A Laboratory Investigation on Rutting Characteristics of HMA & WMA Mixes when Reinforced with Fibers

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Abstract: Construction industry is one of the major causes for polluting the environment due release of harmful gases. We as civil engineers should take responsible for reducing carbon foot print during construction of hot mix asphalt (HMA). This study reveals that the mixing temperature of warm mix asphalt (WMA) is lower than conventional mix (HMA). WMA prepared with evotherm does not offer good resistance towards rutting & stripping properties. In order to improve the rutting characteristics of conventional and WMA mix fibers are added. The test results were compared with standard PMB 40 mix which is well known for rutting characteristics. The results infer that WMA prepared with evotherm exhibits less resistance towards rutting when compared with all mix combinations in the study. WMA mix is then reinforced with polypropylene fiber. The test result infers that there is good resistance offered by the mix for rutting and stripping properties.

Keywords: Rutting, HMA, WMA, Modified Bitumen, Fiber (max: 6 keywords)

1. INTRODUCTION

Infrastructure facilities like pavement construction play a vital role in economic progress of countries development. Pavements with better riding quality shall certainly play an important role in promoting national integrity, more particular for a country like India. In our country most of the pavements are constructed using bitumen as a binder and is referred as Hot Mix Asphalt (HMA). Preparation of HMA requires large amount of fuel for attaining mixing temperature so as to obtain homogeneity. This results in a negative impact on environment by releasing toxic gases. Warm Mix Asphalt (WMA) can be used as substitute to HMA mix so as to handle the alarming bells of mixing temperature. There are different types of additives used in preparation of WMA as Cecabase, Sasobit, Reciemul-90, Evotherm etc. Evotherm, a chemical additive used in the present study. WMA mixes is recognized for its importance in other parts of the Asian and developing countries like China, Brazil and India. It is observed form literature that WMA prepared with Evotherm exhibits less resistance towards rutting & stripping characteristics. In order to improve the rutting characteristics of WMA mix fibers are added. In the present study two fibers are used namely basalt and poly propylene (PP) fibers. Poly propylene belongs to alkenes group of hydro carbons. Its chemical formula is C_nH_{2n}. Basalt fiber is produced from basalt rock. Figure 1 provides fiber used in the study.

Figure 1. Poly Propylene and Basalt Fibers used in the study.

Basalt fiber was added to conventional mix and PP fiber was added in Warm mix prepared with Evotherm .

1.1 Objectives of Present Study

To ascertain marshal properties for conventional and warm mix asphalt when added with different proportions of fibers.

To evaluate the rutting & stripping characteristics of conventional and warm mix asphalt when reinforced with fibers.

2. LITERATURE

Warm mix asphalt (WMA) technologies were introduced for the first time in Europe in 1996 (Yang et al. 2012), and have become increasingly popular in the road industry in the United States and Europe (Lee et al. 2009). There have been numerous trial road sections paved with WMA in Europe (D'Angelo et al. 2008) and the United States (Zhang 2010). WMA is usually produced at lower temperatures, from 30°C to 50°C lower than conventional hot mix asphalt (HMA) (D'Angelo et al. 2008, Yang et al. 2012). There has been limited information about long-term performance of WMA so far (D'Angelo et al. 2008, Mogawer et al. 2011), but using WMA clearly has many benefits compared to traditional HMA, such as lower energy consumption, lower emissions, better working conditions (D'Angelo et al. 2008, Mogawer et al. 2011). A few of the along with their contributions are given in table 1

