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PERFORMANCE EVALUATION OF ADDITIVES FOR BITUMEN MIXES

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ABSTRACT

To study the effects of ground plastic pipe wastes on bitumen. For this purpose, three modified bitumen samples with modifier contents of 2%, 4%, and 6% along with pure bitumen were prepared and tested. To understand the effect of modifier on bitumen, conventional bitumen tests, rotational viscosity tests at 135 °C and 165 °C, dynamic shear remoter tests at three different frequencies that represent three different traffic speeds, and bending beam remoter (BBR) test were performed. The BBR test results showed that resistance of pure bitumen to low-temperature cracking increased by using additives up to 4%. Based on the results of this study, it can be said that waste plastic pipes can be used as modifier for the bitumen binder. The 4% additive showed the best performance. The results revealed a decrease in penetration value with increasing polymer content in Asphalt, suggesting that the polymer hardens the modified bitumen mixes; increasing softening point with increasing polyethylene content due to the polyethylene added; and increasing fire and flash points of the modified asphalt with increasing polythene content, suggesting low propensity of hazardous situation since the inflammability of bitumen mixes decreases with increasing polymer content. The study concluded that waste plastic materials are effective in modifying bitumen mixes for construction of flexible pavements despite the need to ascertain the exact proportions of the mix for achieving the best modified bituminous concrete.

Keywords: bitumen mixes flexible pavements.

I. INTRODUCTION

Bituminous mixes are most commonly used all over the world in flexible pavement construction. It consists of asphalt or bitumen (used as a binder) and mineral aggregate which are mixed together, laid down in layers and then compacted. Under normal circumstances, conventional bituminous pavements if designed and executed properly perform quite satisfactorily but the performance of bituminous mixes is very poor under various situations. Today's asphaltic concrete pavements are expected to perform better as they are experiencing increased volume of traffic, increased loads and increased variations in daily or seasonal temperature over what has been experienced in the past. In addition, the performance of bituminous pavements is found to be very poor in moisture induced situations. Considering this a lot of work has been done on use of additives in bituminous mixtures and as well as on modification of bitumen. Research has indicated that the addition of polymers to asphalt binders helps to increase the interfacial cohesiveness of the bond between the aggregate and the binder which can enhance many properties of the asphalt pavements to help meet these increased demands. However, the additive that is to be used for modification of mix or binder should satisfy both the strength requirements as well as economic aspects.

In the present study, dense graded bituminous mix specimens were prepared using natural aggregate as coarse aggregates, bottom ash as partial replacement of fine aggregates and fly ash as mineral filler with sisal fiber as a stabilizing additive. Design of the mixtures was done as per Marshall procedure. For characterization of the mixes, various tests such as indirect tensile strength (ITS) and moisture susceptibility test in terms of tensile strength ratio (TSR) and retained stability were taken up.

GENERAL:

Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment as well a reliable performance of the in-service highway can be achieved. Two things are of major considerations in flexible pavement engineering–pavement design and the mix design. The present study is related to the mix design considerations.

A good design of bituminous mix is expected to result in a mix which is adequately

(i) strong
(ii) durable
(iii) resistive to fatigue and permanent deformation
(iv) environment friendly
(v) Economical and so on. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions and finalizes with the best one. The present research work tries to identify some of the issues involved in this art of bituminous mix design and the direction of current research.

Preparation of existing pavement:

Exploration and tests of the existing pavement should be made to locate all areas of distress in the existing pavement and to determine the cause of the distress. Areas showing extensive and progressive cracking, rutting, and foundation failures should be repaired prior to the overlay. Such repair is especially needed in areas where excessive pumping, bleeding of water at joints or cracks, excessive settlement in foundation, subgrade rutting, surface rutting, and slides have occurred. If testing of the existing pavement indicates the presence of voids beneath a rigid pavement, they should be filled by grouting prior to the overlay. The properties of the existing pavement and foundation such as the modulus of subgrade reaction, CBR (California Bearing Ratio), thickness, condition index, and flexural strength should be determined. The exact properties to be determined will depend upon the type of overlay to be used.

REQUIREMENTS OF A PAVEMENT:

An ideal pavement should meet the following requirements:

- Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil,
- Structurally strong to withstand all types of stresses imposed upon it,
- Adequate coefficient of friction to prevent skidding of vehicles,
- Smooth surface to provide comfort to road users even at high speed,
- Produce least noise from moving vehicles,
- Dust proof surface so that traffic safety is not impaired by reducing visibility,
- Impervious surface, so that sub-grade soil is well protected, and
- Long design life with low maintenance cost.

Types of pavements

The pavements can be classified based on the structural performance into two, flexible pavements and rigid pavements. In flexible pavements, wheel loads are transferred by grain-to-grain contact of the aggregate through the granular structure. The flexible pavement, having less flexural strength, acts like a flexible sheet (e.g. bituminous road). On the contrary, in rigid pavements, wheel loads are transferred to sub-grade soil by flexural strength of the pavement and the pavement acts like a rigid plate (e.g. cement concrete roads). In addition to these, composite pavements are also available. A thin layer of flexible pavement over rigid pavement is an ideal pavement with most desirable characteristics. However, such pavements are rarely used in new construction because of high cost and complex analysis required.

