A Study on Marshall Properties of Hot Mix Reclaimed Asphalt Pavement

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***Abstract*—In this paper, we mainly focused on the use of waste construction materials (Reclaimed Asphalt Pavement-RAP), here we adopt Marshall mix design method for the construction of new surface course of flexible pavement. Four different percentages of RAP (15%, 20%, 25% and 30%) were mixed with the virgin graded aggregate for job mix. Optimum Binder Content (OBC)of convectional mix of Virgin aggregate was used in job mix for Marshall mix design. Marshall stability and flow value of all the four percentage of RAP mix at OBC are in usable range without using Rejuvenating Agent-RA (recycling agent). Addition of 10% RA slightly decrease the Marshall stability but aid for increasing the flow value at OBC.**

***Index Terms*—Reclaimed Asphalt–Hot Mix Recycling–Bitumen– Aggregate**

I. Introduction

A. Background

1) Reclaimed Asphalt Pavement:

Reclaimed asphalt pavement (RAP) is defined as removed pavement materials containing asphalt and aggregates. These materials are generated when asphalt pavements are removed for reconstruction, resurfacing, or to obtain access to buried utilities. When properly crushed and screened, RAP consists of high-quality, well-graded aggregates coated with bitumen. [1]

2) History of RAP:

Asphalt pavement has been Americans most recycled material for a long time. First sustained effort to recover and reuse old asphalt paving materials was conducted during 1947 in Nevada and Taxas. Using RAP material has well-recognized financial and environmental benefits. [1]

3) RAP in Context of Nepal:

Asphalt pavement has recent history in the context of our country Nepal. After few years, reconstruction, resurfacing of asphalt pavement will be essential in our country too. For these purpose, reclaimed asphalt/recycled pavement may be the best solution. Recycling pavement conserves not only materials, but also energy. Recycling pavement provides an even greater economy by eliminating the cost associated with the removal and hauling of waste materials. Based on cost effectiveness, environmental impact, energy savings, and shortage of quality materials, reclaimed asphalt pavement (RAP) used for pavement construction does not only reduce aggregate need, but it also solves the problem of RAP disposal. Thus, RAP is the best solution for pavement rehabilitation and reconstruction in the developing country like ours.

Guidelines for RAP:

Standard Specification for Road and Bridge Works, 2073 describe only the general introduction for application of recycle material. [2] No coder provision are built for the use of RAP in our country.

Scope of research:

The outcome of this research help in the following context of the flexible pavement design. i. Hot mix design

ii. Recycled waste use

iii.Derive a recommended mix of RAP for general use pavement

Objective of research

The major objective of this research proposal is the use of Recycled Asphalt Concrete and recommended desirable quantity of Recycle Asphalt Concrete in mix design of new asphalt pavement.This will finally results reduce in aggregate need and haulage problems of recycle materials.

Specific objective

i. To determine OBC of virgin mix (without RAP)

ii. To determine optimum mix (maximum Marshall and Flow Value) among the different RAP percentage at OBC.

iii.To recommend the effectiveness of the recommended mix in use as asphalt pavement as per the specification given [2]

Assumptions

i. Addition of different percentage of RAP satisfied the gradation of virgin job mix as per SSRBW, 2073, table 13.26 [2]

ii.Mix design of Virgin aggregate of one quarry and RAP sample of another quarry satisfy the Marshall Mix Design.

Limitations

i. The properties of mix were defined based on only Marshall test

ii. RAP wastes from a single site was selected of a particular age for the study

iii. Study of only Hot Recycled Mix was performed

iv. Tests for recovered bitumen was not conducted.

