International Journal of Advanced Technology in Engineering and Science
Vol. No.3, Special Issue No. 01, September 2015
www.ijates.com
ijates
ISSN 2348 - 7550

LABORATORY STUDIES ON RECYCLING OF MODIFIED BITUMINOUS MIXES ON BC II GRADE

Vivekanand Korishetti [1], Nityanand S. Kudachimath[2]

[1,2]Assistant Professor, Civil Engineering Department, Angadi Institute of Technology & Management, Belgaum

ABSTRACT

Recycling as recognized by many researchers, engineers and policy makers alike is one of the most efficient and effective way to conserve natural resources, save energy and reduce cost of production of Bituminous pavements. In the present study polymer modified bituminous concrete mix is obtained from a NH site located near hiriyur in Chitradurga district. The material was tested for original binder content and aggregate gradation by solvent extraction test. Four mixes were prepared viz., fresh bituminous mix, recycled bituminous mix, recycled bituminous mix with coarse aggregate replacement and recycled bituminous mix with fine aggregate replacement. The mixes were designed using Marshall method of mix design as per MS-2 guidelines. The mixes were tested for moisture susceptibility using Tensile strength ration (TSR) test. It was found that the binder requirement for the recycled mixes was lesser than the fresh mix and the recycled mixes with aggregate replacement showed better results than fresh bituminous mixes

Index Terms: Recycling, Marshall method, Indirect tensile strength (ITS) test, Tensile strength ration (TSR) test, Moisture susceptibility

I. INTRODUCTION

Recycling is a common term applied in various fields of engineering. It is inevitable as it forms the most effective solution in a ecofriendly practice. Recycling in road construction leads to reuse of old/used materials for new construction preferably with addition and mixing of new materials, savings in energy in processing new materials, considerable reduction in cost for purchase of new materials and also savings in non-renewable natural resources. Recycling is already being adopted all over the world with satisfactory performance. Some of the major drawbacks in recycling is the machinery required for milling of the old material, its proper mix design and reliable field performance.

The objectives of present study are

1. To determine the properties of aggregates and modified binder and assess their suitability for the work
2. To determine the gradation and binder content of recycled bituminous material
3. To determine Marshall properties of bituminous mixes as per MS-2 guidelines
4. To determine Moisture susceptibility of the bituminous mixes by Tensile strength ration test

II. LITERATURE REVIEW

Recycling is being adopted by researchers and engineers around the world from 1960. Many research and field implementation is being done in the area of pavement recycling. Sondag [1] measured the resilient modulus of 18 different mixes incorporating three different asphalt binders, two sources of RAP at varying amounts. He showed that adding RAP material increases stiffness and hence the resilient modulus. Also he found that addition of RAP did not show any influence on moisture susceptibility. Al-Rousan [2] showed that by addition of RAP to fresh mixes it is advantageous in all properties measured except fatigue test. The mix containing RAP showed less reduction in both loss in stability and indirect tensile strength, improved stripping resistance and better creep performance than the mix with fresh aggregates. Reyez-Ortiz [3] found that higher ITS and TSR values were obtained for mixes with 100% replacement with RAP. All TSR values were above 80%. Stroup-Gardner [5] showed that addition of coarse RAP decreased moisture susceptibility of the mixes. Brownie and Hironaka [6] showed that addition of RAP doesn't improve the moisture sensitivity of the mixes.

It is found that the properties evaluated with RAP mixes vary from one site to another. This is mainly due to various factors such as ageing of binder at site, site gradation, compaction characteristics, type of processing etc.,

III. EXPERIMENTAL INVESTIGATIONS

In the present study recycled material was obtained from a NH site at Hiriyur in Chitradurga district. The material was recycled from site, packed in plastic covers and stored in lab for testing. Four mixes were prepared viz., fresh modified bituminous mix, recycled mix, recycled mix with coarse aggregate replacement and recycled mix with fine aggregate replacement. The mix design was carried out as per MS-2 guidelines. The mixes were evaluated for Marshall properties, Indirect tensile strength, Retained tensile strength and Tensile strength ration.

3.1 Aggregates

The aggregates used in the study are collected from a nearby quarry plant. They were cleaned, free from dust and soft or friable matter. They were tested for physical properties and the results are shown in Table 3.1.