Flexible pavements:

Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure

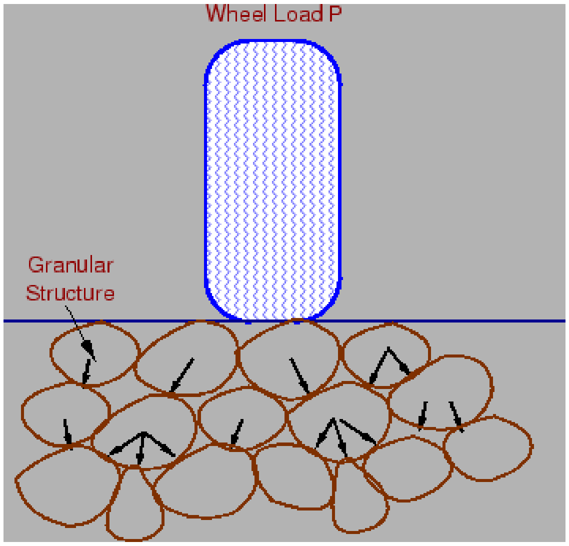


Figure 1: Load transfer in granular structure

The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of this stress distribution characteristic, flexible pavements normally has many layers. Hence, the design of flexible pavement uses the concept of layered system. Based on this, flexible pavement may be constructed in a number of layers and the top layer has to be of best quality to sustain maximum compressive stress, in addition to wear and tear. The lower layers will experience lesser magnitude of stress and low quality material can be used. Flexible pavements are constructed using bituminous materials. These can be either in the form of surface treatments (such as bituminous surface treatments generally found on low volume roads) or, asphalt concrete surface courses (generally used on high volume roads such as national highways). Flexible pavement layers reflect the deformation of the lower layers on to the surface layer (e.g., if there is any undulation in sub-grade then it will be transferred to the surface layer). In the case of flexible pavement, the design is based on overall performance of flexible pavement, and the stresses produced should be kept well below the allowable stresses of each pavement layer.

Types of Flexible Pavements

The following types of construction have been used in flexible pavement:

- Conventional layered flexible pavement,
- Full - depth asphalt pavement, and
- Contained rock asphalt mat (CRAM).

Conventional flexible pavements are layered systems with high quality expensive materials are placed in the top where stresses are high, and low quality cheap materials are placed in lower layers.

Full - depth asphalt pavements are constructed by placing bituminous layers directly on the soil sub-grade. This is more suitable when there is high traffic and local materials are not available.

CLASSIFICATION OF BITUMINOUS MIXTURES:

A bituminous mixture is a combination of bituminous materials (as binders), properly graded aggregates and additives. Bituminous mixtures used in pavement applications are classified either by their methods of production or by their composition and characteristics. By the method of production, bituminous mixtures can be classified into Hotmix asphalt (HMA), Cold-laid plant mix, Mixed-in-place or road mix and Penetration macadam. Hot-mix asphalt is produced in hot asphalt mixing plant (or hot-mix plant) by mixing a properly controlled amount of aggregate with a controlled amount of bitumen at an elevated temperature. The mixing temperature has to be sufficiently high such that the consistency of bitumen is fluid enough for proper mixing and coating the aggregate, but not too high as to avoid excessive stiffening of the asphalt. HMA mixture must be laid and compacted when the mixture is still sufficiently hot so as to have proper workability. They are the most commonly used paving material in surface and binder courses in bituminous pavements. Cold-laid plant mix is produced in a bitumen mixing plant by mixing a controlled amount of aggregate with a controlled amount of liquid bitumen without the application of heat. It is laid and compacted at ambient temperature. Mixed-in-place or road mix is produced by mixing the aggregates with the bitumen binders in the form of emulsion (medium setting or slow setting) in proper proportions on the road surface by means of special road mixing equipment. Penetration macadam is produced by a construction procedure in which layers of coarse and uniform size aggregate are spread on the road and rolled, and sprayed with appropriate amounts of bitumen to penetrate the aggregate. The bituminous material used may be hot bitumen or a rapid setting bitumen emulsion.

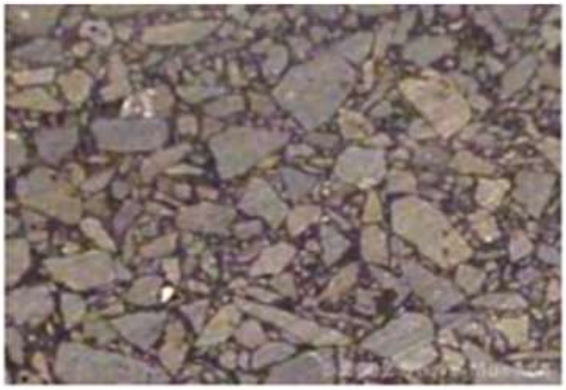
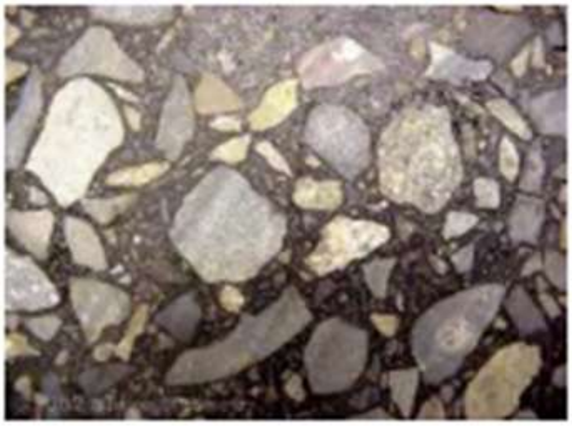