II. Literature Review

A. RAP properties on hot mix

RAP mixes were observed to have higher values of strength . Minimum strength requirement of 43 MPa was achieved by mortar mixes with 25% RAP aggregate content showing the potential of the same as a replacement aggregat. [3]

Hot Mix Recycling techniques have higher advantages and are well suited for Indian conditions. [4]

RAP mix has good resistance to moisture damage at low RAP percentage whereas there is no significant increase in resistance to moisture damage with increase in RAP percentage in mix. [5]

The layer thickness of granular sub-base and base can be reduced by using RAP. [6]

Based on mechanical properties, volumetric and performance criteria, 20 percent RAP performs better than conventional mixes) under similar conditions. [7]

Resilient modulus values for RAP containing mixes are higher than mixes without RAP at 25C, 35C and 45C temperatures, which indicate mixes with RAP has better load spreading properties than mixes without RAP. [8]

Replacing virgin coarse aggregate by RAP in a typical PCC pavement mix has caused reductions in compressive strength, modulus of elasticity, exural strength and splitting tensile strength. [9]

The 40%RA mix has the best fatigue performance followed by the 0%RA and 20%RA mixes. [10]

RAP concrete mixtures exhibited satisfactory strength properties allowing them for use in low-strength and high ductility applications. [11]

Rejuvenating Agent

Rejuvenating Agent are organic compounds derived from petroleum extracts during petroleum hydrocarbon processing used to regain the properties of aged bitumen used in RAP. RA can be divided into three main types: super-soft asphalt cement, naphthanic (aromatic) oils and paraffin oils. (User Guidelines for Waste and Byproduct Materials in Pavement Construction, Publication no. FHWA-RD-97-148, FHWA, 2016)

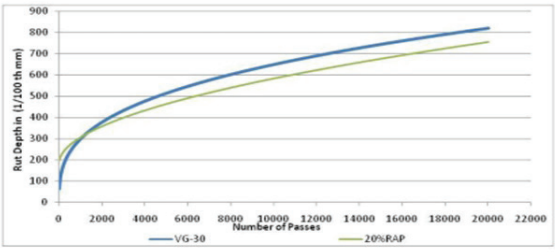

Fig. 1. Rut depth per number of passes [7]

The recommended quantity of Rejuvenating item is 10 percent. [7]

The RAP can decrease the moisture resistance of the asphalt mixture, but the rejuvenating agent can improve the moisture resistance, although the Marshall stability decreasing slightly when rejuvenating agent was added. [12]

B. Enhancing the property of RAP by the addition of other compounds

Use of a small amount of sodium chloride was shown to be effective in increasing strength of RAP-fly ash-Carbide lime blends as well as improving durability (after 12 wetting-drying cycles). [13]

Chilena natural zeolite (clinoptilolite-modernite type) can be used to design WMA mixtures with RAP, allowing a decrease of 20^o in manufacturing temperature in relation to HMA conventional mixture. [14]

The exural strength of cement-treated recycled pavement materials depends mainly on cement content, while their strain at break is highly influenced by RAP percentage; increasing RAP percentage leads to a more ductile behavior (strain at break increased about three times when RAP varied from 20% to 70% [15]

III. Sample collection, preparation and Testing

A. Extraction of Reclaimed Asphalt Pavement (RAP)

The sample of RAP were taken from Stadobato-Lagankhel road section which in extra widening phase.

According to the report of DOR of Lalitpur District, the age of asphalt concrete of this section is only about 5 years and the aggregate used for that mix design was taken from Tikabhairav of Lalitpur district and the binder used was 60/70 penetration grade bitumen.

The specific gravity and bitumen content of RAP sample is found as 2.394 and 5.21 % respectively.

B. Test Result of Recovered aggregate

Recovered aggregates are obtained by extraction of bitumen by adding benzene on old asphalt concrete by

