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A Study on Laboratory Evaluation of Warm Mix Asphalt Incorporated With Reclaimed Asphalt Pavement

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ABSTRACT
Sustainable Development Goal-11 envisions making cities and human settlements inclusive, safe, resilient and sustainable. This includes sustainable transport in the context of infrastructure, public transport systems, good delivery networks, affordability, efficiency and convenience of transportation, improving urban air quality and health and reducing greenhouse gas emissions. Warm mix asphalt (WMA) and reclaimed asphalt pavement (RAP) are the most leading sustainable materials in asphalt concrete pavements. WMA has been in use for quite some time; however, innovations and increased usage have been stimulated by the greater emphasis on sustainable infrastructure systems. WMA enables decreased production temperatures with the help of wax, water, or other chemicals. The effects of decreased production temperatures include lowered fuel use and emissions, improved compaction, and possible RAP concentration rises. RAP is the recycled product of the old asphalt concrete pavements, and its use leads to trimming in new aggregate and asphalt requirements. However, substantial performance issues can rise from the incorporation of WMA or RAP materials in asphalt concrete. This study assesses the prospects of WMA technologies and their integration with RAP. Initially, a detailed literature review was done to understand the advantages, disadvantages, and past field and lab performance of WMA and RAP mixtures. Marshall Tests, Indirect tensile strength test, aggregate coating and skid resistance tests were conducted on virgin, and varied RAP proportioned mixtures to examine the effects of RAP percentage on Optimum bitumen content, Marshall stability and flow values, aggregate coating and skid resistance. The results of this experiment provided several crucial observations. First, the OBC decreased with an increase in RAP percentage. Secondly, moisture susceptibility, as well as aggregate coating, decreases with the increase in RAP dosage. Furthermore, the inclusion of RAP to WMA mixtures decreased the skid resistance of asphalt concrete as determined by a portable skid resistance tester.

Keywords
Sustainability, RAP, Asphalt, Pavement, Recycle

1 .INTRODUCTION
Today in the world full of resource crisis there is an ever need to find the alternative ways in order to reduce the further pressure on the resources. Sustainability is very important goal that we have to achieve in order to reduce the resource crisis. From construction materials to the construction techniques and methods we have to adopt such ways that can help us in achieving the goal of sustainability. RAP is simply old asphalt that is salvaged for usage. In its most prominent form, it is gathered in loose form of pellets as a result of pavement restoration or rebuilding. Reclaimed/Recycled Asphalt Pavement is one such method of sustainability in which the pavement materials are screened properly that contains binding material bitumen and other aggregates.

1.1 Benefits of Reclaimed Asphalt Pavement (R.A.P)
The benefits of the R.A.P can be understood from the following points:

- Safe to Environment: By using recycled material in the construction of a pavement a lot of virgin materials are saved and thus it paves a way towards saving our environment.
- Economical: When already reclaimed materials are used in the pavement a lot of funds get saved automatically. Thus by using recycled materials in the construction, the cost of the project can be brought down.
- Availability: Whenever old pavement is renovated the recycled material already comes out and thus can be used. It further reduces the transportation charges.
- Others: Apart from this there are a number of benefits of using the recycled aggregates in the pavement as it is a great step in saving our time, resources, and economy.
- Thus from the above points it is vividly understood that using recycled pavement materials it has got a number of benefits.

1.2 Need for R.A.P
The need for R.A.P arises as there are limited resources on the earth.

- The building of asphalt pavements needs a huge number of resources, mainly aggregates and bitumen, which are restricted in nature.
- In addition, the usage of natural limestone aggregates raises project expenses substantially.
- There is a need to reduce the usage of virgin / natural aggregates and transition to sustainable road building.
- Reclaimed Asphalt (RAP) is one of the finest strategies to eliminate the requirement for fresh aggregates and binders.
- This will also lower the health risk of construction employees and provide them with a safe working environment.

2. OBJECTIVES OF STUDY
The objectives of the research are summed as:

- To explore the impact of RAP on different parameters of Warm Mix asphalt.
- To evaluate the impact of freeze-thaw settings on the Warm asphalt samples.

