Reclaimed Asphalt Pavement as Partial Replacement of Natural Aggregate

Prajakta Gavankar[1], Komal Mhetre[2], Nilima Omase[3], Nikhil Prabhuzantye[4], Rashmi. B. Shankargouda[5]

[1,2,3,4]Student, Final Year Civil Engineering, KITCOE, Kolhapur
[5]Second Assistant Professor, Department of Civil Engineering, KITCOE, Kolhapur

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Abstract - *Recycling is the running trend through all over the world. To save money and keep environment pollution free recycling of waste materials is the best way. Reclaimed Asphalt Pavement (RAP) is such type of waste materials, which are obtained huge amount from spoiled pavement. During this investigation an attempt is made to study the behavior of RAP materials for reuse in road construction. The main objective of this study aims to determine the maximum amount of reclaimed asphalt pavement material percent that can be used in Virgin mix with Virgin VG-30 Grade bitumen. Aggregate Crushing Value, Aggregate Impact Value, Loss Angeles Abrasion Value and Ten percent fine value tests are also performed to determine the strength properties of coarse aggregate. All the characteristics were found to be within specified specifications as per MoRT&H and IS standards. Standard Marshall Mix Design procedure is followed in the design and testing of those mixes. The study reveals that untreated RAP materials are not good as a bituminous mix, but it can be acceptable with additional 1% bitumen content for use in the surface course of bituminous pavement. The investigation also indicates the possibility of adding coarse aggregate from RAP materials in the bituminous mixes with fresh aggregates, which gives satisfactory results. In our Indian subcontinent like Bangladesh, the rate of using RAP materials is very low. For that reason, the findings of the study will help in the development of sustainable road infrastructure for recycling in Indian Subcontinent.*

Key Words: **Bituminous Road, Reclaimed Asphalt Pavement, Marshall Mix Design, Aggregate Grading, Optimum Bitumen Content**

1. INTRODUCTION

The progress of the city reflects the progress of country. And, in progress and urbanization of city road network plays an important role. Road networks are like arteries of country. This is the reason for demand for extensive and adequately designed pavements is increasing. The demand for natural resources for road construction and road renovation has increased but their reserves are limited. Over the past decade, there has been a significant increase in the application of waste materials in different layers of flexible pavements, including asphalt surface, base layer and sub-base layer.From the view point of environmental preservation and effective use of resources, focus on the Reclaimed Asphalt Pavement (RAP) i.e old asphalt pavement milled up from existing pavement can provide enormous benefit. RAP is the material, generated when asphalt pavements are removed for reconstruction, resurfacing. It constitute a major part of generated solid wastes as a result of renovation and construction project. Therefore the aim of this laboratory investigation is to perform precise evaluation of the reclaimed asphalt pavement characteristics. It includes physical and mechanical properties through a series of test on RAP.In this present study of reclaimed asphalt pavement i.e removed upper layer for the purpose of construction, renovation etc will be partially replaced with natural aggregates and it will be tested to be used for different layers in road.

1.1 OBJECTIVES OF INVESTIGATION

1. To determine the basic engineering properties of reclaimed asphalt pavement materials.
2. To study the obtained RAP for the use in bituminous concrete.
3. To investigate the effect of RAP as partial replacement to natural aggregate.
4. To specify the limits of replacement of RAP.
5. To determine optimum strength by using appropriate proportion of RAP and conventional material.

1.2 FACILITIES REQUIRED FOR PROPOSED WORK:

Instruments:
Marshal Stability Test Machine, Los Angeles Test Machine, Impact Testing Machine, Weighing Balance, Water Bath, Oven, etc.

Materials:
Natural aggregates, Recycled coarse aggregates, Crushed sand, Bitumen (VG-30), etc.

2. Laboratory Investigation

For this investigation the RAP sample was collected from Five Star MIDC Kagal. ASTM D2172-01E01 method was followed for quantitative extraction of bitumen from bituminous paving mixtures. After extraction of bitumen from RAP, the aggregate appearance is displayed in Figure After separating RAP materials 90% aggregates, 5% mineral filler and 5% bitumen were found. The gradation of aggregate is shown in Figure 1,2. After that the RAP materials were gone through various tests and their suitability were checked. The test results of the fresh coarse aggregate and coarse aggregate from RAP are shown in Table 1. The aggregates from RAP were found to satisfy the requirements as per LGED.