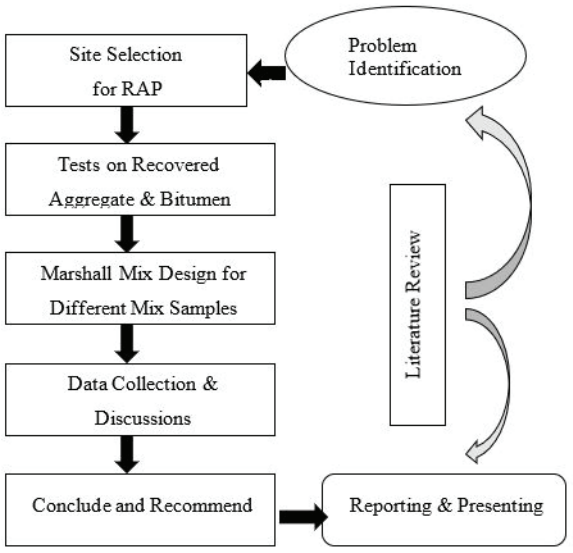

Fig. 2. Flow diagram of study procedure

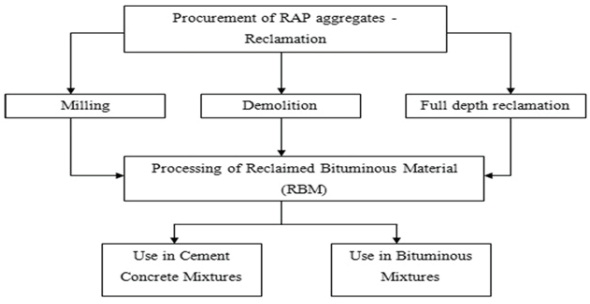

Fig. 3. Flowchart of production of RAP aggregates. Source: S.M. Abraham, G.D.R.N. Ransinchung,2018 [16]

Centrifuge Method . Aggregate Impact Value of RAP aggregate is found as 15.02%. Gradation of recovered aggregate are as shown in table.

C. Selection and Test Result of Virgin aggregate

The virgin aggregate for this thesis work is taken from Chalal Ganesh Quarry of Kavre District.

The major source of material for construction work in and around the Kathmandu valley is Tikabhairav, due to massive use there will be chance of shortage of materials . So, in this research work I have select the Quarry of Kavre district which is near to valley and substitute the need of material requirement in near future.

Three types of Aggregate namely 20 mm down, 10 mm down and 4.75 mm down were taken from that quarry. The properties of new aggregate are listed in table.

1) Gradation of New Aggregate:

Three type of aggregated taken from Chalal Ganesh of Kavre District are arranged to meet the gradation specified by Standard specification for Road and Bridge Work ,2073. The combined gradation (job mix design) of the three aggregate chosen are given in the table and figure 7.

Fig. 4. RAP sample of Satodabato- Lagankhel road section

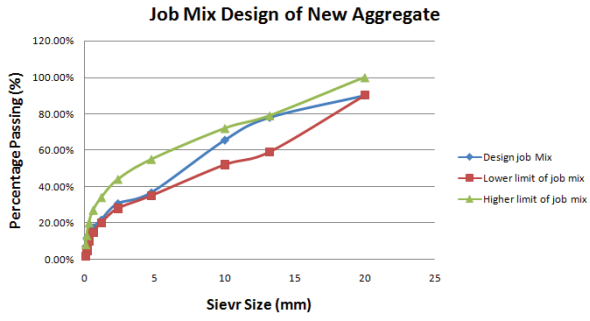

Fig. 5. Job mix design of New Aggregate as per SSRB, 2073

D. Selection of Bitumen

The bitumen used in this thesis work is viscosity grade 30 bitumen. The test result of VG-30 bitumen is listed in the table.

Dosage of Rejuvenating Agent:

The dosage of rejuvenating agent (RA) was fixed as 10% by weight of recovered bitumen, since at this dosage the properties of the rejuvenated bitumen are similar to that of the VG-30 bitumen. [7]. This result is shown in table.

E. Marshall Hot-Mix proportion

Marshall specimens of mixture RAP, selected three types of natural aggregate and selected bitmen are prepared as per the standard specified by (ASTM-D6926,2010) [17]

TABLE I
GRADATION OF RAP SAMPLE

IS Sieve Designation	Wt. retained indivisual	Cum. Wt. passing	Cumulative Percentage of Wt. retained	Cum .Percentage of Wt. Passing
(mm)	(gm)	gm	(%)	(%)
13.2	97.1	831.2	10.46%	89.54%
10	142.3	688.9	25.79%	74%
4.75	332.1	356.8	61.56%	38.44%
2.36	71.1	285.7	69.22%	31%
1.18	115.9	169.8	81.71%	18.29%
0.6	32.7	137.1	85.23%	15%
0.3	41.7	95.4	89.72%	10.28%
0.15	24.7	70.7	92.38%	8%
0.075	28.3	42.4	95.43%	4.57%
Pan	42.4	0	100.00%	0%
	928.3			

