Zemedkun Bereket Samuel
ID No- 16503984

Fundamental study on performance of recycled HMA mixtures with various RAP contents

I. INTRODUCTION

From 1970's, year by year, use of reclaimed asphalt pavement (RAP) has been an indispensable part of pavement technology due to its feasibility in terms of environmental, economic, and technical benefits.

Investigation and application of RAP is a challenging task due to its nature of variability, an undocumented source of its origin, and contamination. Most previous researchers have done research in wider intervals i.e. 10%-25% RAP content to assess the performance of mixtures. The variable nature of RAP is known, the present study evaluated recycled HMA mixtures containing RAP with 5% interval to assess the marginal difference in mixtures performance. In the current study, three different pavement distresses were selected, those are moisture damage, rutting and cracking. For the study four laboratory tests were conducted, namely, Marshall stability and flow test, Indirect tensile strength test (IDT), wheel tracking test (WTT), and three-point bending test (3PBBT). The tests assessed the stability, moisture susceptibility, rutting, and cracking performance of mixtures respectively.

Past studies showed that inclusion of RAP in asphalt mixes changes the physical, mechanical, and chemical properties of the HMA mixes. The existing findings on the effect of RAP in recycled HMA can be identified into three groups, improvement, and/or decline, or similarity in the performance achieved compared to the new or less RAP containing mixtures. Therefore, it is difficult to have consent among researchers on predicting the effect of RAP in a performance of mixes consistently. This happened due to varies research approaches and differences in materials source used for experimental work.

On the current study the following two objectives were addressed;

- To assess the recycled HMA mixtures having 5% interval of RAP contents.
- To give recommendations for taking necessary measures when using recycled HMA mixtures.

II. MATERIALS AND METHODS

On this section, the ingredients used for research work and mix design procedure were discussed.

A. Materials

***The aggregate*:-**new and RAP aggregates had a nominal maximum aggregate size(NMAS) of 12.5mm and the combined gradation were done to satisfy specification limit for wearing course of Ethiopian standard.

***Asphalt binders*:-** the old asphalt from RAP materials had a penetration grade of 15(1/10mm). The new asphalt which was used as a softening agent was straight asphalt with penetration grade of 60/80.

B. Methods (Laboratory tests)

Marshall Mix design procedure:- generally the procedure consists of; aggregate and asphalt selection, specimen preparation, volumetric parameters calculation, stability and flow determination, and optimum asphalt content selection. On this study, the design of recycled HMA mixtures was done by assuming 100% re-activation binders from RAP.

Moisture susceptibility test: - moisture damage is the deterioration of asphalt mixtures important performance properties, due to the presence of water inside the mass of mixtures. On the present study one of the moisture susceptibility tests, IDT was conducted. The indirect tensile strength of asphalt samples can be calculated by using equation 1.

$$ITS = \frac{2P}{\pi \times h \times d} \quad (1)$$

Whereas *ITS* is indirect tensile strength in (MPa), P is peak load at failure in N, *h* is specimen thickness in mm, *d*= specimen diameter in mm.

The tensile strength ratio (*TSR*) was used as an indicator for damages caused by moisture on mixtures, by providing the retained indirect tensile strength of specimens after conditioning the samples. The *TSR* of specimens was calculated using equation 2:

$$TSR = \frac{ITS_{conditioned}}{ITS_{unconditioned}} \quad (2)$$

Whereas:

$ITS_{conditioned}$ = conditioned specimen indirect tensile strength

$ITS_{unconditioned}$ = unconditioned specimen indirect tensile strength

The higher *TSR* value indicates mixtures which are resistant to moisture damage. In general, a value above 0.70 is the most likely acceptable limit.

Permanent deformation test:- rutting is distress which leads to a permanent deformation in pavement structure. WTT is used to assess the rutting performance of HMA mixtures. As per the Japanese standard Dynamic Stability (DS) expressed in cycle

per millimeter is used as an indicator of rutting performance of the mixture. DS can be calculated using equation.

$$DS = 1.5x\frac{42x15}{d_{60} - d_{45}} \quad (3)$$

Whereas, D_{60} and d_{45} are rutting depth at 60^{th} and 45^{th} minutes respectively in mm.

Cracking test:- cracking can happen due to the environmental effects and/or repeated traffic load. The TPBBT used to evaluate the flexural properties of the asphalt mixtures in term of resistance to cracking. The TPBB tensile have two outputs, i.e. stress (σ_f) and tension strain (ε_f) at failure. The parameters of The TPBB test can be calculated as follows (JRA B005):

$$\sigma_f = \frac{3}{2}\times\frac{P_{ult}\times L}{b\times h^2} \quad (4)$$

$$\varepsilon_f = \frac{6\times h}{L^2}\times d \quad (5)$$

Whereas, P_{ult} is a peak load; L is a span of the bending support; h is a height or a thickness of prismatic specimen; b is a width of prismatic specimens, and d is a deformation at the peak load.

III. Results AND DISCUSSIONS

A. Marshall stability results

The Marshall mix design results showed that all mixtures in the study satisfied the specification range of most of the volumetric parameters, except the slight decrease of VMA at the 30% RAP containing mixture. The stability which indicates the mixtures resistances to deformation, the RAP containing mixtures performed well compared to 0% RAP mixture. This may be due to the stiffness of mixtures due to aged asphalt from RAP.

B. Indirect tensile strength test results

The test result clearly showed that the 0% RAP mixture and 20% RAP mixtures had insignificant differences on the IDT values. On the other hand, adding 30% of RAP showed significant improvement of IDT value on unconditioned specimens. For the conditioned specimens, it has been seen that the IDT values increased up until 25% RAP inclusion and it declined slightly at 30% RAP mixture.

The test results showed that the TSR of 0% (controlled) and 20% RAP mixtures exhibit similar tendency in resisting moisture damage. On the other hand, the addition of 25% RAP improved the resistance to moisture damage. Here it was seen that 5% RAP increment i.e. from 20% to 25% increased the TSR value about 54%. On the other hand, increasing RAP from 25% to 30% in mixtures declined the TSR value by 15 %.

C. Wheel tracking test results

From the WTT it was observed that as the RAP content increased in the mixtures the rutting depth of decreased.

The 20%, 25%, and 30% RAP recycled mixture increased the DS values of mixtures by 107%, 121%, and 248% respectively.

RAP increment by 5%, i.e. from 20% to 25% had an insignificant change in DS values. Whereas, increasing the RAP content from 25% to 30% improved the DS value by 57%. The DS value of 0% RAP found lesser compared to the RAP containing mixtures. The lower DS value of 0% RAP was might be due to instability of virgin asphalt at the testing temperatures.

D. Three point bending test results

The test results showed that the bending stresses of RAP containing mixtures were higher compared to 0% RAP containing mixtures. On the other hand, strain value of 0% RAP at the failure points of mixtures has the highest value. The highest tensile strain value indicates the ductility of materials, which means that the material withstands extended external stress before its failure strain.

IV. CONCLUSIONS

The findings of the current study are summarized as follows;

- The study showed that addition of RAP in the mixtures improved the stability, rutting resistance, and moisture susceptibility.
- Alteration of 5% RAP interval has insignificant effects on the stability and cracking of RAP containing mixtures. On the other hand, a 5% change of RAP content considerably affects the rutting resistance and moisture susceptibility of the mixtures.
- Based on the findings, it is important to consider 5% RAP content variation, while designing for rutting, moisture damage and cracking.

Reference

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