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Review Paper on Effect of Various Fillers on Bituminous Mixes

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Abstract

This paper summarises the ongoing researches about the effect of various fillers on bituminous mixes. Many studies regarding bitumen fillers that have been carried out earlier were studied, and their effects on the bituminous paving mixes were also analyzed. Bitumen in combination with filler forms mastic. This mastic can be seen as a constituent of mixture of asphalt that holds the aggregates together. An important role is played by the fillers that pass through 0.075mm sieve. With the increase in the amount of filler, Marshall Stability of the bitumen mix increases directly. Use of 4-8% filler in asphalt concrete is recommended by the Asphalt Institute. It was concluded that various fillers such as carbon black, fibres, rubbers, polymers, fly ash, silica or their combination not only hardens the mastic at high temperature during its production an placement but also obtained high binder content for increase in durability. By addition of fillers to bituminous mixes a considerable amount of increase in Marshall Properties can also be observed.

Keywords

Fillers, Voids in Mineral Aggregates (VMA), Marshall Stability value, Marshall flow value, Asphalt.

I. Introduction

Being the second largest growing economy in the world, road infrastructure in India is developing at a very fast rate. Road infrastructure developmental projects like Pradhan Manthri Gram Sadak Yojna (PMGSY) and National Highway Development Project (NHDP) are in progress at a very large scale. Due to the growth of traffic and overloading of vehicles life span of the roads laid with conventional bituminous mixes decreases. Due to this riding quality also gets reduced, which results in exorbitant vehicle operating costs and frequent maintenance interventions due to early failure of pavements. Due to variation in climate, rainfall intensities terrain condition, and soil characteristics providing durable roads have always been a problem for a country like India. To solve the problems associated with pavements a good amount of research is throughout the country in this field. Considerable attention has been 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 later.

II. Functions of different Highway materials

1. Coarse Aggregates

The coarse aggregates should have good abrasion value, impact value and also crushing strength. The function of coarse aggregates is to bear the stresses due to wheels. Function of Coarse aggregates is also resisting wear due to abrasion.

2. Fine Aggregates

Voids which remain in the coarse aggregates are filled by the fine aggregates. So the function of fine aggregates in to fill the voids of coarse aggregates. Fine aggregates consist of crushed stone or natural sand. Fine aggregates shall be the fraction passing 600 micron and retaining on 75 micron sieve. The aggregates should satisfy the requirements as specified in Table 1.

3. Fillers

As the name indicates function of fillers is to fill up the voids. Fillers used may be brick dust, stone dust, concrete dust, limestone dust, fly ash or pond ash. The filler should be graded within the limits indicated in Table 2.

Table 1 : Requirement of Aggregates as Per IRC, MORTH and BIS

Properties	Specification
Crushing Strength	Max 30% (IRC and BIS)
Los Angles Abrasion Value	Max 30% (MORTH)
Specific Gravity Fine aggregates Coarse aggregates	 2.5-3.0(MORTH) 2.5-3.0(MORTH)
Elongation index	No recognition
Flakiness index	Max 25% (IRC and BIS)
Impact Value	Max 24%(MORTH)
Water Absorption	Max 2%(MORTH)

4. Bitumen

Bitumen is used as water proofing material as well as binding material. Bitumen used should meet the requirements of BIS and are laid down in Table 3.

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Table 2 : Requirements of Mineral Filler [MORTH, Clause 507.2.4]

IS SIEVE (mm)	CUMULATIVE PERCENT PASSING BY WEIGHT OF AGGREGATES
0.6	100
0.3	95-100
0.075	85-100

Table 3 : Specifications for bitumen laid by BIS

Properties Tested	**Specification IS:73-2013**	**BIS code for Testing**
Softening Point Test temp. ^{0}C	40 min.	IS:1205
Penetration Test (mm)	80min	IS:1203
Specific Gravity Test	1.01min	IS:1202
Ductility Test (mm)	75min	IS:1208
Viscosity Test at 135^{0}C (Cst)	250min	IS:1206(part-2)

III. Bituminous Mix Design

A well designed bituminous mix will withstand heavy traffic loads under the adverse conditions. It will also fulfill the structural and pavement surface characteristics. The objective of the design of bituminous mix is to establish an economical mix through several trial mixes. The gradation of aggregates and the binder content should be such that the resultant mix should satisfy the following conditions.