Table -1: Strength properties of coarse aggregate.

Properties	Coarse Aggregate (Fresh)	Coarse Aggregate (RAP)	Limiting Value
Los Angeles Abrasion Value(GradeA), Percent	19	25.5	≤ 40
Aggregate Impact Value, Percent	8	15.96	≤ 40
Aggregate Crushing Value, Percent	18	21	≤ 35

2.1 SIEVE ANALYSIS

Sieve Analysis is a method of determining the particle size distribution of material the process separates fine particles from more coarse particles by passing the material through a number of sieves of different mesh sizes.

Sieve sizes:45mm, 37.5mm, 26.5mm, 19mm, 13.2mm, 9.5mm, 4.75mm, 2.36mm, 1.18mm, 600 µ, 300 µ, 150µ, 75µ.

Table -2: Sieve analysis for sample 1.

Is Sieve Size (mm)	Weight Retained (Gm)	%Of Mass Retained	Cumulati-ve %	% Finer
45	-	-	-	-
37.5	-	-	-	-
26.5	-	-	-	100
19	230.2	48.46	48.46	51.54
13.2	141.8	29.853	78.313	21.68
9.5	57.8	12.168	90.481	9.519
4.47	27.3	5.747	96.228	3.772
2.36	1.5	0.316	96.544	3.456
1.18	2.4	0.505	97.049	2.951
600µ	1.2	0.253	97.302	2.698
300µ	3.4	0.716	98.018	1.982
150µ	3.3	0.695	98.713	1.287
75µ	5.3	1.116	99.829	0.171
PAN	0.8	0.168	99.997	0.003
TOTAL	475	99.997		

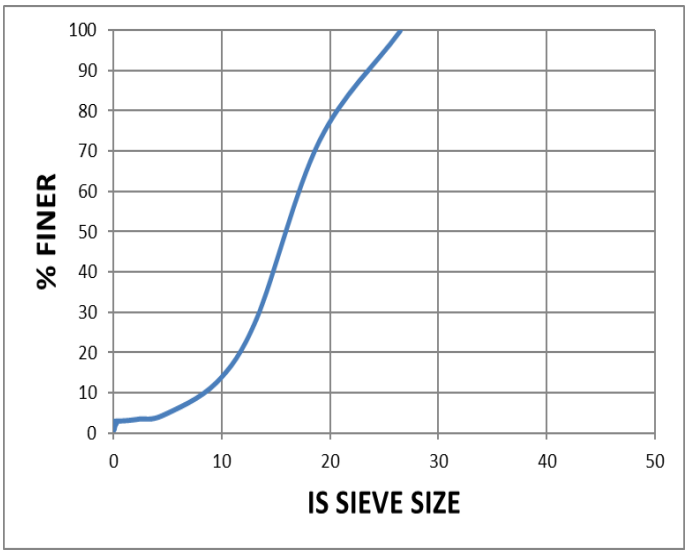

Fig -1: Graphical representations of sieve analysis for sample 1.

Table -3: Sieve analysis for sample 2.

Is Sieve Size (Mm)	Weight Retained (Gm)	%Of Mass Retained	Cumulati-ve %	% Finer
45	-	-	-	-
37.5	-	-	-	-
26.5	-	-	-	100
19	128.4	27.418	27.418	72.582
13.2	206.9	44.181	71.599	28.401
9.5	74	15.802	87.401	12.599
4.47	38.6	8.243	95.644	4.356
2.36	3.8	0.811	96.455	3.545
1.18	1.8	0.384	96.839	3.161
600µ	0.9	0.192	97.031	2.969
300µ	1.2	0.256	97.287	2.713
150µ	4	0.854	98.141	1.851
75µ	4.6	0.982	99.123	0.877
PAN	3.3	0.705	99.828	0.172
TOTAL	467.5	99.828		

