ANALYZING THE STRUCTURAL BEHAVIOR OF BITUMINOUSMIXES FOR FLEXIBLE PAVEMENT PREPARED WITH WASTE BITUMINOUS CONCRETE

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ABSTRACT: ***The use of Reclaimed Asphalt Pavement (RAP) has been enormously increased from the last two decades. In fact using RAP in pavement construction has now become most common practice in many countries. Using RAP not only economical and environmental friendly but also preserve the natural resources and similar or even better in performance than virgin asphalt mixtures. Lack of sufficient funds has led to low volume roads being left in a deplorable state. The main objective of the study was to evaluate the suitability of a mix of reclaimed asphalt concrete, virgin aggregates and a cationic emulsion as a surfacing material for the construction of low volume roads. The use of reclaimed asphalt pavement in the pavement industry in India evaluating the effects of partial and total replacements of bituminous concrete by RAP varying from 10 to 40% and virgin HMA mix on the mechanical properties of HMA mixtures. The virgin bitumen used in this study was of VG-30 grade and virgin aggregates from local quarry. The experimental process involves determination of characteristics of the materials procured. Marshall Stability, flow tests, Indirect tensile strength and Fatigue Life cycle Index were carried out on the samples prepared with both virgin and recycled mix.***
Keywords: Bituminous concrete, Marshall Stability, Flow value, Density, Indirect tensile strength, Fatigue Life cycle Index etc.

I. INTRODUCTION

Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment as well a reliable performance of the in-service highway can be achieved. Two things are of major considerations in flexible pavement engineering–pavement design and the mix design. The heating of bituminous binder, aggregates and production of huge quantities of Hot Mix Asphalt (HMA) releases a significant amount of green house gases and harmful pollutants. The amount of emissions becomes twofold for every 10°C increase in mix production temperature and increasingly, higher temperature is actually being used for the production of HMA with modified binders. Also, there is a problem of the scarcity of aggregates, which forces transportation of materials from long distance. The use of diesel for running trucks leads to emission of pollutants.

RECLAIMED ASPHALT PAVEMENT (RAP)

On the other hand Recycling of asphalt pavements is a Nobel approach in terms of technical, economical, preservation of natural resources and environmental issues. Use of RAP in pavement rehabilitation project has advantages over virgin materials due to the increasing cost of asphalt, insufficiency of quality aggregates and the need to preserve the environment. Many state agencies have also reported when RAP is used, it results in significant cost saving and subside the amount of waste produced and hazards of disposal problems of highway construction materials particularly in large cities. In 1996, it was calculated that about 33% of all asphalt pavement in the United States was recycled into HMA.

BENEFITS OF ASPHALT RECYCLING The following points suggest the generalized benefits:

- Reuse and Conservation of non-renewable energy sources
- Preservation of the environment and reduction in land filling
- Energy conservation and improved pavement smoothness
- Cost saving over traditional rehabilitation methods
- Improved pavement physical properties by modification of existing aggregate gradation, and asphalt binder properties

PROPERTIES OF RAP

RAP has a higher content of fines as a result of degradation of material during milling and crushing operations. Typical physical properties of RAP are tabled below

Table: Typical Properties of RAP

S. No.	Parameters	Values
1	Unit Weight (Kg/m³)	1900- 2250
2	Moisture Content	Max 3- 5%
3	Asphalt Content	5- 6%
4	Asphalt Penetration(%) at 25°C	10-80
5	Compacted Unit Weight (Kg/m³)	1500- 1950
6	California Bearing Ratio (CBR)	100% RAP : 20-25%

Consumption of natural aggregate can be reduced by using Reclaimed asphalt pavement (RAP) materials. Amount of binder can also be reduced in asphalt paving mixes by using Reclaimed asphalt pavement (RAP) materials. Increase demand of aggregates and binder supply can be meet out up to certain extent by using Reclaimed asphalt pavement

(RAP) materials in hot mix asphalt (HMA) and other courses of the flexible pavements like sub-base and base. recycling asphalt creates a cycle of reuse that optimizes the use of natural resources and sustains the asphalt industry. Economy, ecology and energy conservation are all achieved when the two main components i.e. asphalt and aggregate are reused as construction materials to provide a strengthened and improved pavement. The major advantages of use of RAP are listed below:

- Lower cost.
- Reduction in consumption and use of natural resources.
- Reduction in damages to other roads due to transportation of materials from quarry sites.
- No increase in pavement thickness, very important for urban roads and highways.
- As the transportation is minimized resulting in energy saving i.e. less consumption of diesel.