International Journal of Advanced Technology in Engineering and Science
Vol. No.3, Special Issue No. 01, September 2015
www.ijates.com
ijates
ISSN 2348 - 7550

Table 3.1 Physical Properties and Requirements of Aggregates

No.	Properties	Test results	MoRT&H V Revision specifications
1	Aggregate impact value	18.87%	Max. 24%
2	Aggregate crushing value	25.63%	-------
3	Aggregate abrasion value	29.60%	Max. 30%
4	Combined flakiness and elongation index	27.50%	Max. 30%
5	Water absorption	1.60%	Max. 2%
6	Specific gravity		
	Coarse aggregate	2.62	-------
	Fine aggregate	2.63	-------
	Filler (cement)	2.99	-------

3.2 Binder

The mix at the site was laid with PMB-40. Hence lab studies were conducted using the same binder. The binder was tested for physical properties and results are shown in Table 3.2.

Table 3.2 Physical Properties and Requirements of PMB-40

No.	Properties	Test results	Requirements as per IRC SP 53-2011
1	Penetration at 25°C, 0.1mm	45	30-50
2	Softening point, °C	52.2	60
3	Loss on Heating		
	Increase in softening point, °C	2.25	Max. 5°C
	Reduction in penetration at 25°C, 0.1mm	23.5	Max. 35
	Elastic recovery of half thread in ductilometer at 25°C	59.5	Min. 50
4	Specific gravity	0.99	

3.3 Aggregate Gradation

The recycled material obtained from site was subjected to solvent extraction test to determine its binder content and gradation. The results are shown in Table 3.3. It was found that the recycled material had an asphalt content of 4.68% and the mix contained 62.89% coarse aggregate and 37.11% fine aggregate by weight of mix. Fresh bituminous mixes were prepared as per BC-2 gradation adopted from MoRT&H V revision. Two mixes were proportioned with partial replacement of coarse aggregate and fine aggregate respectively in the BC-2 mix with recycled materials. The designed gradation is shown in Table 3.4

Table 3.3 Gradation of Recycled Material by Solvent Extraction Test

Sieve size, mm	% passing of recycled material
19	100
13.2	94.07
9.5	81.54
4.75	54.53
2.36	37.11
1.18	28.92
0.6	20.94
0.3	14.55
0.15	9.69
0.075	6.86
Binder	4.68%

Table 3.4 Proposed Gradations for Trial Mixes

Sieve size, mm	Recycled material	BC-2 gradation	Coarse aggregate replacement		Fine aggregate replacement	
			Recycled material	Fresh material	Recycled material	Fresh material
19	100	100	10.5			10.5
13.2	94.07	89.5	10.5			10.5
9.5	81.54	79	17			17
4.75	54.53	62		12	12	
2.36	37.11	50		10	10	
1.18	28.92	41		9.5	9.5	
0.6	20.94	32.5		9.5	9.5	
0.3	14.55	23		7	7	
0.15	9.69	16		9	9	
0.075	6.86	7		5	5	

3.4 Trial Binder Content

In general the trial binder content to be adopted for BC-2 gradation is given by MoRT& H guidelines and it ranges from 4-6%. Hence trial binder content for fresh mixes were varied at 0.5% intrevals from 4.5 to 6%. For recycled mixes procedure outlined in MS-2 was followed using the formula

$$P_{nb} = \frac{(100^2 - rP_{sb})P_b}{100(100 - P_{sb})} - \frac{(100 - r)P_{sb}}{(100 - P_{sb})}$$

Where,

P_{nb} = percent of new binder in recycled mix

r = new aggregate in the recycled mix

P_b = percent bitumen content of total recycled mix

P_{sb} = percent bitumen content of scarified material

From the above formula trial binder content were determined for the recycled mixes. The adopted values are shown in Table 3.5

Table 3.5 Adopted Trial Binder Content for the Mixes

Type of mix	Trial binder content, %			
Fresh mix	4.5	5	5.5	6
Recycled mix	2	2.5	3	3.5
Recycled mix with coarse aggregate replacement	2	2.5	3	3.5
Recycled mix with fine aggregate replacement	3	3.5	4	4.5

IV. RESULTS AND DISCUSSIONS

4.1 Marshall Properties

Marshall specimens were prepared by adopting proposed gradations and trial binder contents shown in Chapter III. The specimens were subjected to density-voids and stability-flow analysis. The results are presented from Table 4.1 to Table 4.4. Optimum binder content (OBC) was selected for binder content giving maximum stability, maximum density and 4% air voids. The properties of mixes at OBC are shown in Table 4.5.

