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Laboratory performance of Recycled Asphalt Mixes containing wax and chemical based Warm Mix Additives using Semi Circular Bending and Tensile Strength Ratio tests

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HIGHLIGHTS

- RAP to asphalt mixture may require higher strain energy before it fails in fracture.
- Wax based WMA may have better fracture properties compared to chemical based WMA.
- RAP addition may improve fracture properties based upon evaluated upon J_λ variation.
- Wax and chemical WMA additive may be recommended based upon satisfying TSR value.

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ABSTRACT

Durability and sustainability are two major requirements of the asphaltic pavement structure. Durability aspect may involve performance parameters such as fracture property, moisture sensitivity etc., whereas, sustainability aspect may involve utilization of Recycled Asphalt Pavement (RAP) and Warm Mix Additive (WMA) in the conventional asphaltic mixture. Though improvement in high temperature performance may be expected with the addition of RAP due to its stiffer nature, it may degrade intermediate temperature performance. Additionally, RAP utilization may also increase the mixing and compaction temperature during the construction phase. Therefore, researchers have recommended using different WMA additives to decrease production temperature of mixes containing RAP. Though the use of WMA additives with RAP may decrease mixing and compaction temperature, their effects on various performance parameters of the asphaltic mixture must be evaluated. Sufficient research works have been reported on the performance of RAP and WMA mixes at high temperature, however, so far, limited work is available on understanding effects of RAP and WMA additives on fatigue and moisture sensitivity of asphalt mixture. Therefore, the present research work aimed at evaluating intermediate temperature fracture properties and moisture sensitivity of asphaltic mixture containing RAP and WMA. Five different RAP contents (0%, 10%, 20%, 30%, and 40%), two different types of WMA additives (2% wax based "Sasobit" and 0.5% chemical based "Evotherm") and one without WMA additive (Control mixture) were considered. Fracture properties of different asphaltic mixture combinations were evaluated using Semi Circular Bending (SCB) test. Improvement in fracture property of Control mixture was observed with increase in RAP content, however, the addition of wax based and chemical based WMA additives showed an overall reduction in fractured resistance. Further, the asphaltic mixture containing wax based WMA additive showed better fracture performance compared to the corresponding mixture containing chemical based WMA additive. Similarly, moisture sensitivity of asphaltic mixtures was evaluated using Tensile Strength Ratio (TSR) approach. Addition of both WMA additives resulted in lowered Indirect Tensile Strength (ITS) under dry as well as wet condition. Though the addition of WMA additive showed a negative impact on moisture sensitivity, all mixture considered in the present research work passed the minimum TSR requirement. Therefore, wax and chemical based WMA additive may deem acceptable from moisture sensitivity point of view.

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1. Introduction

Durability is one of the foremost requirements for asphaltic pavement. Along with consideration of durability aspect, considerable importance has been given to sustainability for construction of pavement structure in recent years. Considering this, utilization of Recycled Asphalt Pavement (RAP) and Warm Mix Additives (WMA) may have an important contribution towards achieving such goals. Researchers across the world working in this area are putting best of their efforts to maximize use of RAP to have sustainable and durable pavement structure. RAP is obtained from asphaltic pavement which has consumed its design life or has distressed beyond a certain level, and may deem unfit for carrying further vehicular loading. In the present day scenario where every construction industry yearns for sustainable development approach, utilization of RAP is a step forward in this direction. Use of RAP as a partial replacement to fresh asphaltic mixture helps in different ways such as: (a) disposal problem associated with RAP, (b) reduction in overall demand of fresh aggregate and asphalt binder, and (c) overall reduction in cost associated with the material. Along with RAP material, use of WMA has also got considerable attention in recent years due to its ability to: (a) reduce the energy requirement during the construction stage, (b) reduce the amount of hazardous fumes emission during the construction stage, (c) increase the hauling distance, and (d) improve the workability of asphaltic concrete mixture. Though the addition of WMA may be considered as important technological advancement, its contribution towards various performance parameters of the asphaltic mixture must be evaluated.

