Experimental Study on Bitumen Mix using Plastic Waste

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Abstract— Waste material management is one of the powerful concepts in recent year. To overcome the plastic waste by leaps and bond requires reuse of waste materials in road construction. The use of these materials in road making is based on technical, economic, and ecological criteria. Several million metric tons plastic wastes are produced in India every year. If these materials can be suitably utilized in highway road construction, the pollution and disposal problems may be partly reduced. In this paper we used Low Density Polyethylene bags in road construction and study on the various test performed on aggregates, bitumen and bituminous mix.

Key words: WPB, OBC, Plastic, Bitumen

I. INTRODUCTION

Plastic is a very versatile material. Due to the industrial revolution, and its large scale production plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packaging, automobile, electronics, electrical, building construction, communication sectors has been virtually revolutionized by the applications of plastics. Plastic is a non-biodegradable material and researchers are found that the material can remain on earth for 4500 years without degradation. Several studies have proven the health hazard caused by improper disposal of plastic waste. The health hazard includes reproductive problems in human and animal, genital abnormalities etc., Looking forward the scenario of present life style a complete ban on the use of plastic cannot be put, although the waste plastic taking the face of devil for the present and future generation.

II. MATERIAL USED

A. Aggregate

The quantity of aggregate used in first coat surface dressing should be $0.15m^3$ per $10m^2$ area of 12mm nominal size and the quantity of aggregate used for second coat of surface dressing should be $0.15m^3$ per $10m^2$ area of 10mm nominal size.

B. Bitumen

The grade of straight run bitumen is chosen depending upon the climatic conditions of the region in which surface dressing is to be constructed. In most parts of India 80/100 and 180/200 grades bitumen is used.

C. Plastic

Generally LDPE (Low Density Poly-Ethylene) plastic wastes available in the form of carry bags are very thin and also easily available.

III. EXPERIMENTAL INVESTIGATION

A. Penetration Test on bitumen

It measures the hardness or softness of bitumen. The initial reading of the penetrometer dial is noted. Then the needle is released by pressing a button and a stop watch is started. The needle is released exactly for period of 5.0 secs. At least 3 measurements are made on this sample by testing at distance of not less than 100mm apart. The difference between the initial and final penetration readings is taken.

Reading	Trials		
	1	2	3
Penetrometer Dial Initial Reading	0	0	0
Penetrometer Dial Final Reading	30.5	32	38
Penetration Value	30.5mm	32mm	38mm
Mean Value			33.5mm

Table 1: Penetration Value

B. Softening point test on bitumen

Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test. The test is conducted by using Ring and Ball apparatus.

Temperature (^{0}C) at which I ball touches the bottom plate	Temperature (^{0}C) at which II ball touches the bottom plate	Final Softening Point Temperature
42^0c	44^0c	43^0c

Table 2: Softening Point Value

C. Ductility Test

A certain minimum ductility is necessary for a bitumen binder. This is because of the temperature changes in bituminous mixes and the repeated deformations that occur in flexible pavements due to the traffic loads.

Sl. No.	Ductility (cm)
1.	200
2.	204
3.	202

Table 3: Ductility Test

D. Viscosity

Viscosity is defined as the increase of fluidity. The test is conducted as per IS: 1206. The tar cup is properly leveled and water in the bath is heated to the temperature specified for the test and is maintained throughout the test.

Test		Trials		Mean Value
	1	2	3	
Viscosity, Sec	65	67	68	66.67

Table 4: Viscosity Test

E. Casting of Specimen

The aggregates of different gradation are taken to prepare the bitumen mix specimen and bitumen of different percentage (4.5, 5, 5.25, 5.5, 5.75 and 6%) added to determine the Optimum Bitumen content. In this study, the aggregate is heated at 170^0c and the bitumen is added to the aggregate heating at a temperature of 200^0c then the bitumen mix filled to the mould and the test sample compact to a total of 75 blows each being delivered at an interval of not less than one second and turn the mould repeated the above procedure. Then the specimen placed inside mould minimum of 24hours and removes the mould taken to test.

F. Marshall Test

Marshall Method for designing bituminous mixtures is used to determine the optimum bitumen content to be added to specific aggregate blend result a mix where the desired properties of strength and durability are met. According to standard 75-blow Marshal design method designated as (ASTM D 1559-89) a number of 12 samples each of 1200 gm in weight were prepared using six different bitumen contents (from 4.5 - 6% with 0.5 % incremental). Twelve samples were used to prepare bituminous mixture with bitumen content to have an average value of Marshal Stability and flow. Marshall Properties of the bituminous mix such as stability, flow, density, air voids in total mix, and voids filled with bitumen percentage are obtained for various bitumen contents. The following graphs are then plotted in Stability vs. Bitumen Content & Flow vs. Bitumen Content. These graphs are utilized to obtain optimum bitumen content.