Table 4.1 Marshall properties for fresh bituminous mix

Sl no.	Trial Binder content	Bulk density	% voids	% Voids in mineral aggregates	% Voids filled with bitumen	Stability, kN	Flow, mm
1	4.5	2.221	9.532	20.691	53.965	8.346	3.5
2	5.0	2.293	5.968	18.281	67.365	9.81	5.0
3	5.5	2.343	3.202	16.652	80.78	12.82	2
4	6.0	2.336	2.85	17.424	83.655	8.1	3

Table 4.2 Marshall properties for recycled bituminous mix

Sl no.	Trial Binder content	Bulk density	% voids	% Voids in mineral aggregates	% Voids filled with bitumen	Stability, kN	Flow, mm
1	2.0	2.34	7.73	12.46	38.06	11.25	4.5
2	2.5	2.41	4.46	10.53	57.64	13.48	4.5
3	3.0	2.42	3.30	10.62	68.93	16.75	6.5
4	3.5	2.40	3.29	11.76	72.04	15.96	7

Table 4.3 Marshall properties for recycled bituminous mix with coarse aggregate replacement

Sl no.	Trial Binder content	Bulk density	% voids	% Voids in mineral aggregates	% Voids filled with bitumen	Stability, kN	Flow, mm
1	2.0	2.408	5.51	10.37	46.91	12.36	3
2	2.5	2.414	4.5	10.60	57.52	13.38	3
3	3.0	2.435	2.95	10.33	71.46	14.42	5
4	3.5	2.42	2.07	10.63	80.52	13.87	6.5

Table 4.4 Marshall properties for recycled bituminous mix with fine aggregate replacement

Sl no.	Trial Binder content	Bulk density	% voids	% Voids in mineral aggregates	% Voids filled with bitumen	Stability, kN	Flow, mm
1	3.0	2.355	6.138	13.274	53.761	18.86	2.9
2	3.5	2.363	2.936	11.292	73.997	19.17	2.65
3	4.0	2.404	2.790	12.503	77.685	17.61	2.2
4	4.5	2.401	2.200	13.113	83.226	17.11	3.5

Table 4.5 Marshall properties of mixes at OBC

No.	Properties	Test Results				Requirements as per MoRT&H
		Fresh mix	Recycled mix	Recycled mix with coarse aggregate replacement	Recycled mix with fine aggregate replacement	
1	OBC, %	5.46	2.9	2.91	3.68	---------
2	Stability, kN	12.47	16.33	14.16	18.433	Min. 9kN
3	Flow, mm	3.8	6.5	4.5	3.25	2-4 mm
4	Unit weight, g/cc	2.423	2.336	2.430	2.342	----------
5	Air voids, %	4.55	5.85	3.31	5.77	3-6%
6	Voids in mineral aggregates, %	17.31	12.75	10.45	14.90	12-13%
7	Voids filled with bitumen, %	73.81	54.19	68.50	61.28	65-75%

From Table 4.5 it is observed that recycled mix require lesser OBC than fresh bituminous mix. This is due to the fact that the recycled material already contains binder coated to the aggregates. Hence very little quantity of binder is required to bring bonding between aggregates in the mix.

From Table 4.5 it is observed that the recycled mixes show higher stability than the fresh mixes. This may be due to the fact that with ageing the binder in the site mix has become brittle and hard giving rise to higher stability. Also with addition of fresh binder and aggregates to the mix additional densification is brought in the mix.

From Table 4.5 it is observed that the unit weight of recycled mix is lower than other mixes. This may be due to the fact that with ageing there is loss of binder in the mix and when reheated and remixed sufficient density cannot be achieved. However when fresh binder is added to the recycled mix with fresh aggregates there is densification of the mix and hence unit weight of the mix increases.

From Table 4.5 it is observed that recycled mix has less voids filled with bitumen and failing to meet MoRT&H criteria. However all other mixes have satisfied the required criteria.

4.2 Indirect Tensile Tests

The ITS was carried out on two sets of fresh and recycled mixes prepared at OBC using Marshall mix design procedure. The first set of samples were tested after immersing in water bath for 2 hours at 25°C and then tested for Indirect tensile strength. The second set of samples were kept in water bath at 60°C for 24 hours and then tested for Retained tensile strength. Both values were compared to find the Tensile strength ratio viz., moisture susceptibility of the mixes. The results are presented in Table 4.6.