Table 1 contributions from different authors

Name of Author	**Type of Modification**	**Improvements brought in through modification of mixes.**
Sayyed *et. al* (2009)	Reinforcement of asphalt mixes with fibers	If the fibers are too long they form balling i.e. some of the fibers may lump together and may not mix well with asphalt.
Shu *et al* (2013)	Warm Mix Asphalt technology	Rutting resistance of the WMA reduced when more cecabase was added. Co2 is reduced of about 30% .45^{0}c is said as rutting temperature
Dinis *et al* (2012)	Warm Mix Asphalt with bitumen emulsion	Has carried on stiffness and fatigue resistance for Warm mix asphalt. Permanent deformation was determined by wheel tracking test.
Arun and Sunil (2013)	Warm Mix Asphalt	The study reveals that WMA is applicable for Indian paving operations and environmental conditions. Sasobit additive is used for preparation of WMA
Zhao *et al* (2013)	Different types of aggregates	When lime stone aggregate is used WMA mix prepared with sasobit and evotherm both are more effective in pavement performance characteristics of mix. Whereas when basalt aggregate is used in WMA mix prepared evotherm is less effective.

2.1 Critical Gap

Most of the studies were conducted on WMA prepared with Cecabase, Sasobit, Reciemul-90, Evotherm. To improve performance characteristics of WMA mix fibers were added. However WMA prepared with evotherm exhibits less resistance for rutting characteristics. An attempt is made to evaluate influence of poly propylene fibers in WMA mix.

3. METHODOLOGY

In the present investigation a methodology is proposed for evaluation of warm mix asphalt prepared with evotherm and inclusion of poly propylene fibers at different proportions. Figure 2 provides methodology adopted for study.