Studies have shown that use of RAP as partial replacement with bituminous concrete as different percentage is used in various projects of National Highway Development Plan (NHDP) in India. Recycling of milled bituminous material has been gaining popularity in India in recent times due to several successful trials in selected projects. A detailed laboratory investigation is required in order to use RAP in Hot mix asphalt (HMA) to ensure that mixes have necessary minimum strength and durability. For better performance the following points should also be considered which are listed below:

- Quality control and additional processing
- Classifying RAP
- Changing the virgin binder grade
- Preparing materials for mix design
- Blending the virgin and RAP binders
- Evaluation of performance

Sources of RAP: The various possible sources of RAP are as follows-

- Generation from milling of HMA layer
- Full depth pavement removal
- Waste from HMA generated at plant

Milling is the process of scraping and removing any distressed upper layers of existing pavement to a specified depth. The process includes grinding by machine and loading of RAP into a truck for transportation.

II. RESULTS AND DISCUSSIONS

BITUMEN PRESENT IN RAP

Percentage of bitumen was determined using centrifugation method in bitumen centrifuge extractor. It was found that the RAP contained 4.8% bitumen as given in Table.3.8.

RESULTS OF MARSHALL STABILITY TEST (kg) Vs BITUMEN AND RAP 10%, 20%,30%,40%.

The experimental results (average) of different parameters of Marshall Stability, Density, Flow, VA, VMA, and VFB Test for Virgin mix as given in Table.3.2 and optimum binder content are given in Table 3.4. It is observed that stability value increases with increase binder content up to certain binder content; then stability value decreases as given in Table 3.3 and 3.15. Variation of Marshall Stability value with different binder content is given fig 3.2. Marshall Test data along with their volumetric properties in details with RAP, 10%, 20%, 30% and 40% is given in Table.3.14. The Marshall stability found at Virgin mix at OBC is 1232.70 Kg and and Marshall Stability at RAP 30% is 1148.85 kg against the requirement is 900 Kg the maximum Marshall stability found at RAP 30%.

RESULTS OF DENSITY (Gm/cc) Vs BITUMEN AND RAP 10%, 20%,30%,40%.

After the laboratory investigation it is observed that the density of fresh bituminous mix is 2.443gm/cc and density at RAP 30% is 2.434 the variation of maximum density is negligible as given in Table.3.3 and Table. 3.15. This indicates that the binder in RAP materials perfectly blended with fresh binder as Marshall Test data given in Table.3.14. The density of Virgin BC material increased up to binder content 5.8% density is 2.443 and density decreased 2.432 at 6.0% and 2.424 at 6.20% bitumen, Similarly in RAP the density increased up to RAP 30% density is 2.434 and decreased at 40% 2.416 up to The density of various bitumen content of virgin mix and RAP 10%, 20%, 30%and 40% is given in Table.3.3 and Table.3.15.

FLOW VALUE Vs BITUMEN AND RAP 10%, 20%, 30%,40%.

It is observed that flow value at OBC is 3.27mm and RAP 10 % is 2.33mm,RAP 20% is 2.90mm, RAP 30% is 3.20mm and RAP 40% is 4.43 against the requirement is 2 to 4MM the detailed as given in Table.3.2 and Table no.3.14 for virgin mix and different percentage of RAP.. From the above it can be concluded that flow value at OBC of virgin mix is 3.27 mm and flow value at RAP content 30% is 3.20mm the difference is negligible and acceptable as per "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS", MORTH (fifth revision), published by Indian Roads Congress. (2mm - 4mm) as specified in table 500-11.

VOIDS IN AGGREGATE (VA %).

It is observed that the VA value at OBC 5.8% is 3.99% and VA in RAP 10 % is 7.01%,RAP 20% is 5.31%, RAP 30% is 4.05% and RAP 40% is 4.75 % against the requirement is 3 to 5 % the detailed as given in Table.3.2 and Table no.3.14 for virgin mix and different percentage of RAP. From the above it can be concluded that Voids in aggregate VA at OBC of virgin mix is 3.99% value at RAP content 30% is 4.05% the difference is negligible and acceptable as per "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS", MORTH (fifth revision), published by Indian Roads Congress. The requirement is 3-5% as specified in table 500-11.

VOIDS IN MINERAL AGGREGATE (VMA %).