Figure2. : Dense graded HMA

Figure3. : Open graded HMA



Polymer as an additive Bituminous pavements have experienced accelerated deterioration due to traffic growth and climatic conditions. When a load is applied to the surface of a bituminous pavement it deforms. But bitumen, being a viscoelastic material, the majority of the deformation recovers when the load is removed. However, there is a minute amount of irrecoverable viscous deformation which remains in the bitumen and which results in a very small permanent residual strain. Accumulation of millions of these small strains due to axle loading results in the surface rutting familiar on heavily trafficked pavements. Laboratory tests that attempt to measure the rutting resistance, i.e., the resistance to permanent deformation of a bituminous mix, are: the Marshall test, static and dynamic creep tests, wheel-tracking tests, and laboratory test track tests 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 blends depend on the concentrations and the type of polymer used.

DIFFERENCE BETWEEN SMA & CONVENTIONAL MIXES:

SMA is successfully used by many countries in the world as highly rut resistant bituminous course, both for binder (intermediate) and wearing course. The major difference between conventional mixes and SMA is in its structural skeleton .The SMA has high percent about 70-80 percent of coarse aggregate in the mix .This increases the interlocking of the aggregates and provides better stone to stone contact which serves as load carrying mechanism in SMA and hence provides better rut resistance and durability. On the other hand, conventional mixes contain about 40-60 percent coarse aggregate. They does have stone to stone contact, but it often means the larger grains essentially float in a matrix composed of smaller particles, filler and asphalt content .The stability of the mix is primarily controlled by the cohesion and internal friction of the matrix which supports the coarse aggregates .It can be followed from diagram of the grain size distribution of the mixes given below. The second difference lies in the binder content which lies between 5-6 percent for conventional mixes. Below this the mix becomes highly unstable. Above this percent will lead to abrupt drop of stability because the binder fills all the available voids and the extra binder makes the aggregates to float in binder matrix. The SMA uses very high percent of binder > 6.5 percent which is attributed to filling of more amount of voids present in it, due to high coarse aggregate skeleton. The high bitumen content contributes to the longevity of the pavements.

II. LITERATURE REVIEW

Mohammad AltafBhat et al (2013) studied the Effect of Fillers on Bituminous Mixes. To satisfy the design requirements of stability and durability the bituminous mixes should be designed effectively. The ingredients of the mixture include dense grading of coarse aggregates, fine aggregates, fillers and bitumen binder. In this Study an attempt was made to find the effect of filler on the behavior of bituminous mixes. Fillers play an important role in the filling of voids and hence change the physical and chemical properties. Thus their effect is of utter importance. 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. In India, waste concrete dust and brick dust are considered to be cheaper and are available in plenty. In this study an attempt was made to find the effect of fillers on the bitumen mixes. In this study, concrete dust and brick dust was used as filler. The properties of bituminous mixes containing these fillers were studied and compared with each other. For the purpose of comparison Marshall Method of mix design was used. In this study various tests were also conducted on aggregates and bitumen and the results were compared with the specifications. The study revealed that use of concrete dust and brick dust as filler improves the physical characteristics of bitumen. Marshall Stability and flow value of bitumen mix also improved.

R. E. Long and R.W. Floyd (1982) studied that aggregate shortages and increased transportation costs have greatly increased prices of related construction items in areas of Texas which is not blessed with natural aggregates. Some natural aggregates are not performing up to expectations as documented by stripping, rutting and other visual signs of pavement distress noted throughout the Department. Because of these spiralling construction costs and need to field evaluate bottom ash, District 1, supported by the Materials and Tests Division, decided to construct three field test pavements substituting bottom ash for part of the natural aggregates in hot mix asphaltic concrete (HMAC).They conclude that that bottom ash blend mixes require more asphalt than natural aggregates, mixes produce lower compacted density, mixes cool fast, requiring adequate rollers working closely behind the laying operation, mixes exhibit high internal friction with no lateral displacement during compaction, this mix has maintained acceptable skid values after 14 months of interstate traffic, the cost of bottom ash blend mixes is somewhat higher based on additional asphalt used and aggregate transportation costs.

III. METHODOLOGY

In order to achieve the objectives of the study, a thorough review is done to have knowledge of the works available in literature. First of all collection of plastic waste can be done. After that shredding or cutting of plastic into small pieces can be done After that ordinary tests can be performed on aggregate and bitumen. After that using plastic waste coating of aggregate can be done and tests will performed. After that plastic is mixed with bitumen and laboratory tests can be performed. At last comparison of both test results with and without plastic waste can be done.