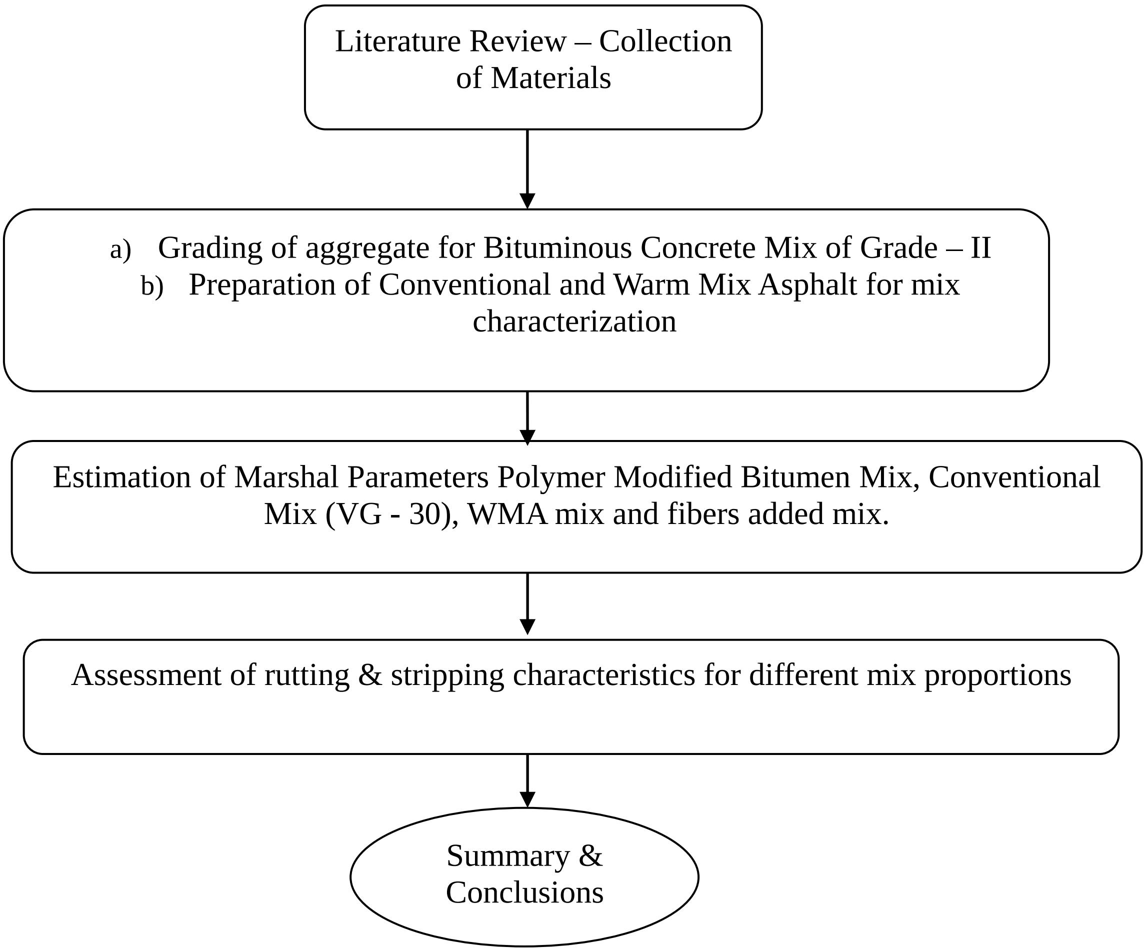

Figure 2. Methodology adopted for study.

3.1 Preparation Mixes

Aggregates and stone dust was collected from local quarry, bitumen was collected from refinery. Physical properties were carried on materials in the laboratory. Warm mix asphalt is prepared by addition of evotherm (0.5%) of weight of bitumen is doped. It is stirred thoroughly for arriving warm mix. Fibers are used as reinforcement for resisting top down cracking in the pavements. In the present study poly propylene (PP) and basalt fibers are used.

4. EXPERIMENTAL PROGRAM

4.1 Marshal properties

Marshall Specimens were prepared to determine optimum bitumen content (OBC) and optimum fibre content (OFC). Specimens are prepared in 100 mm in diameter and compacted with 4.54 kg rammer, falling from a height of 45.7 cm with 75 blows on each face of the specimen. The compacted specimen shall have a thickness of 63.5 mm. stability corrections were applied for variation in thickness. The sample is allowed to cool for a few hours and then extracted using a sample extractor. The specimen is placed in the testing assembly and the load is applied on to it at the rate of 50.8mm/minute. The specimen is tested at a temperature of 60^{o}c. A load cell is used to record failure load and a linear variable displacement transducer (LVDT) for recording flow values. Three samples were prepared for each percentage of bitumen mixes. The peak load resisted by the specimen is termed as Marshall Stability value. The flow is recorded down in terms of mm or units (1 unit=0.25 mm). A total of 54 specimens were prepared and tested to obtain OBC and OFC values of different mix combinations. Figure 3 provides marshal set up

Figure 3 Marshal setup – Online DAQ with automatic compactor

4.2 Rutting characteristics

The specimen was prepared in a slab compacter with volume of 6000 cc and is shown in figure 5. Mixes combinations were prepared with densities arrived from Marshall Test. It is compacted until desired densities of mix is achieved

4.2.1 Immersion type of wheel tracking device

An accelerated test simulated in the laboratory for estimation of rutting resistance as shown in figure 5.The wheel used in the study is steel wheel for a total weight of 710N. An LVDT is used to measure the rut depth corresponding to number of passes. Specimens are immersed in water at a temperature of 50^{o}c and were preconditioned. Stripping property of different mixes was analysed from immersion test. Travel of wheel path is 230 mm and the speed of the wheel for one pass is approximately 1.46 kmph (72 wheel passes per min). 24102 passes will simulate traffic of 30 msa in the field (Nahi , 2012) The image of the foot print of the wheel is shown below in figure 4