1. Sufficient binder so as to make sure that the pavement is durable by providing a water proofing coating on the aggregate particles and binding them together under compaction.
2. Sufficient stability so as to provide the resistance against deformation under sustained or repeated loads. The binder in the mix develops interlocking and cohesion between the aggregates thus providing resistance against deformation.
3. Sufficient flexibility to avoid early cracking due to repeated deformation by the traffic and also to intercept shrinkage cracks at low temperatures. Proper amount and grade of bitumen ensures the sufficient flexibility.
4. Sufficient air voids in the compacted bitumen to compensate for the additional compaction by the traffic.
5. Sufficient workability for easy placement. Sufficient workability not only enhances easy placement but also avoids segregation.

1. Gradation of Aggregates

Gradation of aggregates is one of the most essential factors for the design of bituminous mix. The gradations of aggregates used should be as per IRC grading 2 as given in the table 4 (MORTH: Specifications for Road and Bridge works 2003). Further Mix design criteria for bitumen are given in Table 5.

Table No: 4 IRC Grading 2 for bituminous paving mixes

Grading	2
Nominal aggregate size	13mm
Layer thickness	30-45mm
I.S sieve	Cumulative percent by weight of total aggregate passing
19 13.2 9.5 4.75 2.36 1.18 0.6 0.3 0.15 0.075	100 79-100 70-88 53-71 42-58 34-48 26-38 18-28 12-20 4-10
Bitumen content by mass of total mix Bitumen Grade (penetration)	4.5-7.0 65

Table 5 : Bitumen filler mixture design criteria

Design Parameter	Design Criteria
Percent Air Voids	3-5%
Percent voids in mineral aggregate (VMA)	17(minimum)
Stability value	6200N(minimum)
Flow value	2-4 mm
Retained Stability (LS-283).	70(minimum)
Drain down @ Production Temperature(AASHTO T305)	0.3% (maximum)

IV. Status Of Ongoing Researches

In 2014 it was examined that using waste material is one of the powerful concept in recent year. Reuse of waste materials in road construction helps to overcome the plastic waste by leaps and bond requires reuse of waste materials in road construction. The plastic waste is a serious threat to environment, being non-degradable in nature. This threat has stressed the need to find suitable solutions for effective plastic waste management. Natural resources are needed for the rapid growth of the infrastructure in road construction. Disposal of different wastes (plastic waste) produced from different Industries is a great challenge now-a-days. In many industrialized and developing countries, applications of industrial wastes have been considered with great interest in road construction. Reusing of wastes material is a very simple but powerful concept. In this paper Low Density polyethylene (LDPE) is used in road construction. The waste grinded plastic of size 2mm to 8mm was used to coat the stone aggregates so as to make them polymer coated aggregate before they were blended in hot mix plant (HMP). Then, the bitumen polymer coated aggregate mixture was used in road Construction. There is a need to investigate the feasibility of use of plastic waste in road construction. This paper covers the study on the various test performed on bitumen, aggregates and methodology of using plastic waste in bituminous mixes. It was concluded that Use of waste plastic 0.76% by weight of aggregate and3% filler significantly improve the volumetric properties of bituminous mixes resulting better performance of BC with plastic waste than control mix(without plastic waste)[1].