Characteristics of Polymer Modified Bitumen:

An alternate use of plastic waste is also under study where plastics is mixed with bitumen and used for preparing the mix. The mix was used to study the basic properties of bitumen like softening point, penetration point and ductility. The penetration value was decreased to a very low value and similarly the ductility. More than 4% addition of waste plastics to the bitumen results in a hard polymer modified bitumen with very poor visco-elastic property (The minimum values for a suitable bitumen P.V = 85; Ductility ≈ 49)

Table 1: Properties of Polymer Modified Bitumen

% of Plastics	Ductility (cm)	Penetration (mm)	Softening Point (°C)
1%	**66**	**93**	**56**
2%	**56**	**89**	**51**
3%	**23**	**80**	**50**
5%	**16**	**60**	**78**

The polymer bitumen blend is a better binder compared to plain bitumen. The blend has increased Softening Point and decreased Penetration Value with a suitable ductility. When used for road construction it can withstand higher temperature. Hence it is suitable for tropical regions. It has decreased Penetration Value. Hence its load carrying capacity is increased. The blend with aggregate has no Stripping Value. So it can resist the effect of water. The Marshall Stability Value is high. The bitumen required can be reduced depending upon the % of polymer added. It is a good saving too. No toxic gas is produced. Disposal of waste plastic will no longer be a problem. The binding properties of polymer also improve the strength of mastic flooring. The use of waste plastics on the road has helps to provide better place for burying the plastic waste without causing disposal problem. At the same time, a better road is also constructed. It also helps to avoid the general disposal technique of waste plastics namely landfilling and the incineration, which have certain burden on ecology.

Production of Bitumen:

Bitumen is the residue or by-product when the crude petroleum is refined. A wide variety of refinery processes, such as the straight distillation process, solvent extraction process etc. may be used to produce bitumen of different consistency and other desirable properties. Depending on the sources and characteristics of the crude oils and on the properties of bitumen required, more than one processing method may be employed

Rigid and Flexible Pavements:

A rigid pavement is constructed from cement concrete or reinforced concrete slabs. Grouted concrete roads are in the category of semi-rigid pavements.The design of rigid pavement is based on providing a structural cement concrete slab of sufficient strength to resists the loads from traffic. The rigid pavement has rigidity and high modulus of elasticity to distribute the load over a relatively wide area of soil.

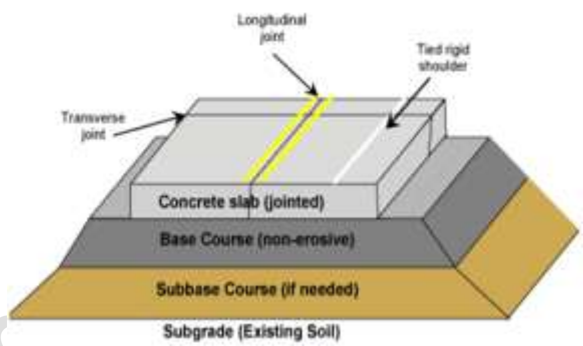


Figure 4.: Rigid Pavement Cross-Section

Minor variations in subgrade strength have little influence on the structural capacity of a rigid pavement. In the design of a rigid pavement, the flexural strength of concrete is the major factor and not the strength of subgrade. Due to this property of pavement, when the subgrade deflects beneath the rigid pavement, the concrete slab is able to bridge over the localized failures and areas of inadequate support from subgrade because of slab action.

The two major types of pavement design are rigid and flexible with each achieving a different design solution based on their method. A rigid pavement is very stiff, often comprising premixed concrete. While higher in initial cost, it can have a much longer life and its objective is to achieve a lower overall pavement service cost. A flexible pavement is less stiff, allowing it to flex rather than crack under major loads. Within Australia flexible pavements tend to dominate the regional and rural road network because of their lower cost, however rigid pavements are common depending on the application.

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Sustainability Metrics for ECC Pavement Overlays As summarized by total life cycle results represent the environmental impacts the material module, construction module, distribution module, traffic congestion module, usage module,

Table.2: Material Mix Proportions and Materials Properties (kg/m3)

Mix	Cement	Sand Gravel	Water
579	462	319	319
414	456	319	319
324	453	317	317

Consumption and Environmental Impacts per m3 for Individual Mix Designs

Mix	Tot E (GJ)	CO2 (kg)	NOx (kg)	PM10 (mg)	SOx (kg)	BOD (kg)
1	6.69	670	3.55	5.88	2.62	0.21
2	5.56	506	2.97	5.7	1.98	0.21
3	4.95	416	2.63	5.75	1.63	0.21

Materials used in study

In this study following materials are taken in to consideration to prepare the bituminous mix.

- Stone chips (as coarse aggregate)
- Bottom ash (as fine aggregate)
- Fly ash (as mineral filler)
- VG-30 (as bitumen binder)
- Sisal fiber (as additives)
- SS-1 emulsion (as fiber coating agent)

Aggregate

Coarse aggregates comprised of stone chips were procured from a nearby crusher and were stored by sieving in to different sizes. For this study, stone chips comprising coarse aggregate fractions and upper size fractions of fine aggregates ranged from 26.5 mm to 0.3 mm were used as shown in Figure.