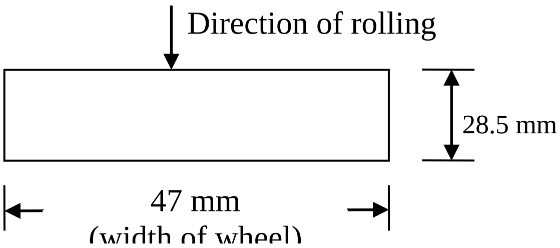

Figure 4. Foot print of wheel

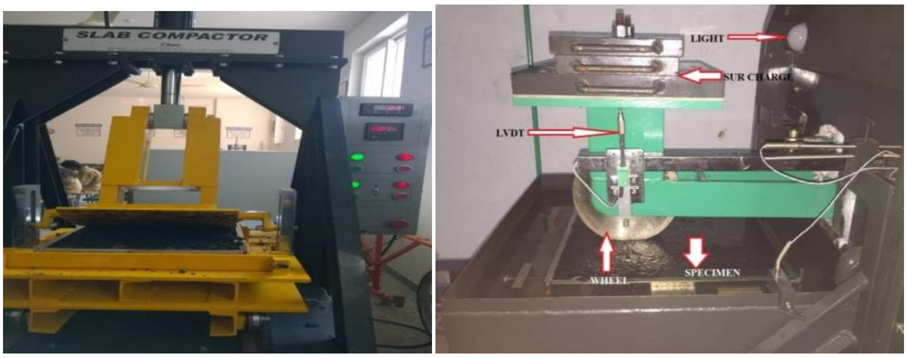

Figure 5. Slab Compactor and Immersion Type Wheel Rutting with Online DAQ

5. RESULTS & DISCUSSION

In the present study conventional mix (HMA) is reinforced with fibre and as HMA releases harmful gasses during preparation of the mix, WMA is used to reduce the effect in release of harmful gases. As WMA when prepared with evotherm cannot exhibit good resistance towards the rutting it is reinforced with fibre. Bituminous concrete mix grading – II (closed grading) was used as specified in MORTH specifications. Figure 6 shows the gradation adopted for the study.

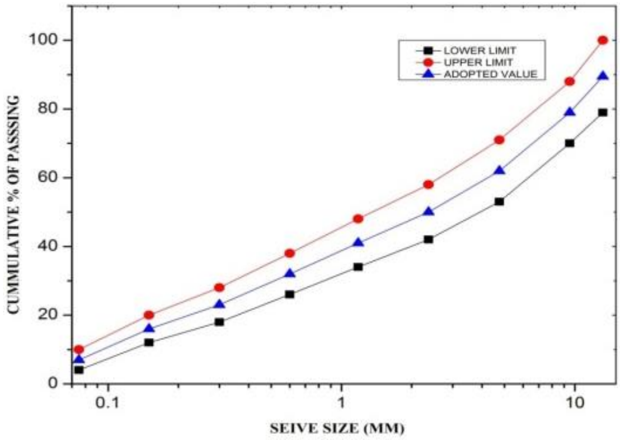

Figure 6. Gradation Curve

5.1 Engineering Properties of Aggregates

These properties are helpful in knowing the suitability of aggregates for a particular layer or type of mixes used in the pavement. Table 2 shows the engineering properties of aggregates used in the study.

Table 2 Engineering Properties of Aggregates

Test conducted	Results (%)	MORTH Specification (%)	Test code
Aggregate crushing value	21.5	Max 30	IS:2386(IV)
Aggregate Impact Value	15.315	Max 30	IS:2386(IV)
Combined EI &FI Indices	22	Max 30	IS:2386(I)
Water absorption	1.06	Max 2	IS:2386(III)
Specific Gravity (no units)	2.704	--	IS:2386(III)
Los Angeles abrasion value	20.56%	Max 40	IS:2386(IV)

Aggregate materials are satisfying for preliminary test properties as per MORTH requirements.

5.3. Bitumen Properties

Bitumen is collected from local refinery in the city and its properties are analysed in the laboratory for arriving the grade of bitumen. Table 3 shows the properties of the VG-30, WMA and Polymer modified bitumen (PMB.)

Table 3 Properties of

(i)VG-30 Bitumen.