Many research works are available where researchers have been trying to understand the effect of RAP addition to Hot Mix Asphalt (HMA) on different performance related parameters, considering the sustainability aspect associate with it [1–7]. Similarly, many research work has been reported on the understanding effect of different WMA additives on various performance parameters, considering lower energy requirement during construction stage [8–11]. Considering the sustainability aspect associated with RAP utilization and reduction in energy requirement associated with the use of WMA additive, researchers in recent years have been trying to integrate RAP with WMA. Mogawer et al. [12] and Tao and Mallick [13] investigated the effect of different types of WMA additives on the workability of an asphaltic mixture containing different RAP proportions. Addition of WMA additives was found to be significantly improving the workability of RAP containing asphaltic mixture. Similarly, different researchers have been trying to understand the combined effect of WMA additives and RAP on performance related parameters. For example, Mallik et al. [14] evaluated rutting performance of mixture containing high RAP level (up to 75% RAP content) with wax based WMA additive. It was concluded that though the addition of wax based WMA additive imparts stiffening effect to the asphaltic mixture, it may not improve the rutting performance of WMA and RAP mixture in comparison with HMA and RAP mixture. Similarly, Middleton and Forfylow [15] evaluated rutting performance of foam based WMA additive and RAP mixture. They found that addition of foam based WMA additive did not degrade the rutting performance. Also, the addition of RAP did not significantly stiffen the asphaltic mixture. Similarly, other research works in this area are also available where central research focus has been high temperature performance and moisture sensitivity [16–23]. Though the majority of research work pertaining to RAP and WMA mixture focuses on high temperature performance and moisture sensitivity, limited research work is available on evaluating the effect of WMA and RAP addition on intermediate temperature performance. Though utilization of RAP and WMA is an important step towards sustainable asphaltic pavement construction, intermediate temperature performance aspects such as fracture property should not be compromised in order to provide durable pavement structure.

Fracture forms an integral part of cracking mechanism to the asphaltic pavement in intermediate to low temperature conditions. Therefore, a rational design approach to asphaltic pavement must incorporate important fundamental properties such as fracture behaviour of the asphaltic mixture to ensure long term pavement performance [24]. Though the various causes to intermediate temperature distresses are distinctive, the basic cracking mechanism can be better understood by fracture characterization approach [25]. Use of single edge notch beam test is one of the conventional approaches for evaluating intermediate temperature fracture properties of the asphaltic mixture [26–28]. This approach involves three point loading test on notched beam. However, certain complexities are associated with it, such as: (a) sagging of beam under its own weight, especially under elevated temperature leading to considerable error in calculation [29], (b) not efficient for field core samples which are usually circular disks [30], (c) development of crack under self-weight in case of deep notched beam [31], and (d) difficulty in sample preparation etc. Considering the limitations of three point beam bending test, recently developed "*Semi Circular Bending (SCB) test*" has got considerable attention among research community for evaluating fracture properties of the asphaltic mixture [32–37]. Advantages of SCB tests over single edge notch beam test are as: (a) suitability for field core samples, (b) easiness and effective in sample preparation, and (c) repeatability in testing outcomes [35,36]. With the help of SCB test, a parameter "*J-integral* (J_λ)" is evaluated which represents the strain energy release rate during fracture process of the notched specimen. J_λ evaluated from SCB test have been used as an indicator for examining fracture properties of an asphaltic mixture [29,38–40].

The present research work aimed at evaluating intermediate temperature fracture properties of asphalt mixture containing different RAP percentages (0%, 10%, 20%, 30%, and 40%) and two different types of WMA (wax and chemical based WMA additive). Additionally, moisture sensitivity of asphaltic mixtures containing different RAP percentages and two different WMA additives have also been examined. It is expected that present research work will provide quality information regarding the effect of RAP and WMA addition to the conventional asphaltic mixture on intermediate fracture and moisture sensitivity performance. Overall, the present research work is a step towards providing sustainable and durable asphaltic pavement structure.

2. Materials and experimental plan

2.1. Materials

2.1.1. Asphalt binder

The present research work utilizes viscosity graded virgin binder (VG-30), collected from Hindustan Colas Ltd., Mumbai, India.

Table 1
Basic properties of VG-30.

Test	Test results	Standard	Limiting value (IS 73:2013)
Ductility at 27 °C, cm	90	ASTM D113	Min. 70
Penetration at 25 °C, 100 gm, 5 s	68	ASTM D5	Min. 45
Absolute viscosity at 60 °C, Poise	2400	ASTM D2170	2400–3600
Softening point, °C	46	ASTM D36	45–55
Kinematic viscosity at 135 °C, cSt	460	ASTM D4402	Min. 350
Loss on heating (%)	0.4	ASTM D1754	Max. 1%
Flash point (°C)	>220*	ASTM D91	Min. 220

* As per manufacturer data sheet.