Bitumen The paving bitumen grade VG-30 (VG-viscosity grade) was used in this experimental study. Initially, two bitumen grades such as VG-30 and VG-10 were used to study the Marshall characteristics of mixes with the materials considered. These initial trials resulted better Marshall characteristics, especially the Marshall stability in respect of mixes made up of bottom ash, fly ash and emulsion coated fiber with VG-30 bitumen as binder. The physical characteristics of VG-30 bitumen tested as per IS standards are given in Table

Table3 .:Physical property of binder

Physical Properties	IS Code	Test Result
Penetration at 25°C/100gm/5s, 0.01mm	IS:1203-1978	46
Softening Point, °C	IS:1205-1978	46.5
Specific gravity, at 27°C	IS:1203-1978	1.01
Absolute viscosity, Brookfield at 160°C, Centi Poise	ASTM D 4402	200

Chemical composition	
Composition	**Test result**
Cellulose, %	65
Hemicellulose, %	12
Lignin, %	9.9
Waxes, %	2
Physical property	
Property	**Test result**
Density, gm/cc	1.51
Tensile strength, MPa	510-640
Young's modulus, MPa	9.5-2.0
Elongation at break, %	2.0-2.5

Experimental Design:

The adopted gradation for DBM sample has been considered as specified in MORTH and is given in Table-Throughout the experimental study the aggregate gradation given in Table4 was followed, and the following tests were performed. The aggregate gradation curve is shown in figure.

Table 4.: Gradation of aggregate

Sieve size (mm)	adopted gradiation(% passing)	specified limit (% passing)
33.7	100	100
25.2	90	90-100
18	85	81-90
14.3	74	71-80
4.73	52	50-71

3.42	34	32-41
0.3	15	9-17
0.075	6	3-9

After adopting the above aggregate gradation the subsequent test were made to ensure the performance characteristics.

- Marshall test of mixes to evaluate volumetric analysis
- Static indirect tensile test
- Resistance to moisture damage (Tensile strength ratio)
- Retained stability test
- Static creep test

Design mix

The DBM mixtures were prepared in accordance with the Marshall procedure specified in ASTM D6927-2015. All ingredients of mixture, such as coarse aggregates, fine aggregates, filler, fiber and VG-30 bitumen were mixed in a specified procedure. Before preparing the samples, fibers were coated with SS-1 emulsion and stored in a hot air oven at 1100C as Coated fiber are stored for 24 hours to ensure proper coating around each fiber and to drain down extra bitumen that may adhere to fiber, Then the fibers were cut into specified lengths of about 5mm, 10mm, 15mm and 20mm as given in figure. The aggregates and bitumen were heated separately to the mixing temperature of 1550C to 160 0C. The temperature of the aggregates was maintained 100C higher than that of the binder. Requiredquantities of bitumen VG-30 and coated emulsion fiber pieces were added to the pre-heated aggregates and thoroughly mixed as shown in Figure

Coating of emulsion on fiber.

Oven dry coated fiber

Cutting of coated fiber.
Addition and mixing of fiber

(a) Pouring of mixture in mould, (b) Compaction of mixture in progress, (c) DBM samples, (d) Marshall test in progress

The quantity of binder to be added was calculated from subtracting the weight of emulsion coated fiber from weight of design binder. Proper mixing was done manually till the colour and consistency of the mixture appeared to be uniform. The mixing time and temperature was maintained within 2-5 minutes and 1500C-1600C respectively. The mixture was then poured in to a pre-heated Marshall mould and compacted using Humboldt Automatic Marshall Compact with 75 compaction blows on each side.

In this experiment, the resistance to deformation of a Marshall cylindrical specimen of DBM mixture is measured. The specimen is loaded diametrically at a deformation rate of 50 mm/min as Here are two major features of the Marshall method of mix design are given below.

1. Stability and flow values

2. Voids analysis

The Marshall stability for bituminous mix is defined as the maximum resistance carried by specimen at a standard temperature of 60°C. The flow value is recorded when the specimen deformed under maximum. The Marshall voids analysis were done before the Marshall stability test. In this voids analysis bulk specific gravity (Gmb), air voids (VA),

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voids in mineral aggregate (VMA), voids filled with bitumen (VFB), and Marshall Quotient were determined, that are discuss in next chapter.

Static indirect tensile test

Static indirect tensile test of bituminous mixes was performed in accordance to ASTM D 6931 (2007) to assess the resistance to thermal cracking for a Marshall cylindrical specimen that is loaded in vertical diametrical plane as shown in figure 4.7. This tests were carried out on DBM specimen which were prepared at their optimum binder content, optimum fiber content and optimum fiber length as calculated from Marshall propeties analysis. The effect of temperature on the Indirect Tensile Strength (ITS) of mixes with and without fiber was also studied. The load atwhich tensile crack were develop in the specimen were noted down from the dial gauge of the proving ring and was calculated.