In 2012 an importance was laid to add the grinded waste plastic bottles to bituminous concrete (BC) mix and to assess the various mix properties like Marshall Stability, bulk density, flow, voids in the mix and VFB. The effect of soaking conditions of the mix was also investigated. Indirect tensile strength investigated for OBC and 8% plastic coated on aggregates which had yielded the highest marshal stability. The optimum plastic content for 60/70 and 80/100 grade bitumen was 8%. Addition of 2% to 12% waste shredded plastic bottles by the weight of bitumen to BC mix resulted in maximum stability of 1552 Kg at 8% waste plastic by the weight of bitumen, 6mm flow at 8% waste plastic and 74.238 VFB at 8% waste plastic for 60/70 Bitumen. Also addition of 2% to 12% waste shredded plastic bottles by the weight of bitumen to BC mix resulted in maximum stability of 1963 Kg at 8% waste plastic by the weight of bitumen, 4.7mm flow at 8% waste plastic and 71.942 VFB at 8% waste plastic for 80/100 Bitumen. [2].

In 2010 feasibility of the use of shredded waste plastics in semi-dense bituminous concrete with 60/70 penetration grade bitumen employing dry process of mixing was studied. On heating the softened plastics, provide a thin coating on the aggregate. Marshall Stability and flow values, over a 50 samples with varying percentage bitumen by weight of mix and percentage plastics by weight of binder were evaluated. There was a 10% saving in the bitumen content which leads to a saving in national economy and also an eco-friendly method for the disposal of waste plastics. The stability value of the mix was increased by about 30%. There is also less ageing of bitumen and no bleeding. The plastic coated aggregates showed no stripping even after 96 hours of water immersion and hence avoid the use of anti-stripping agents in bituminous mixes. Water absorption was found to be less as compared to uncoated aggregates indicating its higher degree of water susceptibility. It was concluded that the Marshall Stability value of stabilized SMA was found to be 17kN, which is higher than the prescribed value of 6.2 KN and the percentage increase in stability value was been found to be 64% as compared to the conventional mix. [3].

In 2010 action of using waste glass powder as mineral filler on Marshall Property of Stone matrix asphalt (SMA) by comparing with Stone matrix asphalt (SMA) where ordinary Portland cement, lime stone was taken as filler with varying content (4-7%) was studied. Marshall's mix design was carried out by changing the lime stone, ordinary Portland cement content at and subsequent tests have been performed to determine the different mix design characteristics. [4].

In 2009 it was concluded that environmental awareness of the drawbacks of landfill sites is tempting nations to look for better ways to recycle. The use of industrial wastes and by-products as Mineral fillers in asphalt mixtures is not a latest technique. Mineral Fillers have been implied in road construction from previous many years. They are dissipated in asphalt mixtures to enhance the characteristics and performance of asphalt concrete pavements. Mineral fillers show immense variation in mineralogy, chemical properties, shape and texture, size, and gradation. The major aim of this preliminary investigation was to carry out whether it is possible to use the local industrial and by-products wastes such as Steel slag, Ceramic waste, Coal fly ash, limestone, and Exempted ceramic raw material as mineral fillers in Stone Mastic Asphalt (SMA) mixtures in Malaysia. Chemical examination using Scanning Electro Microscope (SEM), Energy Dispersive X-ray (EDX) and physical tests were carried out on those local industrial and by-products wastes samples to determine its chemical composition, size and shape of particles, as well as gradation and specific gravity, and were then put on a comparison to limestone dust the common type of mineral filler used in Stone Mastic Asphalt in Malaysia. The test results depicted that the physical and chemical properties of the local industrial wastes are within permissible limits of quality requirements for mineral filler for Bituminous Paving Mixtures AASHTO M17, and in relativity with AASHTO PP41 (Designing of Stone Matrix Asphalt) and these waste materials can potentially be utilized as mineral fillers in Stone Mastic Asphalt (SMA) Mixtures.[5].

In 2008 waste plastic was used for modification of bituminous concrete. Marshall Method was adopted to find out optimum binder content. Marshall specimen were prepared for bitumen content 5,5.5,6,6.5 percent by weight of aggregate with 6%,10%,14% and 18% waste plastics by weight of bitumen. The Marshall Stability values increased by 18%, 45%, 18% for the mix with 10%, 14%, 18% waste plastics. [6].