- To evaluate the influence of RAP on aggregate coatings in the Warm asphalt samples.
- To examine the impact of RAP on the skid tolerance of Warm Mix pavements.

.3. LITERATURE REVIEW

Even though substantial literature on this issue is reasonably large, the bulk of investigations were undertaken by many scholars have been researched. The purpose of this literature review is to synthesize the findings of several hundred papers related to the area of study.

Kennedy et al 1998 [1] has done a research on this issue and according to their opinion the usage of the recycled material in place of virgin materials is a best approach towards improving the economy of the project. Apart from this the environment can be saved from the mess of pollution.

Mallick et al 1997 [2] also did a research on the economy of R.A.P and it was found that 13-15% saving of the new materials was achieved while using the R.A.P in HMA reclaimed pavement. This is a huge number when the economy of a product is to be considered.

Carpenter et al 1980 [3] concluded that the properties of HMA are highly influenced by the agent that is being used in the recycling of the materials. They were also of the opinion that the amount and type of binder material is highly influenced by the type of RAP.

Olive et al 2001 [4] did research on the binding properties associated with the virgin and non-virgin materials and it was found that the non-virgin HMA was having better fatigue strength and also the rutting that occurs in the flexible pavement was low in that of the latter and vice-versa

Stephens et al 2001 [5] proposed the effect of heating time with respect to the strength of the pavement materials on the RAP and new unused materials. It was concluded that the amount of heat required in the case of the RAP was less than the virgin materials. Thus from that point of view, it was very clear that in the case of RAP the energy required was less and thus proves to be economical.

Huang et al 2005 [6] ran a number of experiments on the R.A.P and according to them the after the adequate blending of the R.A.P was done the outside layers of the aggregates were smoother than the interior layers.

Karlson et al 2006 [7] performed research on the R.A.P and concluded that the moisture resistance offered by it was much more superior than the virgin HMA. So from that point of view, it is highly recommended to use the same in pavements to achieve greater superiority and resistance against moisture

4. RESEARCH METHODOLOGY

The methodology used in the research work is summed as:

4.1. Collection of Materials:

The materials that included aggregates, RAP material and Binder materials were collected from the different places. The aggregates were collected from different places, Similarly fine aggregates that include sand and cement were also collected. In the meantime RAP material and Viscosity Grade 10 Bitumen which acts as a binder material was also collected.

4.2. Analysis of the Materials:

The sieve analysis gradation of the aggregates were collected properly in the laboratory and apart from this the necessary testings that are included in the Indian Codes were done. Similarly for the R.A.P material various tests like determination of Bitumen content and other tests were done. For Bitumen grader characterization tests were also done.

4.3. Preparation of the Samples:

After this various mixes were designed so as to find the suitability and to analyze the various reports.

4.4. Results:

At last the results were taken from the study and recommendations were put forward as usage of R.A.P in the asphaltic pavements. After this various tests were done on the specimen samples to find out the properties of the specimens.

5. EXPERIMENTAL STUDY

Aggregates are the most important materials that were used in the whole research. For this aggregates (coarse and fine) were obtained from a local crusher plant. The R.A.P materials were obtained from different sites of highway construction. In the mean time the concentration of bitumen binder in the R.A.P material was done and found to be around 5.35 %.

5.1 Properties of the Aggregates

Table 1: Properties of 40 mm Aggregates

Aggregate Size	Test Performed	Result Obtained
40 mm	Impact Strength	13 %
	Flakiness Index	24
	Abrasion Value	15 %
	Specific Gravity	2.77
	Soundness	9 %

In Table 1, the properties of 40 mm aggregate materials are mentioned.

Table 2: Properties of 20 mm Aggregates

Aggregate Size	Test Performed	Result Obtained
20 mm	Impact Strength	15 %
	Flakiness Index	17
	Abrasion Value	2.76 %
	Specific Gravity	0.92
	Soundness	8 %

In Table 2, the properties of 20 mm materials are mentioned.