Loading and failure pattern of indirect tensile strength test

$$S_t = \frac{2000 \times P}{\pi \times D \times T}$$

Where St= Indirect Tensile strength, kPa

P = Maximum Load, kN

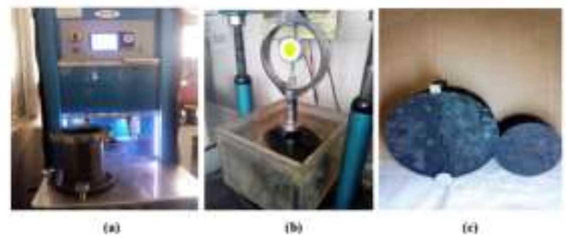
T = Specimen height before testing, mm

D = Specimen Diameter, mm

The test temperature was varied from 50C to 400C at an increment of 50C. The average tensile strength of three sample was reported.

Resistance to moisture damage (Tensile Strength Ratio (TSR)

The resistance to moisture susceptibility of bitumen mixes were measured by tensile strength ratio. The test is similar to Static Indirect Tensile test only the specimen were prepared in gyratory compactor with 7% air void and 150 mm diameter to 62.5 mm height specimen dimension as shown in figure 4.8. Six sample of equal avg. air void was prepared and divided into two subset. One subset was partially saturate to be moisture conditioned with distilled water at room temperature using a vacuum chamber by applying a partial vacuum of 70 kPa or 525 mm Hg (20 in. Hg) for a short time such as five min. after that the partially saturated samples are cured to be moisture conditioned in distilled water at 60+ 1.0°C for 24 hour.



(a) Sample Prepared in gyratory compactor, (b) Moisture susceptibility test in progress, (c) Failure cracks in DBM sample

The dry subset was cured in water bath for 20 min at 25+ 1.0°C while the temperature of moisture conditioned subset was adjusted to 25+ 1°C by soaking it in water bath for 1 hour prior to testing. The test was conducted in accordance with the ASTM D4867/D4867M – 09. The tensile strength ratio of conditioned and unconditioned subset was determined by the equation 2 given below. The average result for TSR value should be minimum 80%, failing to this the sample were considered as damage.

$$\text{Tensile strength ratio (TSR)} = \frac{S_{tm}}{S_{td}} \times 100$$

Where,

TSR= tensile strength ratio, %

S_{tm} = average tensile strength of the moisture-conditioned subset, kPa, and,

Std = average tensile strength of the dry subset, kPa.

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Retained stability test

The loss of stability in bituminous mixes due to penetration of moisture is measure in the form of Retained stability test. This test also shows the sign of percentage striping of bitumen from aggregate. The test was conducted in accordance with the STP 204-22 with standard Marshall Samples, prepared according to the Marshall procedure specified in ASTM D6927-2015. Six specimen were prepared with 4% air void and divided into two subset. Each of the subset were conditioned with water at 60+ 1 0C for half an hour and 24 hours and tested in accordance to Marshall stability test. A minimum of 75% retained stability is required as per MORTH-2013 to claim the mixture can with stand moisture.

$$\text{Retained stability} = \frac{S_2}{S_1} \times 100$$

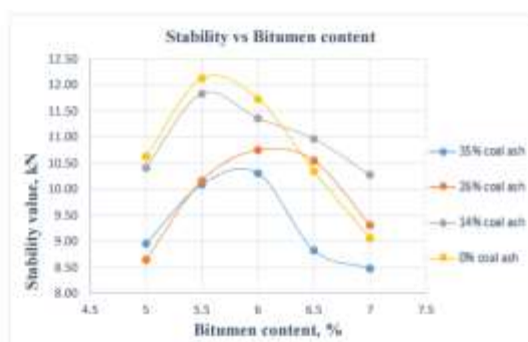
Where, S_1= Unconditioned stability, kN S_2= Conditioned stability, kN (after conditioned 24 hours at 60℃ in water bath)

ANALYSIS OF RESULTS AND DISCUSSION

This chapter deals with results analysis and discussion for test that are carried out for DBM sample in previous chapter. This chapter is divided into three sections. In first section the parameter and the equation used for Marshall properties analysis are given below. Second section deals with calculation and comparison of optimum binder content, optimum fiber content and optimum fiber length of DBM mixes with and without coal ash used as fine aggregate and filler. Third section deals with analysis made from the experiment such done in previous chapter static indirect tensile, static creep test at 400C, moisture susceptibility test (Tensile strength ratio), and retained stability test.It is found that shredded plastic waste of the size 2-8 mm may be incorporated conveniently in bituminous mixes used for road constructions. The optimum dose is around 0.4- 0.5 % by weight of bituminous mix and 6-8% by weight of bitumen. Bituminous Concrete (BC) is a composite material mostly used in construction projects like road surfacing, airports, parking lots etc. It consists of asphalt or bitumen (used as a binder) and mineral aggregate which are mixed together & laid down in layers then compacted. The role of waste plastic bags in the mix was studied for various engineering properties by preparing Marshall samples of BC mixtures with and without polymer. Marshall properties such as stability, flow value, unit weight, air voids were used to determine optimum polythene content for the given grade of bitumen. Thin plastic bags are mainly composed of low density Polyethylene (LDPE) and it's commonly used for packaging, protecting and many other applications. Waste Plastic Bags as one form of polymers were used to investigate the potential prospects to enhance asphalt mixture properties. Thermo gravimetric analysis has shown that there is no gas evolution in the temperature range of 130- 180°C. Moreover the softened plastics have a binding property. Hence, the molten plastics materials can be used as a binder and/or they can be mixed with binder like bitumen to enhance their binding property. This may be a good modifier for the bitumen, used for road construction.