Consistency Characteristics	VG-30	Specifications of VG-30	Test standards
Penetration at 25^{0}C	57	50-70	IS:1203
Softening point(^{0}C)	50	47	IS:1205
Ductility(cm)	73	50	IS:1208
Absolute Viscosity (Poise)	2207	Min 2400	IS:1206(II)
Kinematic Viscosity (cSt)	352.47	Min 350	IS:1206(II)

(ii)Warm Mix Asphalt

Type of Test	Warm Mix Asphalt	Test Standards
Penetration at 25^{0}C	44	IS:1203-1978
Softening point(^{0}C)	67	IS:1205-1978
Ductility(cm)	96	IS:1208-1978

(iii)PMB 40 Mix

Type of Test	Polymer Modified Bitumen (PMB)	Specifications	Test standards
Penetration at 25^{0}C	52	30 to 50	IS:1203-1978
Softening point(^{0}C)	49	50	IS:1205-1978
Ductility(cm)	56	+50	IS:1208-1978

5.4 Mixing Temperature of Virgin and WMA Mixes

The viscosity of bitumen should not be more than 0.5 pa-sec while mixing. Mixing temperatures were found using rotational viscometer and is shown in figure 7.

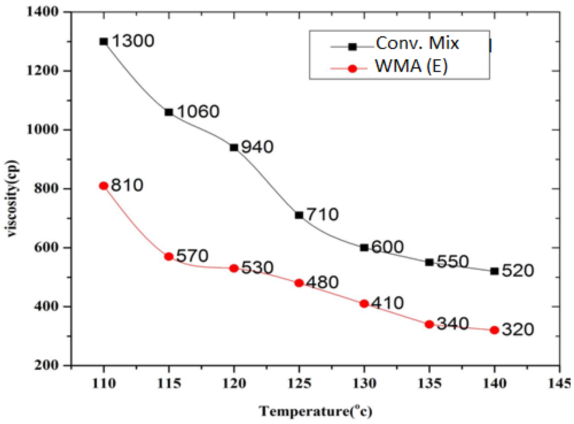

Figure 7. Viscosity Variation of conventional and warm mix asphalt prepared with evotherm

5.5 Marshall Parameters

Marshall Stability test helps in determining the Optimum Bitumen Content (OBC). Flow value and stability value from this test infers about the resistance of the mixes against loading.

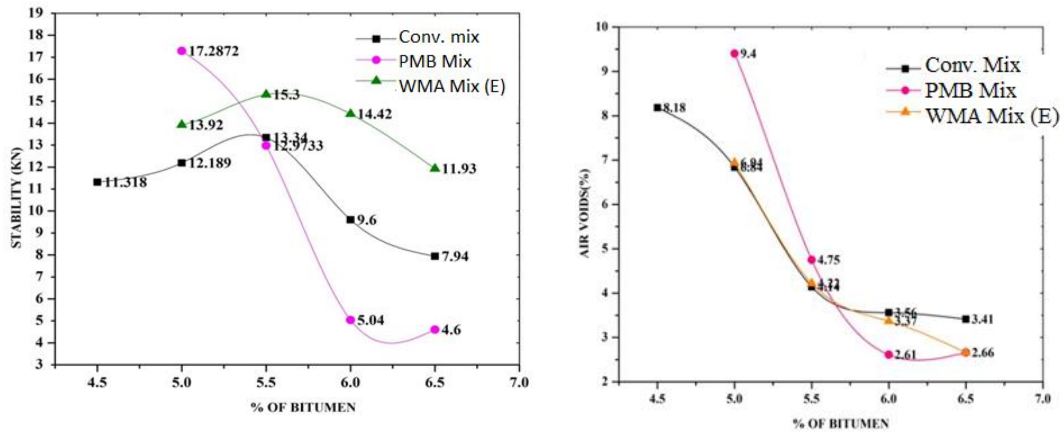

Figure 8. Stability and air voids of different mix combinations

From figure 8 it is observed that at 5.0 % of bitumen content, Stability value for PMB mix is 17.28 kN which is higher than conventional and WMA mixes prepared with evotherm. Conventional mix has low stability value at 6.5 % of binder content. It is observed that stability values are reduced with the increase in percentage of binder content. WMA has higher stability values than conventional mix. The percentage of air voids is more for PMB mix at 5 % of bitumen content. There after % air void for PMB is reduced and is gradual after 5.5%, conventional and WMA mixes follows similar trend in percentage of air voids. As per MORTH (2013) 5th revision guidelines target air voids 4 % shall be considered for determining OBC and is achieved as 5.5 % for different types of bitumen mix combinations.