It is observed that the VMA value at OBC 5.8% is 14.19 % and VMA in RAP 10 % is 16.24%,RAP 20% is 14.71%, RAP 30% is 13.57% and RAP 40% is 14.20% against the requirement is 13% Minimum as given in Table.3.2 and Table no.3.14 for virgin mix and different percentage of

RAP. From the above it can be concluded that Voids in Mineral aggregate VMA at OBC of virgin mix is 14.19% value at RAP content 30% is 13.57 % the difference is negligible and The requirement is 13 % Minimum as specified as per "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS", MORTH (fifth revision), published by Indian Roads Congress.

VOIDS FILLED WITH BITUMEN (VFB %).

It is observed that VFB value at OBC 5.8% is 71.89 % and VMA in RAP 10 % is 56.84%,RAP 20% is 63.92%, RAP 30% is 70.17% and RAP 40% is 66.56 % against the requirement is 65-75 % as given in Table.3.2 and Table no.3.14 for virgin mix and different percentage of RAP. From the above it can be concluded that Voids filled with bitumen, VFB at OBC of virgin mix is 71.79% value at RAP content 30% is 70.17 % the difference is negligible and The requirement is 65-75% table 500-11 as specified in "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS", MORTH (fifth revision), published by Indian Roads Congress.

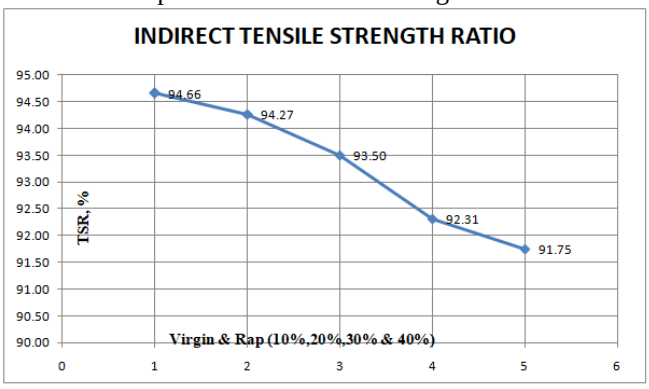
INDIRECT TENSILE STRENGTH TEST

Test was conducted for Virgin and varying % of RAP with OBC of 5.8% which was found after Marshall Stability testing. The ASTM T283 code specifies 80 percent should be the minimum value of Indirect Tensile Strength ratio. The Results were tabulated in table 4.1.

Table: Indirect tensile strength test results

Type of mix	Average Indirect tensile strength, Mpa		TSR%
	Unconditioned	Conditioned	
VG-30	0.656	0.621	94.66
VG-30 + RAP 10%	0.681	0.642	94.27
VG-30 + RAP 20%	0.693	0.648	93.50
VG-30 + RAP 30%	0.716	0.661	92.31
VG-30 + RAP 40%	0.728	0.668	91.75

Graph : Indirect Tensile Strength Ratio



FATIGUE LIFE CYCLE TEST

Test was conducted for different stress ratios 0.6, 0.7 and 0.8 for Virgin and different % of RAP. The concepts of fatigue life cycle tests are presented in previous chapter. The results of this test are tabulated in table 4.2.

Table : Fatigue cycle results for Virgin and different % of RAP

S. No	Materials	Stress level in %	No of cycle
1	Virgin materials	60	1406
		70	985
		80	719
2	10% RAP	60	1317
		70	893
		80	661
3	20% RAP	60	1305
		70	875
		80	645
4	30% RAP	60	1301
		70	870
		80	639
5	40% RAP	60	978
		70	701
		80	478

COST COMPARISON

Following analysis shows a cost comparison between a fresh bituminous mix and mix prepared with RAP 30% for BC

- Cost of laying fresh Bituminous Concrete (BC) = Rs 12000/m³
- Reduction in cost by aggregates by using 30 % RAP = Rs 352.50 /m³
- Reduction in cost by bitumen since RAP contained 4.8 % bitumen = Rs 6075.16/m³
- Total reduction in cost = Rs 6075.16 /m³ + Rs 352.50 /m³ = Rs 6427.66 /m³
- Cost of laying BC using 30 % RAP = Rs 12000 /m³ - Rs 6427.66 /m³ = Rs 5572.34/m³

From the above analysis it can be understood that using RAP makes the project more economical.

