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Performance evaluation of waste plastic/polymer modified bituminous concrete mixes

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This paper describes comparative performance of properties of bituminous concrete mixes containing plastic/polymer (PP) (8% and 15% by wt of bitumen) with conventional bituminous concrete mix (prepared with 60/70 penetration grade bitumen). Significant improvement in properties like marshall stability, retained stability, indirect tensile strength and rutting was observed in PP modified bituminous concrete mixes.

Keywords: Bitumen, Modified bituminous concrete mix, Waste plastic

Introduction

Considerable research has been carried out to determine suitability of plastic waste modifier in construction of bituminous mixes[1,2]. Recycled polythene from grocery bags may be useful in bituminous pavements resulting in reduced permanent deformation in the form of rutting and reduced low-temperature cracking of pavement surfacing[3]. Zoorab & Suparma[4] reported use of recycled plastics composed predominantly of polypropylene and low density polyethylene in plain bituminous concrete mixtures with increased durability and improved fatigue life. Resistance to deformation of asphalt concrete modified with low-density polythene (5%) was improved in comparison with unmodified mixes[5]. Fatigue life of asphalt mix modified by waste plastic bag increased several times than that of asphalt mix prepared with 80/100 penetration grade binder[6]. Dry process involves direct incorporation of waste PP, which is blended with aggregate before adding in bitumen, to prepare a waste PP modified bituminous concrete mix. Wet process involves simultaneous blending of bitumen and waste PP.

This paper presents comparative performance of properties of bituminous concrete mixes containing plastic/polymer (PP) (8% and 15% by wt of bitumen) with conventional bituminous concrete mix (prepared with 60/70 penetration grade bitumen), using dry process.

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Materials and Methods

Materials

Waste PP modifier (Fig. 1) is a mixture of waste PP in shredded form (particle size, diam 2-3 mm). Thermal degradation behaviour of waste PP modifier was studied on Thermal Gravimetric Analyser (TGA) in nitrogen atmosphere using a sample size (7.8 mg) at heating rate of 20°C / min. Waste PP modifier does not degrade while blending with hot aggregates (Fig. 2). Penetration grade paving bitumen (60/70 penetration grade) has following physical properties: penetration (100 g, 5 s, 25°C, IS:1203-1978), 69 dmm; Softening Point, (Ring and Ball Method, IS:1205-1978), 51°C; ductility at 27°C (5 cm/min, IS:1208-1978), >75 cm; and specific gravity (IS:1202-1978), 1.01.. Locally available Delhi quartzite aggregate has following properties[7]: aggregate impact value (AIV), 18%(24% max); combined flakiness and elongation indices, 28% (30% max); water absorption, 0.4%%(2% max); Los Angeles abrasion value (LAAV), 29% (30% max); and soundness, 5% (5% max).

Design of Bituminous Concrete Mixes

For determination of optimum binder content (OBC), Marshall specimens were prepared by adding bitumen (5.0, 5.5 and 6.0% by wt of aggregate) into hot aggregate (Fig. 3). Then, bulk density, Marshall stability, flow, and volumetric properties [air voids, voids filled with bitumen (VFB) and voids in mineral aggregates (VMA)] were determined (Fig. 4). OBC for BC mix was 5.5% (by wt of aggregate). Further, Marshall samples at OBC were cast using modifier (0, 8 and 15% by wt of bitumen),