TABLE II
TEST RESULT OF VIRGIN AGGREGATE

Test	**Limiting Value**	**Result**	**Standard**
Los Angeles Abrasion Test	Maximum 30%	26%	IS: 2386 Part IV
Aggregate Impact Test	Maximum 24%	19%	IS: 2386 Part IV
FI 20mm Down	35% max	20%	IS: 2386 Part I
EI 20mm Down		28%	
FI 10mm Down	35% max	22%	IS: 2386 Part I
EI 10mm Down		26%	
Sodium Sulphat Soundness Test (SSS)	Max 12%	3.72%	IS: 2386 Part V
Stripping value	Min 95%	¿95%	IS:6241
Water Absorption			IS: 2386 Part III
20mm down	Max 2%	0.49%	
10mm down	Max 2%	1.47%	

TABLE III
GRADATION FOR JOB MIX DESIGN

Gradation for job mix design					SSRW, 2073	
(mm)	20mm(30%)	10mm(27%)	dust(43%)	total(100%)	Range for 50mm thickness	
20	20.11%	27%	43.00%	90.11%	90.00%	100.00%
13.2	8.11%	26.88%	43.00%	77.98%	59.00%	79.00%
10	2.54%	20.03%	43.00%	65.57%	52.00%	72.00%
4.75	0.48%	0.37%	35.96%	36.82%	35.00%	55.00%
2.36	0.33%	0.27%	30.25%	30.85%	28.00%	44.00%
1.18			21.91%	21.91%	20.00%	34.00%
0.6	0.20%	0.12%	17.47%	17.79%	15.00%	27.00%
0.3			13.57%	13.57%	10.00%	20.00%
0.15			12.16%	12.16%	5.00%	13.00%
0.075	0.00%	0.00%	7.48%	7.48%	2.00%	8.00%

Marshall Specimens of virgin mix are prepared for the test.Bitumen content is started from 4% and increased at the rate of 0.5% to reach 6.5%. Three specimen of each bitumen content are prepared for virgin mix design.

Marshall Specimen of varying RAP and new graded

TABLE IV
TEST ON BITUMEN

S.N	Characteristics	Method of Test	Value
i	Penetration at 25°C, 100 g, 5 s, 0.1 mm, Min	IS 1203	58.3
ii	Absolute viscosity at 60 °C, Poises	IS 1206 part 2	826
iii	Softening point (R & B) °C,	IS 1205	51.8
iv	Ductility at 25 °C, cm	IS 1208	¿100
v	Specific gravity	IS 1202	1.03

TABLE V
VISCOSITY TEST ON RECOVERED BITUMEN AND DOSAGE OF RA

Property	**Viscosity**
VG-30 Bitumen	2400 Poise
Recovered Bitumen	2820 Poise
10% Rejuvenating Agent	2420 Poise
15% Rejuvenating Agent	2070 Poise
20% Rejuvenating Agent	1740 Poise

[7]

aggregate are prepared at Optimum Binder Content (OBC) of virgin mix . Percentage of RAP are taken as 15%, 20%, 25% and 30% and three Marshall specimens of each RAP contain are prepared.

10% Rejuvenating Agent (RA) of bitumen contained of RAP is added at 30% of RAP mix design for sampling 3 specimen by Marshall mix design at OBC of virgin mix.Rejuvenating Agent(RA) used in this process is normal kerosene which is one of the aromatic oils.

1) Marshall test :

Marshall test has to be performed with respect to the (ASTM-D6927, D6926, [17] SSRBW 2073 [2]), standard test method for Marshall stability and of bituminous mixtures.

