Effectiveness of Cashew Nut Shell Liquid to improve the rutting resistance of warm mix asphalt

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***Abstract*- In order to reduce the dangerous pollutants released into the atmosphere during the creation of conventional Hot Mix Asphalt (HMA), Warm Mix Asphalt (WMA) technology, a sustainable way of pavement construction, has been developed. It is essential to design a long-lasting pavement surface while safeguarding society and the environment. The current study compares the rutting characteristics of WMA with Cashew Nut Shell Liquid (CNSL), a green warm mix additive, with the prevalent WMA technology with sasobit, and with the traditional hot mix asphalt, taking into account the potential benefits of organic additives of WMA technology. In this study, CNSL and sasobit, were added to VG-30 bitumen at their optimum dosages of 2% and 3% of the bitumen's weight to produce warm mix asphalt with CNSL (WMA-CNSL) and warm mix asphalt with sasobit (WMA-Sasobit), respectively. WMA-CNSL exhibited a reduction of 17.01 % and 42.4 % in rut depth compared to that of WMA-Sasobit and HMA respectively and offered excellent resistance to permanent deformation due to the adhesive properties of CNSL. The experimental investigations are justified by the statistical analysis. The results of an ANOVA analysis for the rut depth showed that the type of mix had a significant impact on the resistance of bituminous mix to rutting.**

Index Terms: Warm mix asphalt; Cashew nut shell liquid, Saobit, VG-30 bitumen, Rut depth, Rutting characteristics.

I. INTRODUCTION

One of the major forms of pavement distress is permanent deformation. Rutting is the term for long-term asphalt surface deformation that builds up in the wheel paths as a result of frequent traffic loading cycles. Rutting is a major issue and a potential sign of pavement breakdown because it may be followed by fatigue cracking and other distresses. Because WMA's mixing and compaction temperatures are lower than those of HMA, the binder in WMA ages more quickly and becomes less rigid and more rut-resistant. The degree of voids in asphalt mixes, the type of road construction, the type and temperature of the pavement, and the penetration and viscosity of the asphalt all affect rutting performance [1, 2].

Organic WMA additives (natural or artificial waxes and fatty amides), which can be added either directly to the asphalt mixture or to the asphalt binder, promote the manufacturing of asphalt mixes in a sustainable and economical manner [3]. They reduce the viscosity and enhance the workability of the asphalt mix since they melt at temperatures between 80 °C and 120 °C [4, 5, 6]. When the asphalt binder cools, these additives crystalize, creating a lattice structure with incredibly minute, uniformly dispersed particles [7], stiffening the substance and improving resistance to low temperature cracking and rutting. [8, 9, 10, 11, 12]. Sasobit is a fine crystalline, long-chain aliphatic hydrocarbon that is created during the Fischer-Tropsch process when coal is gasified. Sasobit acts in the mixture as a flow modifier, allowing the aggregates to move freely and get coated by the asphalt binder. Sasobit is added at optimal dosages of 3 to 4 percent by weight of binder [11, 12].

CNSL, oil made of unsaturated phenols and a by-product of the cashew nut industry, has antioxidant properties. The addition of CNSL to asphaltic mixes reduced the stiffness of the bitumen, improved the compatibility of the additive with the bitumen, and prevented the rutting of asphaltic mix [13]. Mixing and compaction temperatures of bituminous mixes are greatly reduced by adding CNSL at an optimal dose of 2% by weight of bitumen and by improving bitumen flow. Experimental tests have shown that CNSL is an effective additive for enhancing the rutting resistance and fatigue life of rubberized asphalt mixtures [14, 15].

A. Research gap and Novelty of the Investigation

Permanent deformation is a major concern with hot mix asphalt technology. Even though warm mix asphalt technology is an efficient way to reduce the energy consumption and emissions associated with conventional hot mix asphalt (HMA) production, to date no organic warm mix additive has been established to contribute better performance than the conventional hot mix asphalt regarding rutting resistance. Therefore, it is crucial to investigate a green warm mix additive that is affordable, sustainable, and made from a renewable resource without sacrificing the durability of pavement.

B. Objectives of the present study

Considering the remarkable benefits of warm mix asphalt technology and CNSL, it is essential to develop an innovative method to guarantee the rutting resistance and durability of pavements while preserving environmental sustainability. The main objective of the present study is to assess the potential of CNSL to improve the rutting resistance of warm mix asphalt by comparing the rutting characteristics of WMA with CNSL, WMA with sasobit and HMA with VG-30bitumen.

II. MATERIALS AND METHODOLOGY

The materials utilized and the methodology followed for the present investigation are explained subsequently.

A. Materials

Aggregates of size 20, 10 and 6 mm and mineral filler that passed through 0.075-mm IS sieve, were used to produce hot and warm mix asphalt specimens. To produce HMA, VG-30 bitumen was used. VG-30 bitumen modified with an optimum dosage of 2 % CNSL(VC) [16] and 3% Sasobit by weight of bitumen (VS)was used for preparing WMA-CNSL and WMA-Sasobit respectively. According to IS 73:2013, the properties of modified and unmodified binders were confirmed [16]. The physical characteristics of aggregates were evaluated in accordance with Indian Standard (IS):2386 Parts I, III, and IV [17, 18, 19]. The aggregate gradation of asphalt mixtures was finalized as per MoRTH [20].

B. Rutting characteristics of hot and warm mix asphalts

For analyzing the rutting characteristics, specimens of HMA, WMA-CNSL, and WMA-sasobit were prepared and tested.