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Table 3: Properties of 10 mm Aggregates

Aggregate Size	Test Performed	Result Obtained
10 mm	Impact Strength	11 %
	Flakiness Index	27
	Abrasion Value	18 %
	Specific Gravity	2.79
	Soundness	9.2 %

In Table 3, the properties of 10 mm materials are mentioned

Table 4: Properties of R.A.P Material

Material	Test Performed	Result Obtained
R.A.P	Impact Strength	14 %
	Flakiness Index	19
	Abrasion Value	16 %
	Specific Gravity	2.4
	Soundness	9.2 %

In Table 4, the properties of RAP materials are mentioned.

Table 5: Properties of Binder Material

Material	Test Performed	Result Obtained
Bitumen (Binder)	Penetration Test	83 mm
	Softening Point	51 °C
	Fire & Flash	249 °C
	Ductility	101 cm
	Dynamic Viscosity	1158.2 p
	Kinematic Viscosity	392.3 p

In Table 5, the properties of binder materials are mentioned

Table 6: Properties of Additive Material

S.No	Property	Values
01	Availability	Pellets Form
02	Melting Point	Around 116 °C
03	Softening Point	99 °C
04	Odour (if any)	No
05	pH	Around 7
06	Colon	Brownish

In Table 6, the properties of additive material are mentioned

5.2 Design of the Mix and Classification/Grading of Dense Asphaltic Macadam

During the course of research a total seven (7) number of samples were made as per the guidelines of ASHTO. In order to remove the moisture from the material the material was subjected to a 125 C temperature from two hours in an oven. Meanwhile the Bitumen was also prepared and the additive material was also mixed with it. The details of same are mentioned in below Table 7.

Table 7: Design Mix Specifications for various Mixes

Size of Aggregate (mm)	Different Types of Specimen						
	Mix A	Mix B	Mix C	Mix D	Mix E	Mix F	Mix G
40	16	15	10	10	10	7	5
20	17	14	15	12	10	8	5
10	29	20	17	20	12	10	8
Dust Material	35	28	25	15	15	12	9

Lime	3						
R.A.P	0	20	30	40	50	60	70
Total	100						
Optimum Content of Bitumen	5.46	5.22	5.02	4.76	4.27	4.01	3.65

6. RESULT AND DISCUSSION

6.1 Marshal Stability Results

Table 8: Stability Results

Specimen	Percentage of R.A.P	Stability Value (kN)
A	C.P	15.58
B	20	14.13
C	30	13
D	40	12
E	50	9.8
F	60	8.2
G	70	7.02

From the tests conducted it was found that Maximum Stability was found in Mix A with value of around 15.6 kN. In Mix B as shown in the graph the stability decreased. Further it can be seen that by inclusion of more and more R.A.P there is a decrease in the stability strength to a great extent. The details are mentioned above in table 8.

6.2 Flow Values

Table 9: Flow values of materials

Specimen	Percentage of R.A.P	Flow Value (mm)
A	C.P	3.89
B	20	3.49
C	30	3.18
D	40	2.93
E	50	2.39
F	60	1.9
G	70	1.8

From the test, it was concluded that flow values remained within the limits upto the Mix F but in Mix G. The reason of the same could have been the old age of the binder. The same is mentioned in the above table No. 9.

6.3 Marshal Quotient

Table 10: Result of Marshal Quotient

Specimen	Percentage of R.A.P	MQ (KN/mm)
A	C.P	3.98
B	20	4.01
C	30	4.03
D	40	4.04
E	50	4.06
F	60	4.09
G	70	4.11

As it is clear from table 10 the Marshla Quoitent increased linearly and thus shows the increase in the fatigue strength.

6.4 Marshal Stability under F-T Cycle Loading

Table 11: F-T Cycle Results for Stability

Specimen	0	2	4	6	8	10
A	15.55	15	14.8	14.3	14	13.6
B	14.12	13.8	13.4	13.1	12.7	12.3
C	13	13	12.7	12.3	12	11.8
D	12	11.5	11.2	11	10.8	10.5
E	9.8	9.2	9	8.7	8.4	8.1
F	8.2	7.8	7.6	7.3	7.1	7
G	7.02	6.8	6.5	6.2	6	5.7

It is evident from the data in table 11 that there was decrease in the stability with an increase in F-T loading. Freeze-Thaw Cycle was seen highest in Mix A and Minimum in Mix G.

