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ISSN: 0193-4120 Page No. 25486 - 25490

Mechanical Performance of Asphalt Mixture Percentage in Recycled Aggregate Pavement

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Article Info
Volume 83
Page Number: 25486 - 25490
Publication Issue:
March - April 2020

Article History
Article Received*: 24 July 2019*
Revised*: 12 September 2019*
Accepted*: 15 February 2020*
Publication*: 30April 2020*

Abstract

Recycled Aggregate (RA) as the pavement material can be used as a recycling material in the pavement construction. Usually, RA has a stiffer binder, to moderate the stiffness a rejuvenating agent is added. Rejuvenators are expected to have a prodigious influence on the RA and virgin binder to blend in the asphalt mixture. The production of RA is limited to the conventional hot mix asphalt and need to be studied in asphalt mixtures. It is a gap-graded asphalt mixture having a high amount of coarse aggregate and asphalt. The aim of the present study is to investigate the performance of the RA in asphalt mixtures. This study compared the performance of asphalt mixtures containing different percentages of RA (0%, 10%, 20%, 30% and 40 %). The addition of RA increased the Marshall stability and Marshall Quotient of the asphalt mixture.

I. INTRODUCTION

The incorporation of Recycled or Reclaimed Aggregates (RA) in the asphalt mixtures started in the USA in the 1970s. Firstly, it was used as a substitute that would reduce the utilization of asphalt and natural aggregates. From the many research studies, it is observed that use of RA makes the asphalt mixtures stiffer with less workability and difficult to compact in the field (Baghaee et al. 2016; Copeland, 2011; Kennedy et al. 1998; Kandhal et al. 1997). Due to the atmospheric oxidation, the asphaltenes/maltenes ratio changes causing an increase in the viscosity and becomes stiffer. In order to reduce the stiffness and viscosity of the RA mixtures a rejuvenator is added. The Rejuvenator is a recycled agent, which acts as a catalyst and can improve the engineering properties and resorts the maltenes (Al-Qadi et al. 2007). Generally, rejuvenator is added to achieve the combined materials (combination of RA and virgin material) viscosity to an accepted range. (Baghaee et al. 2016; Zaumanis et al. 2014). Recent studies on the effect of rejuvenator found that the rejuvenator percentage significantly affected the properties of the RA mixtures. It also showed that the optimum percentage of rejuvenator is a must to produce a stable mixture. It is necessary to determine the optimum percentage of the rejuvenator. While several problems related to production, durability, pavement performance, and blending restrict the RA content (percentage of the RA in the asphalt mixtures) up to 30%, research and trust in the high RA content mixtures are fore shortened. The usage of RA in the dense graded mixtures are favorable and the incorporation of RP in the gap-graded mixtures are needed to study (McDaniel 2000).

II. OBJECTIVE

The current laboratory investigation aimed to prepare and compare the asphalt mixtures with four RA contents 10%, 20% 30% and 40%. To determine the performance of the asphalt mixtures and the maximum RA content that can be incorporated.Asphalt mixtures are prepared as per the Marshall specifications, using VG -0 bitumen, Virgin aggregate, and RA.

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III. MATERIALS USED

RA collected from the nearby bituminous plant and crushed granite aggregates was used to prepare asphalt mixture. The RA material obtained was screened to remove impurities. Table 1 shows the physical properties (strength, toughness, flakiness, durability and specific gravity) of the RA and virgin aggregate as per the Indian Road Congress (IRC) specifications. In this study performance grade 60/70 bitumen was used for the preparation of asphalt mixture and physical properties shown in Table 2. In this study, as per IRC specification 13.2 mm aggregate gradation is used to prepare the asphalt mixtures. It is to be noted that the RA material was fractioned, and at each sieve size virgin aggregate are replaced by specified RA content accordingly.

Table 1. Bitumen physical properties

Property	Virgin Binder	Test Procedure
Softening Point (˚C)	56.5	ASTM D36
Penetration Test	64	ASTM D5
Ductility test (mm)	>100	ASTM D113
Flash Point (˚C)	234	ASTM D92

Table 2. Virgin and RA Aggregate Physical Properties

Test Name	Virgin	RA
Los Angles Abrasion Value (%)	18.10	23.00
Impact Value (%)	15.40	17.70
Water Absorption Test (%)	0.80	0.33
Combined Elongation and Flakiness Test (%)	22.00	21
Specific Gravity Test	2.645	2.576

IV. MIX DESIGN

Marshall specimens were prepared as per ASTM standard D-1559(ASTM 1989). For each specimen preparation, 1200 grams of aggregates are taken as per gradation and along with 0.3% (weight of the binder) of pelletized cellulose fiber are heated in an oven at 170-190˚C for a period of 2hrs(approx.). The required bitumen content is heated upto pouring temperature and mixed with the Combined aggregates. The target mixing and compaction temperature is 150-160˚C. Four trail mix of 5.5%, 6.0%, 6.5% and & 7.0% are used to find the Optimum Bitumen Content (OBC). At each bitumen content, three samples are pre-pared and compacted by 50 blows on each side.