In 2007 it was concluded that the mixture which are modified have a higher stability and VMA (Void in Mix Aggregate) percentage compared to those mixtures that are non-modified. It was also concluded that this positively influences the resistance against rutting of these mixtures. The air void contents of the modified bituminous mixtures are not far from that of the non-modified mixtures. Air void proportion around 4% is not enough to provide space for the expansion of asphalt binder to prevent flushing or bleeding that would reduce the resistance against skidding of the pavement and increase rutting resistance. It was concluded that using the poly-ethylene in asphalt mixtures increase fatigue resistance, reduces pavement deformation and provide better adhesion between the asphalt and the aggregates. Author Concluded that the appropriate amount of polyethylene was determined to be (6-18%) by weight of the optimum asphalt percent (5.4%), which equates to (0.34-1.03%) by weight of total aggregate. However, the optimum modifier content was found to be 12%, which equals only 0.68% of the total aggregate weight. [7].

In 2002 processed plastic bags were used for modification of bituminous concrete. Properties of the modified bitumen were compared with ordinary bitumen. He observed that the ductility and penetration values of the modified bitumen decreased with the increase in proportion of the plastic additive. It was concluded that life of modified bitumen increases the life of pavement in comparison to the use of ordinary bitumen. It was observed that softening point of bitumen that was modified increased with the addition of plastic additive up to 8% by weight. [8].

In 1998 it was reported that generally a modifier improves the properties of bituminous mixtures in many ways. Some of the improvements in the properties are improved elastic properties to withstand severe loading conditions, increase in resistance to deformation, smoother riding surface, increased stability of the mix, higher retained strength after exposure to moisture, improved skid resistance to ageing caused by atmosphere, improved resistance to low temperature cracking, higher softening point etc. [9].

In 1996 the effects of fibre-modified bitumen on bituminous mixtures utilizing asbestos, rock wool, glass wool and cellulose fibres were examined. The tests conducted included resilient modulus, fatigue resistance, rutting resistance and indirect tensile strength. Three studies were performed on a test track in Nantes, France. The first study showed that, fibre modified mixtures maintained the highest percentage of voids with a 13 metric ton axle load for 1.1 million times, compared with unmodified and the other two elastomer modified mixtures. The authors concluded that the decreased susceptibility to moisture related distress in the porous mixtures tested is due to better drainage. In the next study, two million load applications were applied to fibre-modified bituminous mixture which was used as an overlay on pavements with signs of fatigue distress. After the load applications, the pavement surface was noted to have a well maintained, and practically no cracking. In the third study reported by them fibre modified overlays were also constructed over fatigued pavements. After 1.2 million load applications, it was observed that all of the fibre modified overlays showed no sign of fatigue related distresses or rutting compared to the unmodified samples which showed signs of distress. This was in agreement with the findings of the second study, establishing that the fatigue life of the fibre modified pavement is improved over unmodified mixtures. Fibre modification also allowed for an increase in film thickness, which resulted in less ageing and improved binder characteristics. Addition of fibres also resulted in the reduction of temperature sensitivity of bituminous mixtures. [10].

In 1995 it was reported that bitumen with polymers form multiphase systems, which usually contain a phase rich in polymer and a phase rich in bitumen not absorbed by the polymer. The properties of bitumen-polymer mixes depend on the concentrations and the type of polymer used. About 4–6% by weight of polymer is usually loaded with respect to the bitumen. Higher concentrations of polymers are considered to be economically less viable and also may cause other problems related to the materials (Giovanni et al., 2004). Polymers are long-chain molecules of very high molecular weight, used by the binder industry. These can be grouped into three main categories: thermoplastic elastomers, plastomers, and reactive polymers based on the mechanism of resistance to deformation. Thermoplastic elastomers are in no doubt able to confer good elastic properties on the modified binder, while plastomers and reactive polymers are added to reduce deformations under the load and to improve rigidity. For a polymer to be effective in road applications, it should mix with the bitumen and improve its resistance to abrasion rutting, cracking, fatigue, bleeding, stripping, ageing, etc. at medium and high temperatures without making the modified bitumen too viscous at mixing temperatures or too brittle at low temperatures. It can also blend with aggregate and heated so as to have a coating on the aggregate which leads to an improvement in the overall performance of the pavement. In the modification process many polymers have been used but thermoplastic elastomers are enjoying wide acceptance as road bitumen modifiers (Bonemazzi, 1996). [11].