6.5 Indirect Tensile Strength

Table 12: Results for I.T.S

Specimen	Percentage of R.A.P	(Un-conditioned) kPa	(Conditioned) kPa
A	C.P	491	445.7
B	20	429	379.2
C	30	409	349.2
D	40	387	336.2
E	50	372	309.12
F	60	305	250.3
G	70	258	258

The maximum strength was seen in the first mix and then it fell gradually. It is obvious that it decreased due to low strength and absence of good bond between the materials. Same is shown in table 12.

6.6 Coating with Aggregate

Table 13: Results for aggregate coating

Specimen	Percentage of R.A.P	(Percentage of Coating
A	C.P	95
B	20	90
C	30	88
D	40	85
E	50	78
F	60	72
G	70	65

From the Table 13 it is clear that the for the new material the coating was upto 95 % but it decreased gradually as more and more recycled material specimen were used.The maximum coating was 95 % and minimum was around 65 %.

6.7 Skid Resistance

It is observed that the incorporation of RAP resulted in reduced skid resistance. The maximum skid resistance was observed in the control mixture at 48.4, while the lowest value in the mixture with 70% RAP was observed at 27 under wet conditions. This is because RAP material contains aggregates that have been polished over several years. These aggregates have the lowest polishing stone value (PSV).

6.8 Results for B.P.N Wet Conditions

Table 14: Results for B.P.N Wet Conditions

Specimen	Percentage of R.A.P	BPN Wet Condition
A	C.P	48.4
B	20	44.2
C	30	38.5
D	40	34.1
E	50	30
F	60	28.7
G	70	27

After the fourth hour of polishing, the values stabilize and the drop remains fairly constant. The control mixture showed maximum resistance to polishing under all conditions. However, when RAP was added, the skid resistance decreased, so that a mixture with 70% RAP showed the lowest resistance. This may be due to highly polished aggregates in the RAP mixes, so these mixes reflect minimal skid resistance. After the fourth hour of polishing, the asphalt surface reaches the residual state, and more polishing does not significantly reduce the skid resistance. From the following Table 14 it can be seen that the skid value reaches almost a constant value from the fourth to the fifth hour. The extremely high skid value during the second hour may be due to contamination that is created over time by the friction between the wheels of vehicles on the surface of the sample.

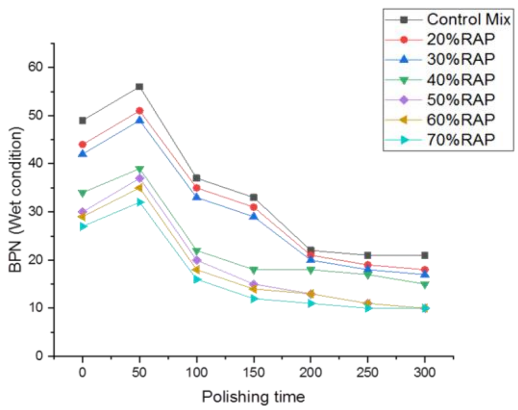

Figure 1: B.P.N Wet Condition Chart

The above Figure 1 shows the BPN Wet condition parameters.

7. CONCLUSION AND RECOMMENDATION

- The OBC of RAP-WMA mixtures is reduced as the proportion of RAP increases. The OBC decreased from 5.46% to 3.65% for control and 70% RAP mixtures, respectively. All RAP-WMA mixes except for mixes with 60% and 70% RAP met the minimum stability requirement.
- The Marshall stability, retained stability, and ITS (conditioned and unconditioned) decreased as the proportion of RAP increased. The TSR also decreased with the increase in the proportion of RAP material. Therefore, the susceptibility to moisture decreases with the increase in the RAP dosage.
- For WMA mix made from virgin materials, a coating of 95% was obtained. It fell to 65% for the WMA mix designed with 70% RAP.
- The incorporation of RAP reduced the skid resistance. The choice of the amount of RAP aggregate in the overall mix must therefore be made carefully.
- The skid resistance of asphalt mixes increased during the first hour of polishing. The polishing effect was more noticeable after the first hour as the skid resistance decreased, and a residual state was reached during the fourth hour of polishing. Therefore, the aggregates with higher PSV values should be selected for roads with higher traffic volumes.

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