Table 4.6 Indirect Tensile Strength Properties of Mixes

No.	Mix	Indirect tensile strength, N/mm^2		Tensile strength ration, %
		First set	Second set	
1	Fresh mix	1.231	1.218	98.94
2	Recycle mix	1.108	0.916	82.67
3	Recycled mix coarse aggregate replacement	1.267	1.260	99.45
4	Recycled mix fine aggregate replacement	1.402	1.392	99.29

From Table 4.6 it is observed that the recycled mix has lower ITS value than other mixes. The recycled mix when partially replaced with fresh aggregates shows higher ITS value. This may be due to the fact that the unit weight of the mix increases as fresh aggregates and binder bring about additional densification in the mix.

From Table 4.6 it is observed that all the mixes have minimum requirement of tensile strength ration of 80%, with recycled mix having the lowest and recycled mix with fine aggregate replacement having the highest value.

V. CONCLUSIONS

From the present study the following conclusions are arrived at

1. The recycled material contains 62.89% coarse aggregate and 37.11% fine aggregate by weight of the mix.
2. The percent binder in the recycled material as determined by solvent extraction test is 4.68%
3. MS-2 guidelines can be followed to determine the trial binder content of the recycled mixes.
4. From Table 4.5 it is seen that the recycled mixes requires only 46% of binder content of fresh bituminous mixes. This value decreases with replacement of fresh aggregates.
5. From Table 4.5 it is seen that recycled mix with fine aggregate replacement and coarse aggregate replacement shows higher stability than fresh bituminous mix 32% and 12% respectively.
6. From Table 4.5 it is seen that recycled mix does not meet criteria for voids filled with bitumen suggesting loss of binder due to ageing process and during processing of material. However all other mixes prepared with addition of fresh binder satisfy the requirements.
7. From Table 4.6 it is seen that the recycled mix with fine aggregate and coarse aggregate replacement have higher ITS value than fresh bituminous mix 12% and 3% respectively.

8. From Table 4.6 it is seen that all the mixes retain minimum indirect tensile strength after conditioning in water bath for 24hrs at 60°C. The mixes are found to be less moisture susceptible contradictory to literature review.
9. It can be concluded that use recycled mixes in place of fresh mixes results in less consumption of binder content but the properties may fall below requirements. However when recycled mixes are partially replaced with fresh aggregates and fresh binder results in properties better than fresh bituminous mixes

VI. ACKNOWLEDGMENT

The authors wish to thank M/s IRB Infrastructure Pvt. Ltd for supplying the recycled material.

REFERENCES

[1] Michael S. Sondag, "Investigation of recycled asphalt pavement mixtures", Technical report, University of Minnesota, 2002, USA
[2] Taleb Al-Roushan, Ibrahim Asi, Omar Al-Hattamleh and Husam Al-Qablan, "Performance of Asphalt mixes containing RAP", Jordan journal of civil engineering, Vol. 2. No. 3, 2008, pp. 218-227
[3] Reyes-Ortiz O, "Evaluation of hot mix asphalt mixtures with replacement of aggregates by reclaimed asphalt pavement material" Procedia-Social and Behavioral science, 2012, pp. 379-388
[4] M. Stroup-Gardiner and Chris Wagner, "Use of RAP in superpave HMA applications", TRR, 1999, pp. 1-9
[5] Brownie R.B., and Hironika M.C., "Recycling of Asphalt concrete airfield pavement-A laboratory study", Federal aviation administration report, FAA-RD-78-58
[6] Rajib B. Mallick, Prithiv S. Kandhal and Richard L. Bradbury, "Using WMA technology to incorporate high percentage of reclaimed asphalt pavement material in asphalt mixtures", TRR 2051, pp. 71-79
[7] Kennedy, T.W., and Perez. I., "Preliminary mixture design procedure for recycled asphalt materials, recycling of bituminous materials", ASCE, ASTM STP 662, L.E.Wood, Ed.,1978, pp.47-67
[8] Basic asphalt recycling manual, ARRA, US department of transportation, 2001
[9] MoRT&H "Specification for roads and bridge works", Government of India, IRC, V revision New Delhi, 2005
[10] IRC SP 53:2011 and IS 15462-2004

AUTHORS

First author - Mr.Vivekanand Korishetti, Assistant Professor, Civil engineering department, Angadi Institute of Technology & Management.

Second author - Mr.Nityanand S.Kudachimath, Assistant Professor, Angadi Institute of Technology & Management