Stone on Stone Contact

In ASPHALT mixtures strength lies in the skeleton of coarse aggregate gravel (Brown 1993). From the national center for asphalt technologies studies there should be proper contact between stone to stone, the aggregates passed through the 4.75mm sieve are responsible to provide the better stone-on-stone contact. However, to determine the stone-on-stone contact is determined through Voids in Coarse Aggregate (VCA) method suggested by Brown &Mallick (1995). The ratio of VCA_{dry} and VCA_{mix} i.e. entire VCA of entire mixtures should be less than one to exists a stone-on-stone contact. Eq 1 and 2 are used to calculate the VCA_{mix} and VCA_{dry} respectively. It is seen from Table.3.

$$VCA_{mix} = \frac{(G_{CA}\gamma_W - \gamma_S)}{(G_{CA}\gamma_W} x100 \quad (1)$$

$$VCA_{dry} = 100 - \left(\frac{G_{mb}}{G_{CA}}\right) xP_{CA} \quad (2)$$

Table 3. Mix Design

Parameters	Requirements (IRC)

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Air Void (%)	3.8
Bitumen Content (%)	5.6 minimum
VMA(%)	16
VCA_{Mix} (%)	Less than VCA in the dry-rodded condition (VCA_{Drc})
Asphalt Binder Drainage (%)	<0.3

V. EXPERIMENTAL METHODS AND RESULTS

5.1 Binder Drainage

Binder Drainage sensitivity test was performed to measure the amount of draindown in asphalt mixture, which gives the information about the sensitivity of the asphalt mixture at elevated temperatures. As per ASTM D6390, a wire basket with 6.3mm standard sieve size opening is used in this test. asphalt mixtures with 0.3% cellulose fiber are prepared as per the ASTM D6390 procedure with 7% BC and OBC. 200grams of asphalt mixture is prepared and poured into the wire basket and placed in the oven at a temperature of 160-170 °C. Drained material is collected from the bottom using catch plate for a period of one hour and weighed. Binder drainage is the weight of drained material and the initial weight of the material expressed in percentage.The test results are examined for the potential of the drain down which should be less than 0.3%. Table 4 shows test results of all the combinations. It was observed from the test results that drain down was less than 0.3% for all the mixtures.

Table 4. Binder Drainage test results

RA %	Binder Drainage at OBC %	Binder Drainage at 7% BC
0	0.195	0.220
10	0.185	0.225
20	0.170	0.233
30	0.163	0.245
40	0.155	0.253

5.2 Volumetric and Marshall Properties

In general, Bituminous mixtures are the main criteria that decide the over-all performance. It includes Bulk Density (G_{mb}), V_a, VMA, Theoretical Bulk Density (G_{mm}), and VFB. The G_{mm} of the loose uncompacted mixtures and G_{mb} of the compacted mixtures are determined as per the ASTM D2041 and ASTM 2276 procedure respectively. Then consequently V_a, VMA, and VFB are determined at each BC level. According to the IRC specification limits shown in table 3, the OBC for each ASPHALT mixtureis determined. From the test results it is observed that the mixtures exhibited VMA nearly equal or greater than 17% and therefore, OBC is considered at 4% V_a as per IRC 78-2008 specification limit. The G_{mb} is observed to be 2.375, 2.380, 2.387, 2.388 and 2.389 for the 10%, 20%, 30%and 40% RA content respectively. The volumetric and Marshall properties are presented in Table 5.

Marshall stability is the maximum load that a specimen test specimen can withstand without failure at a temperature of 60 °C and the test is carried out as per ASTM D6927. While flow is the measure of deformation that occurs to the test specimen during the stability test between no load and maximum load conditions (McGennis et al. 1984). A dial gauge is attached to the breaking heads and is used to measure the FV. Whereas, the stiffness of the asphalt mixtures is determined from the Marshall Quotient (MQ). From the results it is concluded that the asphalt with RA content up to 30% increased the MS value while the further increase in the RA content (i.e. 40%) decreased the MS value.

Table 5. Volumetric and Marshall Properties

RA (%	OBC (	MS (k	FV (m	MQ (kN/	VMA (	G_{mb} (g/m	VCA_{mix}	VCA_{mix}/	VFA (

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)	%)	N)	m)	mm)	%)	m^3)	(%)	VCA$_{dry}$	%)
0	4.17	11.23	2.45	3.83	18.83	2.375	34.64	0.778	76.0
10	4.09	11.50	2.25	4.15	18.50	2.380	35.36	0.794	76.5
20	3.98	12.20	1.86	4.97	19.24	2.387	35.15	0.789	77.0
30	3.91	13.40	1.67	5.77	18.13	2.388	35.17	0.790	78.0
40	3.83	13.25	1.56	5.57	19.05	2.389	35.29	0.793	79.0

VI. CONCLUSION

The current study examined the effect of the RAin asphalt mixtures. Within the scope of this study, it is observed that the asphalt mixture properties are improved with addition of RA. In addition, the results showed that the incorporation of the RA increased the MS and IDT values and decreased the OBC. The interaction between the aged and virgin binder decreased the OBC raised other performance problems such as blending, thermal cracking and rutting. It is observed that the 0.3% cellulose fibre restricted the binder drainage. From the test results, the asphalt mixtures provide enough stone-on-stone contact. The incorporation of the RA influenced the MQ and FV to a greater extent. Whereas, the FV of the RA asphalt mixtures showed similar to the control mixture. The MS value of the asphalt mixtures increased up to 30% RA content. The stripping test confirmed moisture resistance is improved in the RA mixtures when compared with the control mixtures.

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