Fiber was added at OBC for WMA at different percentages with an increment of 0.1%. Mix with 0.6% of fiber shows higher stability. The reinforced mix with maximum stability is considered as OFC. Air voids has decreased initially and increased on increase in percent of fiber content, this may be due to the effect of phenomenon called balling. Figure 9 shows the variation of stability and percentage of air voids for fiber reinforced WMA mixes.

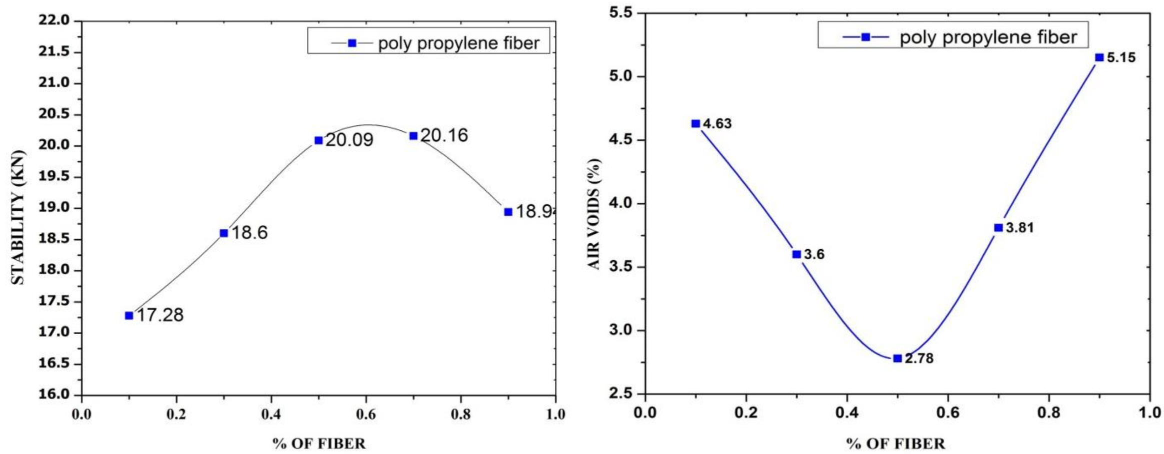

Figure 9. Stability and Air voids for different percentages of fibers

5.6. Rutting characteristics

The test is conducted in accordance with AASHTO-T324 and used for evaluation of rutting and stripping characteristics. Rectangular slabs of size 400 X 300 X 50 mm were casted and are shown in figure 10. Specimens were prepared at OBC of conventional, PMB and WMA mixes. WMA mix prepared with evotherm is failed earlier when compared with conventional mix as mentioned by the previous authors (Zhao 2012)