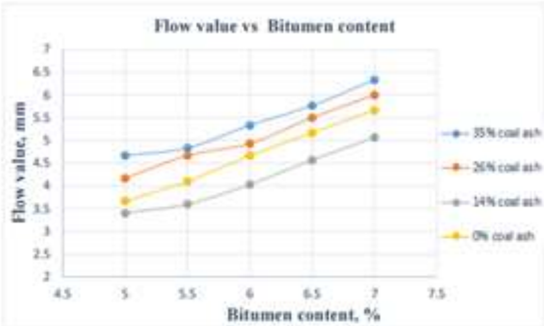
Marshall stability

It is seen from the that using of coal ash in DBM mix is not satisfactory with respect to stability value, when compared with conventional mix. The maximum stability value of 11.83 kN was achieved when 14% of coal ash by weight of the mix was mixed for preparing DBM samples



Graph .1: Variation of Stability value with bitumen content at different coal ash content

It was seen from the flow value vs bitumen content graph shown in that with increase in bitumen content and Coal ash content the flow value increase. But with 14% coal ash content by weight of mix the flow value decrease as compare to the conventional mix.



Graph2: Variation of Flow value with bitumen content at different coal ash content

Indirect tensile strength test:

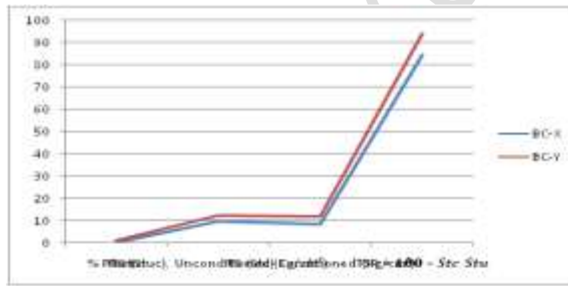
This test is useful in determining the resistance of bituminous mix against cracking and sensitivity of mixture to moisture damage as well. To assess whether the coating of bitumen binder and aggregate is susceptible to moisture damage tensile strength is determined according to ASTM D 4867. Tensile strength ratio (TSR) is defined as the ratio of average indirect tensile strength of conditioned specimens to the indirect tensile strength of un-conditioned specimens. The test sample were prepared as per prescribed norms by maintaining suitable air voids about 7% . The specimens when placed in water bath maintained at a temperature of 60°C for 24 hours and then placed in water chamber maintained at 25°C for 1 hour are termed as conditioned specimens. On the other hand when the samples are placed in water bath maintained at 25°C for 30 minutes are termed as un-conditioned specimens. Both conditioned and un-conditioned specimens were tested for their tensile strength. The load at failure of specimen was recorded and the indirect tensile strength (ITS) was calculated from the following equation no-1. Indirect tensile strength (ITS) = $2P\boldsymbol{\pi t d}$ ---- Equation 1 Where, P is load(Kg), d is the diameter in cm of the specimen, t is the thickness of the specimen in cm. The tensile strength ratio(TSR) was calculated by following relation,

Tensile strength ratio (TSR) = 100 $* Stc Stuc$ ---- Equation 2

Where, Stc is average indirect tensile strength of conditioned specimen and Stuc is indirect tensile strength of un-conditioned specimen.

Table 5. - Indirect tensile strength (ITS) and TSR

Specimens	% Plastic	ITS (Stuc), Unconditioned (Kg/cm²)	ITS (Stc) Conditioned (Kg/cm²)	TSR = $\mathbf{100 * Stc\ Stu}$
BC-X	**0**	**9.76**	**8.25**	**84.53**
BC-Y	**0.8**	**12.32**	**11.56**	**93.83**



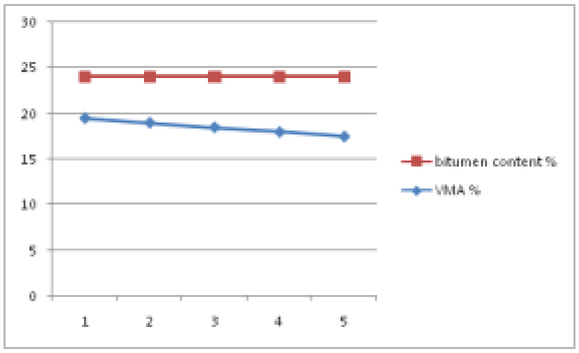
Graph 3: Indirect tensile strength (ITS) and TSR variations

It is observed from the graph shown in that with increase in coal ash the air void increases. By taking 14% coal ash by weight of the mix, the air void is fairly near to the conventional mix, which means coal ash can be used with some modification to achieve optimum properties than conventional mix.From the Unit weight and bitumen content graph shown in it is observed that with increase in coal ash content the unit weight of DBM samples decreases. Coal ash been a lighter material cause the decrease of unit weight.