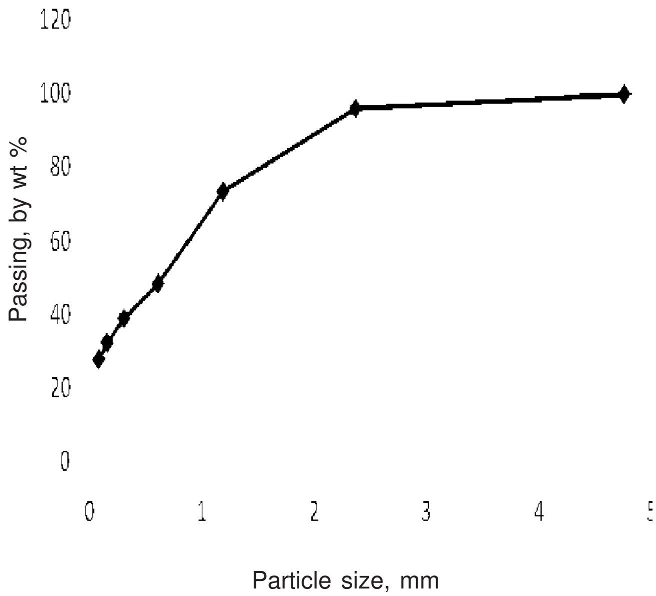

Fig. 1— Gradation of waste plastic/polymer modifier

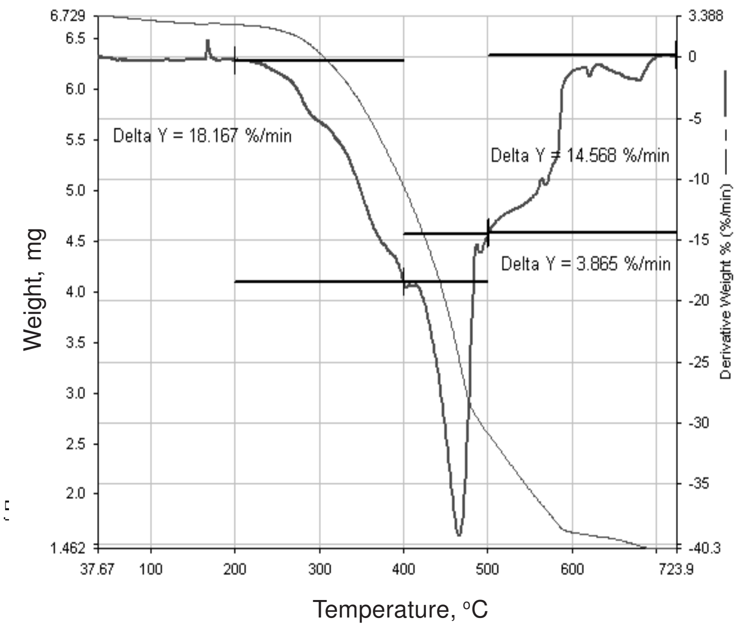

Fig. 2— TGA curve for waste plastic/polymer modifier

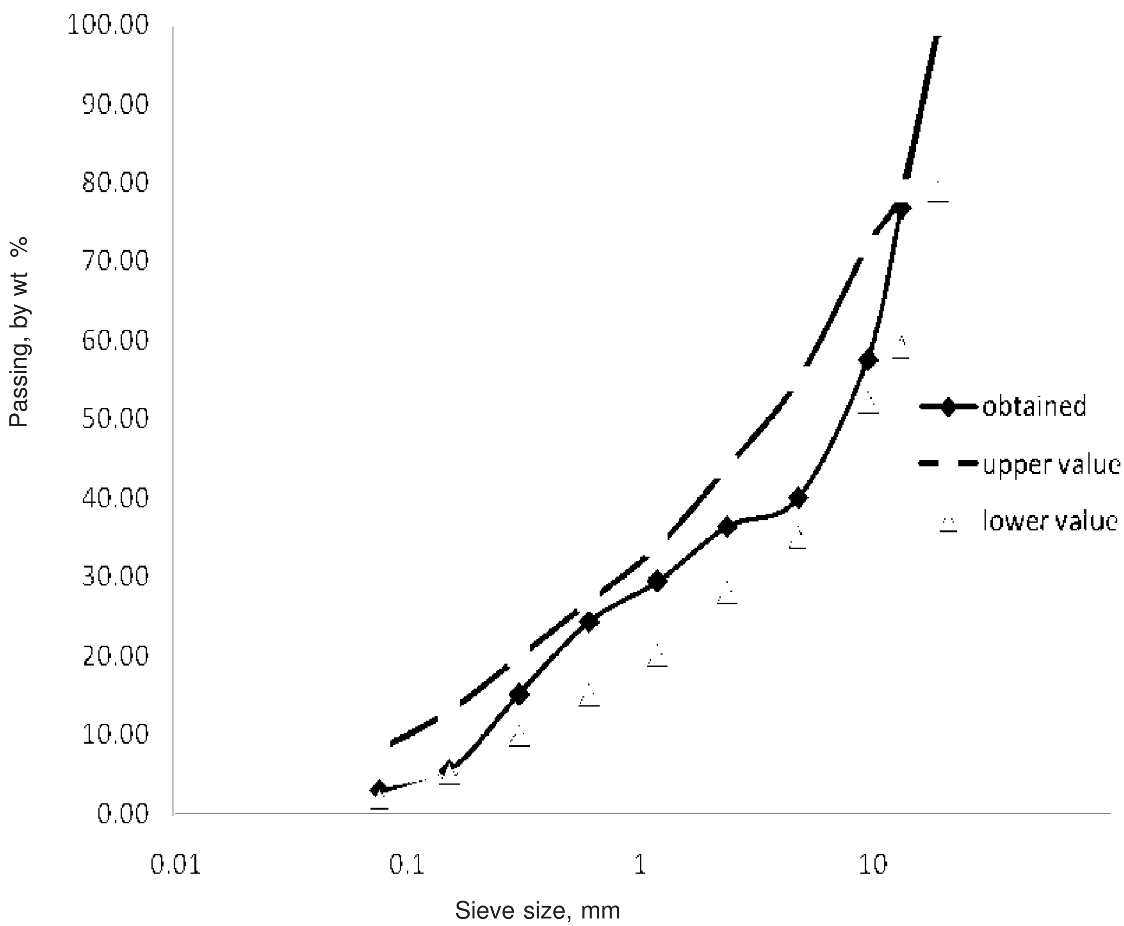

Fig. 3 —Gradation of BC mixes

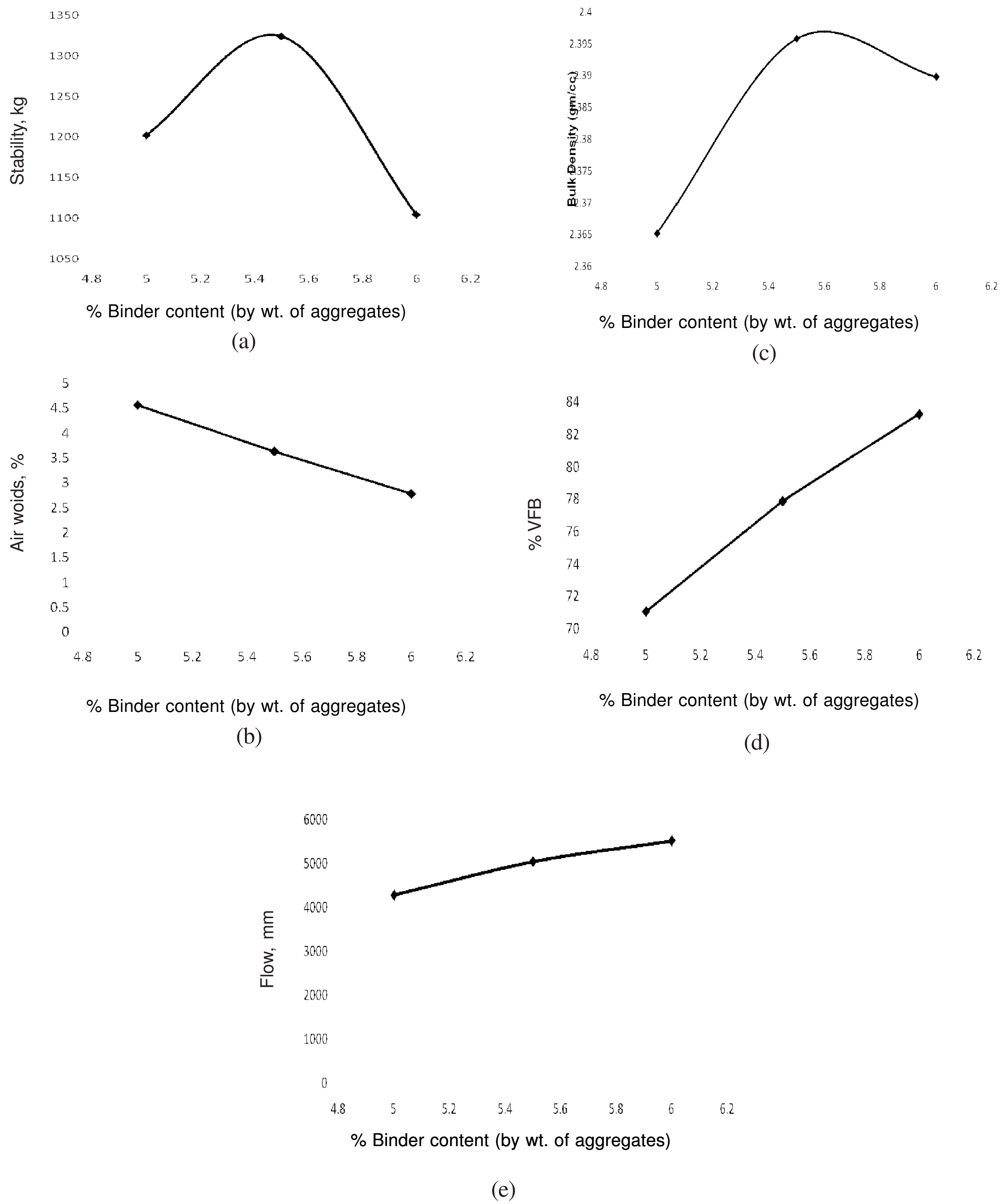

Fig. 4 — Volumetric properties of bituminous concrete mix at binder content vs: a) stability; b) air void; c) flow; d) bulk density; and e) voids filled with bitumen

Table 1. Properties of modified and conventional bituminous concrete mixes at optimum binder content

Properties	Conventional mix (60/70 bitumen)	Modified mix	
		8% waste plastic/polymer	15% waste plastic/ polymer
Marshall stability, kg	1300	1567	1539
Flow, mm	3.8	5.6	5.7
Retained stability, %	76	90	87
Air voids, %	4.5	3.6	2.9