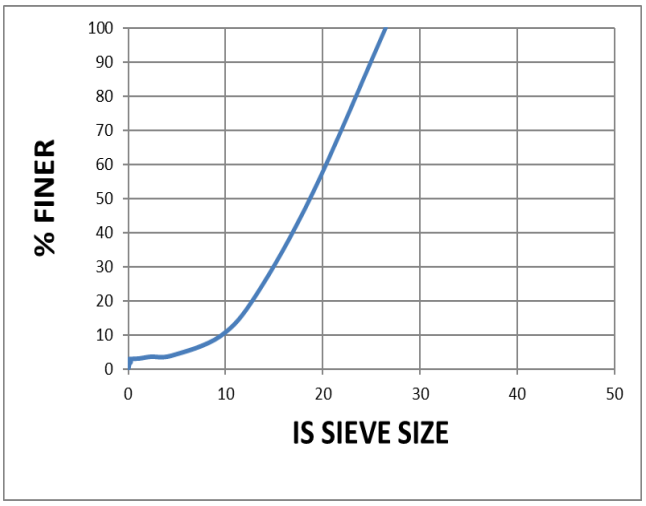

Fig -2: Graphical representations of sieve analysis for sample 3.

Fig -3: Appearance of Aggregate from RAP

2.2 MIX DESIGN

In order to investigate the behavior of asphalt mixes with different aggregates, continuously graded asphalt macadam is essential. The aggregate blend is designed to be evenly graded from coarse to fine in the continuously graded bituminous macadam so as to arrive at a dense mix with a controlled void content, in order to get sustainable paving mix. In the first phase, objective of the study was to investigate the suitability of untreated RAP materials and also to characterize RAP material by the increment of 0.5% additional bitumen content through the determination of Marshall Mix properties.

Mix contains RAP materials + (0%, 0.5%, 1%, 1.5%) additional bitumen content.

In the second phase, objective of this investigation was to make a comparative study of asphalt mixes with RAP materials in varying percentages with fresh aggregate. Five types of mixes were analyzed and these were designated as mix types A, B, C, D and E

Mix A: in which Fresh CA is 100%

Mix B: in which Fresh CA is 90% and 10% CA from RAP
Mix C: in which Fresh CA is 80% and 20% CA from RAP
Mix D: in which Fresh CA is 70% and 30% CA from RAP
Mix E: in which Fresh CA is 60% and 40% CA from RAP.

2.3. Marshall Properties

Maximum load carried by a compacted specimen at a standard test temperature of 60°C is called Marshall Stability test. The deformation of the Marshall Test specimen is called the flow value which undergoes during the loading up to the maximum load in 0.25 mm units. Marshall Stability test is suitable for hot mix design using bitumen and aggregates. The Stability, flow value, unit weight, total voids in a mix, voids in mineral aggregates and voids filled with bitumen were obtained for different percentages bitumen and RAP content. According to Ministry of Road Transportation Highways (MORTH), the maximum acceptable limit of air voids is 4%. The optimum bitumen content (OBC) is the average value of bitumen content obtained from these 3 plotted graphs. The Marshall Test results of first phase is tabulated in Table 4. Marshall test results and OBC values for different percentages RAP content of second phase is represented in Table 5.

3. Analysis of Results

Based on Marshall Test results presented in Table4 it is seen that the unit weight and the Marshall stability value of the compacted specimen is increasing initially with an increase in additional bitumen content up to 1% and then decrease. As bitumen is a binder, with the increase in bitumen content density and stability values are also increased. After reaching to the maximum value, the density decreases because the specific gravity of the excess bitumen is less than that of the mineral aggregates. And shear resistance also decreases due to this excess bitumen. The increasing rate of flow value is greater for higher proportion of bitumen. Because the thick film of bitumen surrounding the aggregates of RAP help to increase the deformation. For 100% RAP (untreated), %Va is 8 which is very much higher than the limiting value and it is the reason of weak and unstable pavement. On the other hand, untreated RAP contains old bitumen, some rounded shape and nearly smooth surfaced aggregates. The ductile and viscous property of the old bitumen are lost and due to the presence of some rounded shape and smooth surfaced aggregates interlocking capacity and shear resistance of the bituminous mixes are also reduced. For that reason, only untreated RAP materials is not suitable for bituminous surface construction.