Figure 10 Rutting specimens

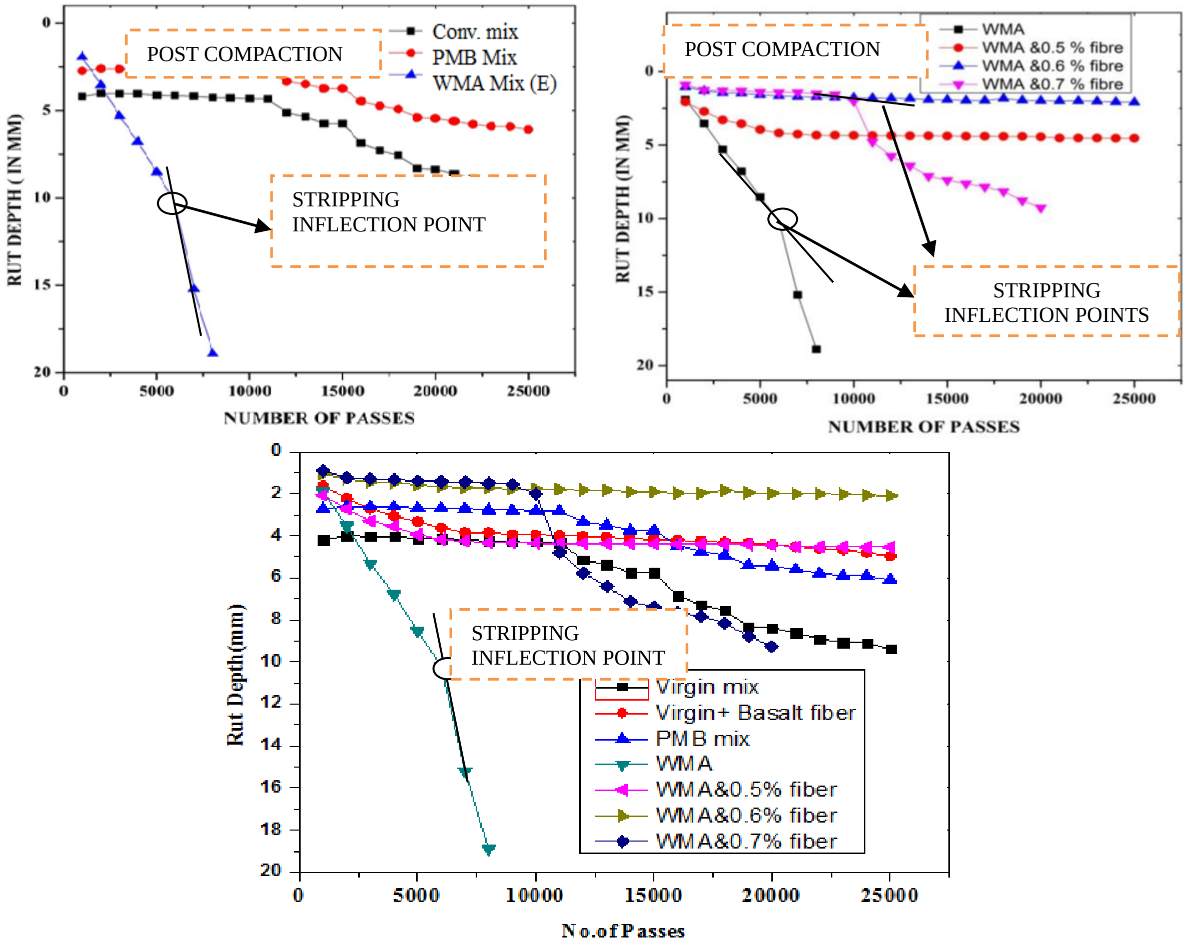

Figure 11. Comparison rutting and stripping behavior for different mixes

From figure 11. It is observed that basalt and poly propylene fiber when reinforced with conventional and WMA mixes exhibited better resistant rutting than un-reinforced conventional and WMA mixes and is competed with PMB mix. 0.6 % fiber added WMA mix showed better resistance towards rutting than all other mixes prepared in the study. Striping values are good for fiber reinforced mixes than all other mixes used in the present study.

6. SUMMARY AND CONCLUSIONS

On the basis of observation and outcomes of Marshall Test properties and rutting characteristics for conventional, PMB, WMA (E) mix and fibre reinforced mixes the following conclusions are drawn.

a. It is observed that WMA can be laid successful at very low temperature at 120^0C having higher stability values than conventional mix. Stability has increased by 31.7% when added with optimum percentage of poly propylene fiber in WMA mix. Further increase in fiber content has lead mixing difficulty.
b. Mixing temperatures was reduced by 20^0 C when prepared with WMA.
c. Maximum stability was achieved at 0.6% fibre content for both basalt and Poly Propylene fibre reinforced mixes which is considered as OFC.
d. With the inclusion of poly propylene fibre in WMA mix exhibits more resistant to stripping than PMB, conventional and un-reinforced WMA mixes.
e. As Stripping accelerates the rut depth is also increasing, which is observed in all mix combinations.

It is concluded that modification of WMA mix with poly propylene fiber increases stability, improves resistance of rut depth, striping resistant in pavements for same number of passes.

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