Bulk density, g/cc	2.391	2.351	2.349
ITS* (Destructive method), kg/cm²	6.4	10.7	8.2

to determine bulk density and strength properties of waste PP modified bituminous concrete mixes.

Laboratory Performance Evaluation of Waste PP Modified Bituminous Concrete Mixes

a) Marshall Stability Test

Graded aggregates were heated at 150-160°C in oven, and waste PP modifier was added into hot aggregates before mixing OBC in dry process. Homogenous mix so prepared is then compacted by applying 75 blows on each side of specimen, using Marshall compaction hammer. Marshall specimens (both conventional and modified mixes) were tested for Marshall stability and flow (Table 1), after being submerged in a water bath at 60°C for about 30 min. Retained stability test was also conducted under water at 60°C for 24 h to determine ability of modified mix to withstand adverse soaking conditions.

b) Indirect Tensile Strength (ITS) Test

ITS test was conducted at 25°C to measure splitting tensile strength of bituminous mixes (both conventional and modified), by application of a diametric compressive force on a cylindrical specimen placed with its horizontal axis between plates of compression testing machine. ITS is calculated as, ITS = 2*p*/À*td*, where *p*, load (kg); *t*, thickness (cm); *d*, diameter of specimen (cm).

c) Rutting Test

Rutting potential was studied using Hamburg's wheel tracking device (HWTD), wherein a wheel rolls over specimen of bituminous surface (size, 300 mm x 150 mm x 50 mm at 50°C) and rutting potential at 20,000 passes/load repetitions is determined (Fig. 5).