Fig. 1: Marshall Specimens for different bitumen %

G. Determination of optimum bitumen content (OBC)

The Optimum bitumen content of proposed mix is the average of two values which includes;

- Bitumen content at the highest stability
- Bitumen content at the highest flow
- Marshal graphs are utilized to obtain these two values.
- (OBC) = Stability Value + Deformation/2

H. Bituminous Mix Modified With Plastic Bags

There are many different methods for utilization of waste plastic materials in asphalt mix. In this study the aim of adding waste plastic bags (WPB) to bituminous mix is to provide an aggregate coating material and not to enhance bitumen properties as bitumen modifier.

After obtaining OBC, 10 samples were prepared at OBC to evaluate the effect of adding WPB to asphalt mixture samples by considering eight proportions of WPB (0.2, 0.4, 0.6, 0.8 and 1% by the weight of aggregate)

The procedure of incorporating WPB in bituminous mix can be summarized as follows:

WPB have to be grinded then sieved to have a granular size (2.00 – 4.75 mm). Requisite amount of grinded WPB is mixed with course aggregates WPB and course aggregates mix is heated at $(185\text{-}190)^0$ C for approximately (2.5) hours. The heating temperature and duration of aggregates were chosen based on many experimental trials to be hot enough to melt WPB that it would stick to the aggregate surfaces and leave textured surface with good adhesion between coated aggregates.

Fine aggregates are heated at the same temperature for the same period but in separated pan.

Experimental trials show that it's better to separate fine aggregates from mix when heating because they would form an insulating layer coating melted plastic which may weaken adhesion between course aggregates and melted plastics. Requisite amount of bitumen is heated until it reaches 150^0C. WPB and course aggregates are mixed with fine aggregates followed by addition of hot bitumen at OBC. All ingredients are mixed vigorously to form a homogeneous bituminous mixture. After preparing modified asphalt mix, specimens are prepared, compacted, and tested according to standard 75-blow Marshal Method designated as (ASTM D1559-89 show Marshal Specimens modified with different percentages of WPB.

Fig. 2: Adding WPB to aggregate during heating

Fig. 3: WPB Modified Marshall Specimen

IV. TEST AND DISCUSSIONS

Results of laboratory work had been obtained and analyzed in order to achieve study objectives which include studying the effect of adding different percentages of WPB on the mechanical properties of asphalt mix and identify the optimum percent of WPB to be added to hot mix asphalt. Laboratory work results are presented in this chapter in two stages. First stage, Marshall Test is carried out with different percentages of bitumen which are (4.5, 5.0, 5.25, 5.5, 5.75 and 6.0%) and the results are analyzed in order to obtain the optimum bitumen content (OBC). After obtaining OBC, the following step is to study the effect of adding different percentages of WPB on asphalt mix properties which are (0.2, 0.4, 0.6, 0.8 and 1%) by the weight of aggregate.

Marshal test results for modified asphalt mixes are analyzed and finally the optimum WPB modifier content is obtained.

A. Marshall Stability

A number of 12 samples each of 1200 gm in weight were prepared using five different bitumen contents (from 4.5 - 6% with 0.5 % incremental) in order to obtain the optimum bitumen content (OBC). Table and Figure show summary of Marshal Test results.

Bitumen Content %	Load in (Kn)	Deformation in (mm)
4.5	15.48	3.4
5	15.748	3.65
5.25	14.45	3.74
5.5	13.068	4.5
5.75	12.108	5.64
6	11.508	5.93
Average	13.727	4.476

Table 5: Marshall Stability Test

B. Stability - Bitumen Content Relationship

Stability is the maximum load required to produce failure of the specimen when load is applied at constant rate 50 mm / min. In Figure (4.1) stability results for different bitumen contents are represented. Stability of asphalt mix increases as the bitumen content increase till it reaches the peak at bitumen content 4.95% then it started to decline gradually at higher bitumen content.

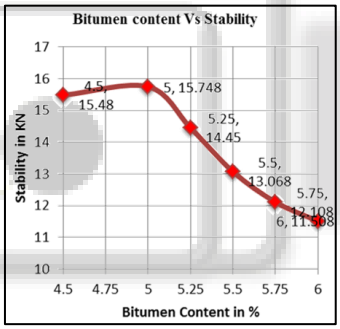

Fig. 4: Stability- Bitumen content relationship

C. Flow - Bitumen content relationship

Flow is the total amount of deformation which occurs at maximum load. In Figure (4.2) Flow results for different bitumen contents are represented. Flow of asphalt mix increases as the bitumen content increase till it reaches the peak at the maximum bitumen content 4.6 %.