The Detailed Calculation of cost comparison:

- As per BOQ (MPRDC) rate of m^3 of bituminous concrete is 12000/m^3.
- [31]The Cost of aggregate /m^3 is 1175.{CPWD SOR 2014 – Page No.8}
- The Cost of 30% aggregate is 352.50/m^3.
- The density of mix is 2.434gm/cc.
- 4.8 % bitumen available in RAP, i.e., 4.8% is 116.83 kg/m^3 bitumen is available in RAP.
- [32]The rate of bitumen at site is 52/kg. {MPPWD SOR 2014, Page 1 - General Notes Road Work}
- We have 116.83×52=6075.16/m^3.
- Then the total reduction in cost is 6075.16+352.50=6427.66 /m^3.
- The saving is with 30% RAP @ 12000/m^3-6427.66/m^3=5573/m^3
- Total saving in percentage is 46.44 %.

III. CONCLUSIONS AND RECOMMENDATION

On the basis of results and discussion of experimental investigation carried out on mixes i.e. BC and RAP following conclusion are drawn.

BC WITH DIFFERENT % OF RAP

As per MORTH Specification mix design requirements of bituminous mix is given in table 5.1.

Table : MORTH Specification (section 500) mix design requirements of bituminous mix

Description's of Test's	Obtained Value of mix @ 5.8 % by Virgin Agg.	Obtained Value of mix of RAP @ 30%	Specified Limits as MORTH
STABILITY (KG)	1232.70	1148.85	900 (Kg)
DENSITY (g/cc)	2.443	2.434	---
Flow (mm)	3.27	3.20	2-4 (mm)
Stiffness (MQ)	3.77	3.59	2--5
Va (%)	3.99	4.05	3-5 %
VMA (%)	14.19	13.57	13% Min.
VFB (%)	71.89	70.17	65-75 %

- The bituminous concrete made of from RAP 30 % satisfies above requirements we can use them for fresh construction. The results is conforming to the requirement of "Specifications for road and bridge works", MORTH (fifth revision), published by Indian Roads Congress.
- Densities of virgin mix at 5.4%,2.388 gm/cc, at Bitumen content 5.6%,2.421gm/cc, at Bitumen content 5.8%,2.443 gm/cc, at Bitumen content 6.0%,2.432gm/cc and Bitumen content 6.2%,2.424 gm/cc similarly density with RAP 10%, 2.359 gm/cc, RAP 20%, 2.402 gm/cc, RAP 30%, 2.434gm/cc and RAP 40%, 2.416 gm/cc. The density of RAP 30%,2.434 gm/cc is very closer to density at OBC 5.8% ,2.443 gm/cc of virgin mix.
- The Marshall Stability values of virgin mixes were found at different binder content is Bitumen percent 5.4%, 902.12 Kg, Bitumen percent 5.6%, 1071.74, Bitumen percent5.8%, 1232.70kg, Bitumen percent6.0%1008.38kg, Bitumen percent 6.2%, 905.33Kg. Simelarly with different percentage with RAP, RAP10%,882.12kg, RAP20%,1043.35kg, RAP30%,1148.85kg and RAP40%,979.03Kg. The stability at 5.8% OBC is 1232.70kg and with RAP30% is 1148.85Kg, the difference is very closer with others and the results is acceptable. The minimum required stability is 900 kg as table 500-11 as specified in "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS", MORTH (fifth revision), published by Indian Roads Congress.
- The matured bitumen has shown the available paving material at different percentages of the virgin binder. There has been consistent increase in the physical properties (Penetration, Ductility, softening point etc) of the old bitumen when invigorated with Virgin VG-30.
- The proportioning of the aggregates with reclaimed aggregates at all specified percentages of 10, 20, 30 and 40 have given correct blending of the aggregates meeting the specification requirements.
- It is observed that by using 30% RAP the project cost was reduced by 46.44%.
- Time period for mixing was similar in all the cases.
- In this present project work, based on the laboratory studies it can be concluded that more than 30% RAP can be suitable to adopt in making the new roads with the RAP. These percentages of the RAP will differently provide an insight to a researcher or field persons to adopt effectively with proper technical alignments for Milling, Mixing, Transporting, Laying and Compacting.
- Overall from this study it was concluded that RAP 30 % showed results similar to that of virgin bituminous mix at their OBC and its performance was best amongst other RAP percentages. Also with the use of RAP 30 % the cost of project was reduced by 46.44 % and the result is qualifying the all requirements of "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS", MORTH (fifth revision), published by Indian Roads Congress.

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