1) Preparation of Test Specimen

HMA, WMA-CNSL, and WMA-sasobit specimens of 600 × 200 × 60 mm were cast at optimum binder contents (OBC) of 4.38%, 4.32%, and 4.55% at mixing temperatures of 160 °C, 135 °C, and 135 °C, respectively by maintaining the air void content of 7 ± 1% in order to study the rutting properties of the mix [21].

2) Testing of Specimen

According to AASHTO T 324[21], an Immersion Wheel Tracking Device was used to examine the rutting characteristics of HMA and WMA samples (Fig.1). Test was conducted at 50 degrees Celsius up to 20,000 wheel passes. A load of 705 ± 4.5 N was applied by maintaining the reciprocating wheel attachment above the centre of each specimen. The compacted specimen was rotated back and forth by a steel wheel at a speed of 50 ± 5 passes per minute. With the use of digital linear variable differential transducers, the rut depth data were observed (LVDT) for HMA and WMA samples.

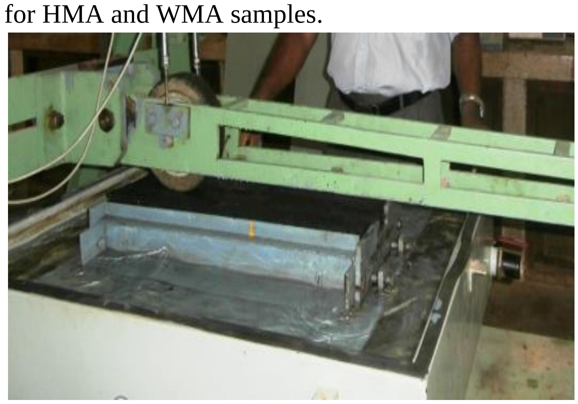

Fig.1. Testing of Specimen in Immersion Wheel Tracking Device

III. RESULTS AND DISCUSSION

Resistance of the mix to moisture induced failures was evaluated by observing the rut depth of HMA, WMA-CNSL and WMA-sasobit samples.

A. Rutting resistance of hot and warm mix asphalts

Rut depth values of hot and warm mix asphalt samples at different wheel passes are shown in Fig.2. The average rut depth of the HMA and WMA-CNSL and WMA-sasobit samples at 20,000 wheel passes were 10.92 mm, 6.29 mm and 7.36 mm, respectively which were within the permissible limit of 20% of the sample's overall thickness [21].

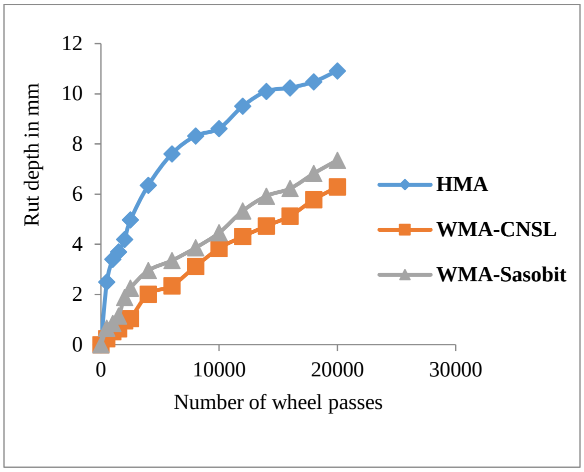

Fig. 2.Rut depth of hot and warm mix asphalts

From Fig.2, it was observed that WMA-CNSL exhibited a reduction of 17.01 % and 42.4 % in rut depth value compared to that of WMA-Sasobit and HMA respectively. Major components of CNSL include Anacardic acids (60–70%), cardols (10–20%), cardanols (3–10%) and 2-methylcardols (2–5%). The chemical structure of phenolic compounds is extremely peculiar, with an alkyl side chain with 15 carbon atoms that is in a meta-position with respect to the hydroxyl group. Physicochemical and surfactant properties of CNSL can provide greater chemical compatibility and adhesion between bitumen and aggregates. WMA offered greater resistance to permanent deformation than HMA because of the adhesive qualities of CNSL. As a result, WMA-CNSL exhibited improved resistance to permanent deformation or the accumulation of the non-recoverable component of responses to repeated loads at high service temperatures compared to WMA-sasobit.

IV. STATISTICAL ANALYSIS

A statistical analysis of the test data was carried out to examine the significant difference in the rutting characteristics of hot and warm mix asphalts using R Programming (RStudio 1.0.136) at a level of significance of 5%. As shown in Table II, analysis of variance (ANOVA) for rut depth was performed.

TABLE II. ANOVA- RUT DEPTH

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Mix	2	0.06677	0.03341	12272	<2e-16 ***
Residuals	15	0.00004	0.00000		
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

To verify the authenticity of experimental results statistical analysis was performed based on a null hypothesis which states that rut depth value of mix does not depend on the type of mix. Based on ANOVA shown in Table II, since the p-value is<0.001, the null hypothesis can be strongly rejected. At a significance level of 0.05, the TSR values of all mixes were noticeably different from one another, showing a significant difference between their abilities to resist moisture damage.

V. CONCLUSIONS

Due to the adhesive properties of CNSL, WMA-CNSL exhibited a reduction of 17.01 % and 42.4 % in rut depth value compared to that of WMA-Sasobit and HMA respectively. Rut depth values of hot and warm mix asphalt samples were within the permissible limit of 20% of the sample's overall thickness. The statistical analysis demonstrates the accuracy of the experimental findings. The results of an ANOVA analysis demonstrated that the type of mix had a substantial impact on the rutting resistance of bituminous mix.

Warm mix asphalt with CNSL plays a vital role in improving the resistance to rutting and durability of pavement by maintaining the sustainability of the environment.

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