In 1994 research was conducted on modified bituminous mixtures using polypropylene, polyester fibres and polymers. Two blends of modified binder were evaluated. An unmodified mixture was used as a control sample. Higher tensile strength and resistance to cracking were found to be in the Mixtures containing polypropylene fibres. [12].

In 1993 it was reported that re-cycled polyethylene from grocery bags may be useful in bituminous pavements, resulting in reducing permanent deformation in the form of rutting and reduced low temperature cracking of the pavement surfacing. Zoorob (2000) and Zoorob and Suparma (2000) have reported greater durability and fatigue life in modified mixes with recycled plastics compared to polypropylene and low density polyethylene. Considerable research has been carried out to determine the suitability of plastic waste as a modifier in construction of bituminous mixes (Schroceder, 1994; Punith and Veeraragavan, 2007). Denning (1993) reported that asphalt concrete which employ polyethylene modified binders during elevated seasonal temperatures are more resistant to rutting. [13].

In 1990 it was shown that some fibres have high tensile strength relative to bituminous mixtures, thus it was found that fibres have good potential to improve the cohesive and tensile strength of bituminous mixes. By the phenomena of reinforcement and toughening, they are believed to impart physical changes to bituminous mixtures. This high tensile strength may increase the amount of strain energy that can be absorbed during the fatigue and fracture process of the blend. Finely divided fibres provide a high surface area per unit weight and behave much like filler materials. [14].

In 1989 it was reported that fibre reinforcement can be used as a barrier for the cracks rather than as a reinforcing element and its function is to carry the tensile loads as well as to prevent the formation and propagation of cracks. Fibres also have the tendency to bulk the bitumen, so during construction it will not run off from the aggregates. Finely divided fibres behave much like filler materials and provide a high surface area per unit weight. Compared to the control mix mixtures with fibre showed a slight increase in the optimum binder content in terms of efficiency. Thus, the addition of very fine aggregates and adding fibres to bitumen are very much similar. Thus, fibre can be used to stabilize the bitumen and also to prevent leakage. [15].

In 1982 it was reported that the degree of homogeneity of dispersion of the fibres within the mix will determine the strength of the resulting mixtures. The results obtained from the different field studies showed that the addition of fibre have a benefit since it will help to produce more flexible mixtures with more resistant to cracking. The design methods of bituminous mixtures primarily include the well-known Marshall Design method and super pave design method. In the design procedure an important role is played by the bitumen content in the determination of engineering properties of mixture, which is determined in terms of the volumetric properties of mixture (air void, specific gravity etc.) in both the Marshall and Super pave mixture design procedures. [16].

V. Conclusion

After going through number of researches I conclude that using fillers in bituminous mixes enhance various properties. Use of fillers not only helps in improving the quality of mixes but also helps in usage of various waste materials as the basic ingredients of the paving mixes thus, reducing the problem of these materials going as a waste. Further it can be concluded that in India Brick dust and concrete dust are available in abundance and are economically available. Thus using a by-product of concrete and bricks in the form of the subsequent dust can be put to use judiciously. Moreover, this dust can be a health hazard if not used. I also conclude that fillers improve the Marshall Stability and flow value of bituminous mix. Further I conclude that the cost effectiveness of these non conventional filler specimens can be realized after performing a cost analysis of these non conventional materials against the conventional specimens resulting in reduction of the construction costs considerably.

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