2) Presentation of data and table :

Result on Marshall Mix Design Of Virgin Mix of Aggregate

Optimum binder content of virgin mix design was found with respect to Marshall Stability, Air Voids and Specific Gravity of virgin mix. The result of test of virgin aggregate are listed as below:

Fig. 6. Marshall sample of virgin mix

Fig. 7. Marshall sample of new graded aggregate with varying RAP%

TABLE VI
MARSHALL HOT-MIX PROPORTION

RAP%	Mix Design	Remarks
15	Marshall mix design method	Maximum Marshall Stability and Flow value is determined under OBC
20		
25		
30	Marshall mix design method with or without RA	
No RAP	Marshall mix design	Optimum Binder Contain (OBC) is found

1) Marshall Stability = 11.537 KN
2) Optimum Binder Content = 5.17%
3) Flow Value = 2.23 mm at OBC
4) Air voids (%)= 4%
5) Voids Filled with Bitumen (VFB)= 78%

Results of Fresh and RAP Marshall Mix design

The test results of virgin and varying percentage (15%, 20%,25% and 30%) of RAP Marshall mix design are tabulated as follows.

The test results show that, at OBC the mix design containing different percentage of RAP have Marshall Stability value greater than 9 KN and Flow Value between 2-3 mm, which is in acceptable range for surface course of flexible pavement.

Marshall Stability at OBC for 15% RAP contain is found as 11.51 KN whereas Marshall Stability at OBC is found as 11.537 KN which are almost same. The flow value at OBC for 15% RAP mix is found as 2.1 mm which is also in range. So we can recommend the use of 15% RAP mix design for the construction of new surface course of flexible pavement which finally aid for reduction of construction cost and solve the problem of haulage of RAP.

Result on 30% RAP mixed with 10% Rejuvenating Agent (RA) Marshall Mix design

The test results of virgin and 30% of RAP mixed with 10% Rejuvenating Agent (RA) Marshall Mix

TABLE VII
RESULTS OF FRESH AND RAP MARSHALL MIX DESIGN

S.N	% of Fresh Aggregate + Bitumen	% of RAP	Sp. Gravity	Marshall Stability(KN)	Flow Value(mm)
1	85	15	2.396	11.51	2.1
2	80	20	2.379	10.15	2.147
3	75	25	2.391	9.57	2.023
4	70	30	2.403	10.33	2.02

design are tabulated as follows.

TABLE VIII
TEST RESULTS OF VIRGIN AND 30% OF RAP MIXED WITH 10% REJUVENATING AGENT (RA)

S.N	% of Fresh Aggregate + Bitumen	% of RAP	Sp. Gravity	Marshall Stability(KN)	Flow Value (mm)
1	70	30	2.403	10.31	2.19

This test result shows that, with the addition of 10% Rejuvenating Agent (RA) at the job mix design of 30% RAP with virgin aggregate, the Marshall stability is slightly decreased and there is increase of flow value at OBC in comparison of mix design of 30% RAP with virgin aggregate. This conclude that, addition of 10% RA enhance the flexibility of surface course of the flexible pavement although it slightly reduce the strength.

IV. CONCLUSION

In this article we studied about the use of different percentage of Reclaimed Asphalt Pavement (RAP) with or without using 10% Rejuvenating Agent in Marshall Mix Design. We have observed the following outcomes in our experiment.

i.Strength (AIV) of the recovered aggregate is found higher than the Virgin Aggregate.

ii. Optimum Binder Content (OBC) of convectional mix design is found as 5.17%. OBC of virgin mix is for the analysis of different percentage of RAP mix.

iii. Marshall stability, flow value for varying RAP (15%, 20%, 25% and 30%) content are in usable range i.e Marshall stability value greater than 9 KN and flow value are in between 2-5 mm at OBC. It can be recommended that 15% to upto 30% RAP can be used on surface course of the flexible pavement.

iv. 15% RAP mix design have greater stability and flow value is also at range. Among the four different RAP percentage, 15% RAP mix design is seem to be the best mix design.

v. At OBC Stability of virgin aggregate and mix of 15% RAP have almost same. So, we can recommended use of 15% RAP in Marshall Mix Design, which helps to reduce the haulage problem of RAP and also decrease the cost of construction of project as easily availability of materials near the site.

iv. Addition of 10% Rejuvenating Agent at mix design containing 30% RAP slightly decrease the stability but increase the flow value, which results the flexibility in surface course of flexible pavement in using 30% RAP mix design.

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