Table no-4: Marshall test results for first phase.

%BC	Bulk specific gravity	Unit weight (kg/m3)	Marshall stability (kN)	Flow (0.25mm)	% Voids in total mix.	% Voids in mineral aggregate	%Voids filled with bitumen
5+0.0=5.0	2.125	2140	4.8	11	8.0	20.9	60
5+0.5=5.5	2.160	2160	7.2	13.5	5.3	19.6	72
5+1.0=6.0	2.190	2200	9.3	15.2	3.3	19.0	78
5+1.5=6.5	2.150	2170	7.0	16.3	3.8	19.7	82

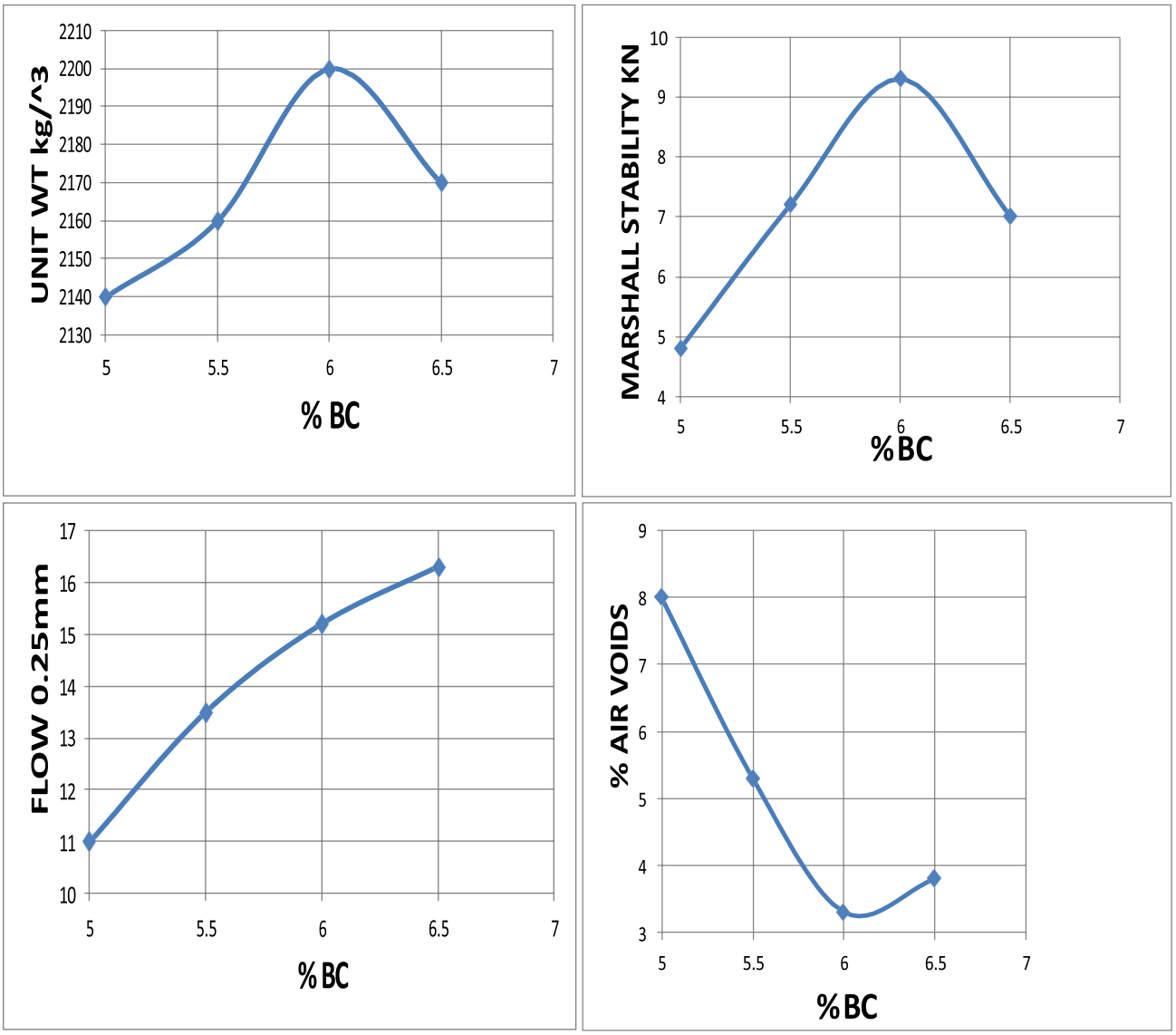

Fig -4: Graphical representations of Marshall Test results for first phase.

Table no-5: Marshall Test results for second phase.

Aggregate Types	O.B.C. (%)	Unit Weight (kg/m3)	Marshall Stability (kN)	Flow Value (0.25mm)	Air voids (%)	VMA (%)	VFB (%)	Marshall stiffness (kN/mm)
A	5.56	2340	15.6	14.6	3.8	13.9	74	1.14
B	5.40	2335	15.3	14.9	3.5	15.2	76	1.07
C	5.48	2325	14.8	15.2	3.4	15.8	77	0.98
D	5.30	2308	13.3	15.3	3.1	16.3	79	0.88
E	5.12	2292	12.0	15.5	2.9	17.0	81	0.61