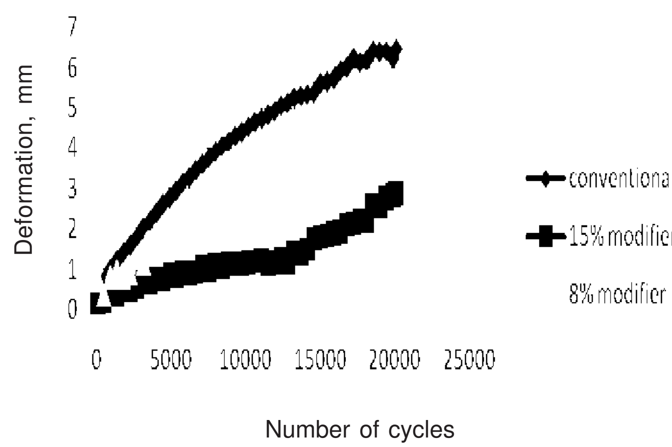

Fig. 5— Rutting potential of conventional and modified bituminous concrete mixes

Results and Discussion

Results of TGA (Fig. 2) indicate that waste PP modifier is thermally stable up to 200°C. It was observed that 60/70 penetration grade paving bitumen and aggregates satisfy specified limits of MoRTH. Marshall stability of modified mixes with addition of modifier (8 and 15% by wt of bitumen) was respectively 1.21 and 1.18 times higher than conventional mixes, as fine layer formed around aggregate enhanced strength of bituminous concrete mix. There was significant improvement in retained stability (%) due to lesser voids percentage (Table 1) in waste PP containing bituminous mixes resulting in reduction of water permeability. However, modified mixes containing modifier (15%) showed slightly decreased values for Marshall stability and retained stability amongst three modified mixes (Table 1).

In dry process, required quantity of waste PP was blended with hot aggregate prior to adding bitumen. Waste PP was coated onto aggregate by melt adhesion process, resulting in reduction of moisture absorption and soundness of aggregate. Water absorption for aggregate without waste PP (0.4%) reduced to nil for aggregate coated with waste PP (8% and 15%). Similarly, soundness of aggregate was 5%, whereas nil for waste PP coated aggregate. Aggregate coated with waste PP (8 & 15% respectively) showed improvement in physical properties: LAAV, 17 & 15%; and AIV, 15 & 13%.

When bitumen was added to waste PP coated aggregate, a better adhesion developed between bitumen and waste PP coated aggregate due to strong inter-molecular bonding. These inter-molecular attractions enhanced strength of bitumen concrete mixes, which in turn helped in enhancing durability and stability of mixes. ITS values obtained at 25°C for conventional mixes were 6.42 kg/cm² while these were 10.7 and 8.2 kg/cm² for modified mixes containing modifier (8 and 15%), respectively. Rutting was higher in case of conventional mix (7 mm) in comparison to bituminous concrete mixes containing 15% modifier (2.7 mm) and 8% modifier (3.7 mm). Rutting potential of modifier (15%) was lower as compared to modifier (8%), which attributed primarily to stiffness of mix due to increased modifier content. Rutting results indicated that modified mixes, containing waste PP modifier, were less susceptible to deformation as compared to conventional bituminous concrete mixes.

Conclusions

Coating of waste PP on stone aggregate improved AIV, LAAV and reduced water absorption capacity of aggregate. Further, inter-molecular bonding between bitumen and waste PP coated aggregate enhanced strength and thus quality of bituminous concrete mixes. Significant improvements were observed in performance parameters in Marshall stability, ITS, Rutting and retained stability of bituminous concrete mixes. Thus waste PP modified bituminous concrete mixes are expected to be more durable, less susceptible to moisture in actual field conditions with improved performance.

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