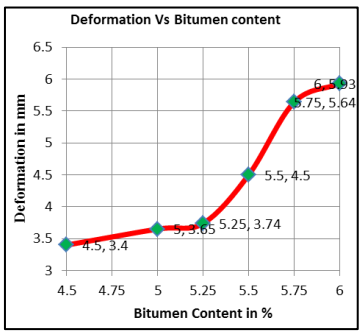

Fig. 5: Deformation Vs Bitumen content

D. Optimum Bitumen Content

Figures are utilized to find two values respectively.

- Bitumen content at the highest Stability = 4.95%
- Bitumen content at the highest Flow = 4.6%
- Optimum Bitumen Content (OBC) = 4.95+5.25!2 = 5.1% and the corresponding stability, flow is 15.5KN and 3.74mm respectively.

E. Effect of adding WPB on the mechanical properties of asphalt mix

According to the procedure 10 samples were prepared at OBC to evaluate the effect of adding WPB to asphalt mixture samples by considering seven proportions of WPB (0.2, 0.4, 0.6, 0.8, and 1% by the weight of OBC). Table 6 shows the mechanical properties of bituminous mix using different percentages of WPB (By weight of aggregate).

Plastic Content	Load (KN)	Flow (mm)
0.2	12.240	2.00
0.4	13.250	2.23
0.6	14.80	5.8
0.8	16.27	3.9
1	12.852	5.1
Average	13.887	3.806

Table 6: Mechanical Properties of Bituminous Mix

F. Stability- WPB relationship

Generally, the stability of modified asphalt mixes is higher than the conventional bituminous mix (15.8KN). All the values of stability for different modifier percentages are higher than stability of conventional mix. The maximum stability value is found nearly (14.34KN) at WPB content around (0.8%). Figure 6 shows that the stability of modified asphalt mix increases as the WPB content increases till it reaches the peak at (0.8 %) WPB content then it started to decline steeply at higher WPB content. The improvement of stability in WPB modified asphalt mixes can be explained as a result of the better adhesion developed between bitumen and WPB coated aggregates due to intermolecular bonding, these intermolecular attractions enhanced strength of bituminous mix, which in turn help to enhance durability and stability of the bituminous mix.

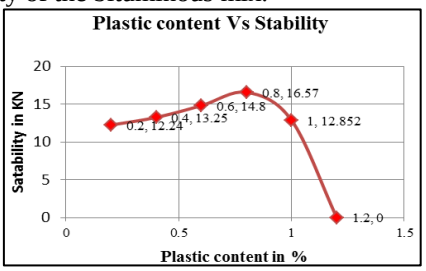

Fig. 6: Stability - WPB content relationship

G. Flow - WPB content relationship

Generally, the flow of modified asphalt mix is higher than the conventional asphalt mix (3.5mm). Figure 7 shows that the flow increases continuously as the WPB modifier content increase. The flow value extend from (3.9mm) at WPB content (0.8%).

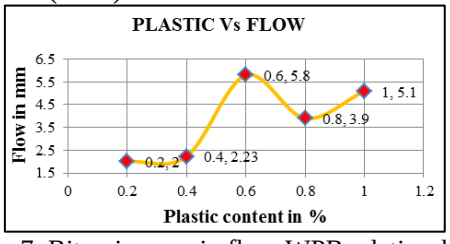

Fig. 7: Bituminous mix flow-WPB relationship

H. Optimum Plastic Content

Figures (6 & 7) are utilized to find two values respectively.

- WPB content at the highest Stability = 0.8%
- WPB content at the highest Flow = 0.8%

Optimum plastic Content (OBC) = 0.8+0.8!2 = 0.8% and the corresponding stability, flow is 16.27KN and 3.9mm respectively.

I. Comparison of control mix with WPB modified mix

A comparison of the mechanical properties of WPB modified asphalt mix at the optimum WPB content (0.8% by weight aggregate) and properties of the conventional bituminous mix is shown in Table 7.

Property	Conventional Mix	(0.8%) Modified Bituminous Mix
Optimum content in %	5.1	5.1
Stability(KN)	15.8	16.27
Flow(mm)	3.74	3.90

Table 7: Comparison of Control Mix with Wpb

V. CONCLUSION

Based on experimental work results for WPB modified asphalt mixtures compared with conventional asphalt mixtures, the following conclusions can be drawn.

WPB can be conveniently used as a modifier for asphalt mixes for sustainable management of plastic waste as well as for improved performance of bitumen mix.

The optimum amount of WPB to be added as a modifier of asphalt mix was found to be (0.8 %) by weight of aggregate of the bituminous mix.

Asphalt mix modified with (0.8 % WPB by weight of aggregate) has higher stability value compared to the conventional asphalt mix.

Asphalt mix modified with WPB exhibit higher flow value as the WPB percentage increased. However, the stiffness of the modified mix is increased.

It is observed that Marshall Stability value increases with polyethylene content upon addition of polythene.ie the resistance to deformation under heavy loads increases.

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