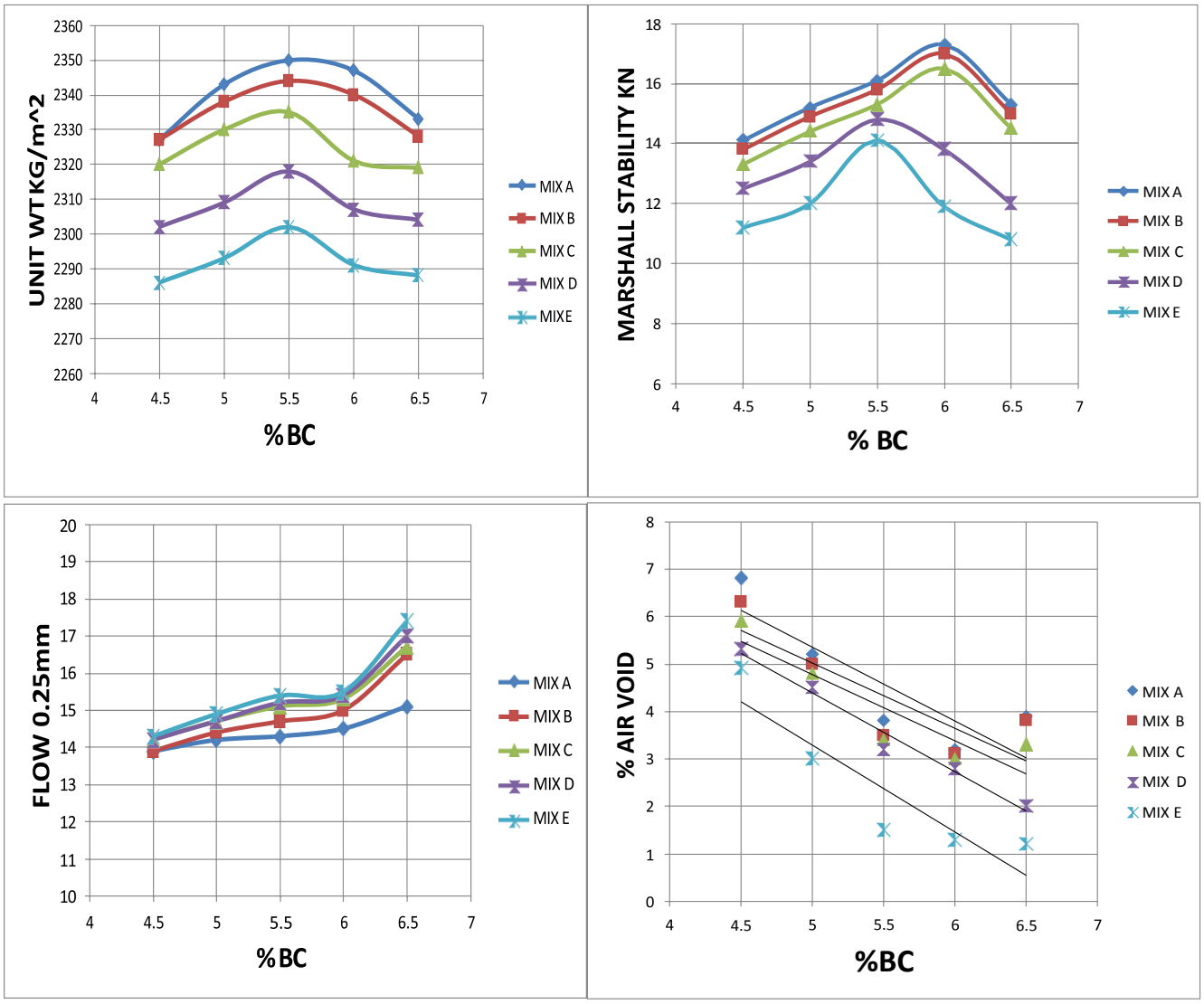

Fig -5: Comparative analysis of Marshall test results for second phase.

Based on Marshall Test results presented in Table 5 it is seen that the optimum bitumen content is decreased as the RAP percent increase. With the increasing percentages of RAP, OBC is decreased due to the old bitumen filled the pores of the RAP. As the presence of some amount of rounded shape coarse aggregates in RAP, it may also occur. Rounded shape particles quickly slips to gain stability and for that reason amount of OBC reduced. Besides, increasing RAP percent from zero to 40% decreases the OBC from 5.56% to 5.12%. It means that saving in OBC by about 9%. With the increasing percentages of RAP, unit weight is decreased gradually. Increasing RAP percent from zero to 40% that reduces the unit weight by only 2.3%. From the Table 5 it is found that, the mix stability is decreased as RAP percent increases. The mix shear resistance decreases due to the presence of some smooth and round shape aggregates in the mix, which ultimately results in decrease in stability. It is also mentioned that with the increasing RAP from zero to 30% decrease the stability value from 15.6 to 13.3 kN i.e. decreased by about 15%. When the recycled percent reaches 40%, the stability value reaches 12 kN i.e. decreased by about 26%. The mix flow value also increases due to the RAP percent increases. With the increasing percentages of RAP from zero to 40%, the flow value increases from 14.6(0.01 inch) to 15.5 (0.01 inch).

