixtures." *Association of Asphalt Paving Technologists*, 49, 416–439. Kandhal, P. S. (1993). "Waste materials in hot mix asphalt—An overview." Use of waste materials in hot-mix asphalt, STP 1193, H. F. Waller, ed., ASTM, Philadelphia, 3–17.

Karasahin, M., and Terzi, S. (2007). "Use of marble waste dust in the mixture of asphalt concrete as mineral filler." *Construction and Building Materials*, Vol. 21(3), pp. 616-620. Katamine, N. M. (2000). "Physical and mechanical properties of bituminous mixtures containing oil shales." *Journal of Transportation Engineering*., 126(2), 178–184.

Ministry of Road Transport and Highways (MORTH), (2013), Specifications for roads and bridge works, *Indian Road Congress*, New Delhi, India.

Suhaibani, A. A., Mudaiheem, J. A., and Fozan, A. F. (1992). "Effect of filler type and content on properties of asphalt concrete mixes." Effects of aggregates and mineral fillers on asphalt mixtures performance, ASTM STP 1147, ASTM, West Conshohocken, PA, 107–130.

Taha, R., Rawas, A. A., Harthy, A. A., and Qatan, A. (2002). "Use of cement bypass dust as filler in asphalt concrete mixtures." *Journal of Materials in Civil Engineering*, 14(4), 338–341. Tamrakar A., Saxena G., Saxena T., (2018), The consequences of waste marble dust on the mechanical properties of the concrete, *International Research Journal of Engineering and Technology,* Vol. 05(09).