Voids in Mineral Aggregate (VMA)Table 4.2

From the observation of VMA vsbitumen content graph in Figure, it is clear that with increase in bitumen content voids in mineral aggregate decrease rapidly first and then increases steadily.

VMA %	bitumen content %
19.50	4.5
19.00	5
18.50	5.5
18.00	6
17.50	6.5

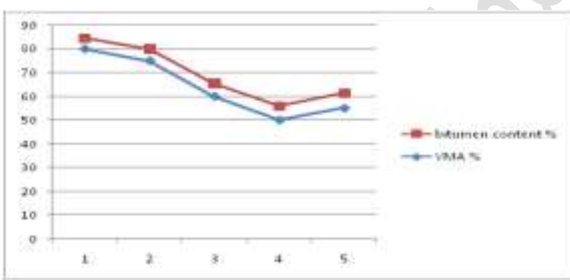


Graph 4: Variation of VMA value with bitumen content at different coal ash content

Voids Filled with Bitumen (VFB)Table 4.3

It is observe from the VFB and bitumen content graph shown in Figure 5.6 that VFB increase rapidly with increase in bitumen and coal ash content.

VMA %	bitumen content %
80	4.5
75	5
60	5.5
50	6
55	6.5



Graph 5: Variation of VFB value with bitumen content at different coal ash content

Effect of Sisal fiber and Coal ash (Bottom ash and Fly ash) on DBM mix

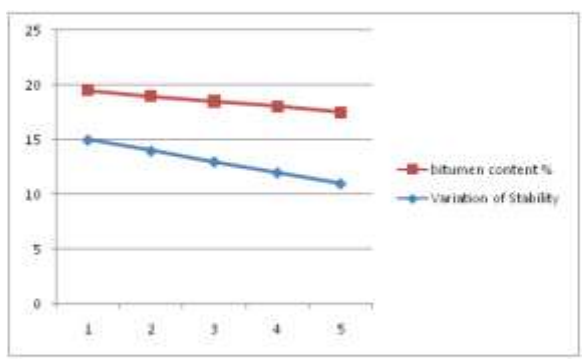
From the above Marshall property of DBM mix that is prepared with coal ash, it is observed that, coal ash cannot deliver satisfactory result when used alone. The stability and flow values are not within the specification made for DBM mix. Also the volumetric analysis such as air void, unit weight, VMA and VFB, are lagging behind the conventional mix. Therefore the Marshall propeties study is done by using coal ash and sisal fiber as an additive. The percentage of coal ash is taken as 14% as it shown better result than other coal ash content. The fiber content varied from 0% to 1% with 0.5% increment, along with fiber length ranging from 5mm, 10mm, 15mm, and 20mm.

Marshall stability

It is observed from the stability and bitumen content graph, shown in figure to that with increase in bitumen content and fiber content as well as fiber length the stability value increased to certain limit and then decreased. From the optimum binder content analysis it is found That the maximum stability of 15kn was achieved at an optimum binder content of 5.57% with optimum fiber content of 0.5% by weight of mixture along with fiber length of 10mm which was duly coated with SS-1 emulsion and cured for 24hours at 110+ 1 ^{0}C.

Table4.4 : Variation of Stability value with bitumen content in 0.25% fiber content at different fiber length

Variation of Stability	bitumen content %	fiber length
15.0	4.5	5mm
14.0	5	10mm
13.0	5.5	15mm
12.0	6	20mm
11.0	6.5	0mm



Graph 6: Variation of Stability value with bitumen content in 0.25% fiber content at different fiber length

IV CONCLUSIONS

To study the effects of ground plastic pipe wastes on bitumen. For this purpose, three modified bitumen samples with modifier contents of 2%, 4%, and 6% along with pure bitumen were prepared and tested. To understand the effect of modifier on bitumen, conventional bitumen tests, rotational viscosity tests at 135 °C and 165 °C, dynamic shear rheometer tests at three different frequencies that represent three different traffic speeds, and bending beam rheometer (BBR) test were performed. The following conclusions are drawn based on the results obtained tin the present study

- The properties of bitumen such as penetration softening point improved with the addition of the waste fiber. There is a significant decrease in penetration values for modified blends, indicating the improvement in their temperature susceptibility resistant characteristics.

- The softening point increase with increase in percentage of fibre and this is so because the bitumen becomes increasingly viscous. The results show that bitumen modified with lower percentage of fibres can be used in road construction satisfactorily, but higher percentage of fibers i.e. more than 0.7 % may be used as a roofing material.

- The ductility value decreases with increase in percentage of modifier, but the rate of decrease is less when fiber is added beyond 0.5 percent. The ductility value less than 50cm should not be used in road constructions, but may be used as crack and joint filler materials.

However, some of the properties such as fatigue properties, moisture susceptibility characteristics, resistance to rutting and dynamic creep behavior can further be investigated. Some other synthetic and natural fibers and other type of binder can also be tried in mixes and compared. Sisal fiber used in this study is a low cost material; therefore a cost-benefit analysis can be made to know its effect on cost of construction. Moreover, to ensure the success of this new material, experimental stretches may be constructed and periodic performances monitored.

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