During bituminous mix design the total air voids in a mix is considered as an important parameter. The limiting of the total air voids in a mix is about 3% to 5 % of the total mix volume. If air voids are lower than 3% bleeding of bitumen will occur. Moreover, for air voids percent greater than 5% of the mix, the pavement will be weak and unstable. For that reason, the bituminous binder is a very sensitive element. From the Table 5 it is found that with the increasing percentages of RAP, decrease the corresponding air voids ratio. The reason behind this problem is the presence of old bitumen filled the aggregate pores which minimize the voids percent. Increasing the RAP percent from zero to 40% decreases the air voids percent from 3.8% to 2.9%. From the Table 5 it is discovered that the voids in mineral aggregate and voids filled with bitumen are increased as the RAP percent increases. This happens due to the ineffective old bitumen in the aggregate pores which prevent the new bitumen from occupying deeply the aggregate pores.

4. CONCLUSIONS

On the basis of experimental results of this study, the following conclusions are drawn.

1. From the consideration of aggregate properties, aggregates collected from RAP known as waste aggregates are suitable for the bituminous mixes.
2. Untreated RAP material is not suitable for bituminous surface course because its stability value 4.76 kN, which is less than the limiting value of 5 kN.
3. Bituminous mix from the RAP materials with 1% additional bitumen content gives the maximum stability and satisfy the Marshall Design criteria.
4. Although stability gradually decreases with the increase of RAP aggregates in the bituminous mixes with fresh stone aggregates, the nature of mixes satisfy the Marshall Design criteria.
5. Total cost of road project is reduced by 20% to 40%.

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