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Experimental Work on Recycle Aggregate of Asphalt Pavement for Rural Road

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Abstract: Increase in the number of high volume roads constructed to bitumen standards in the past years in India has led to a strain in the supply of scarce natural resource aggregates. Many of the constructed pavements are undergoing rehabilitation it requires expulsion of top most asphalte surface. The placement of aged asphalte surface layer into the unlatched area lead to environment deceleration .The major point of the Research is to measure the Suitability of The mixture of the "Reclaimed asphalte concrete" & the Virgin-aggregate & the "cationic-emulsion" as a surface-material for the construction of low volume pavements. The use of the Reclaimed-asphalte-pavement in the Road-industry in India calculating the Effects of Initial &the total "Replacement" of The Bituminous-concrete by 'RAP' varying from 10 to 40% and virgin HMA mixon the mechanical properties of HMA mixtures. The virgin bitumen which is used in this Research 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. All the characteristics were found to be within specified specifications as per MoR T&H and IS standards.

Keywords: RAP, Bituminous concrete, 'Marshall-Stability', 'Flow-value', Density, Indirect tensile strength, Fatigue Life cycle Index etc.

1. INTRODUCTION

The Construction of 'highway-pavement' involve higher Outlay of the Investment. A Accurate engineering-design can control the "considerable-investment" & A reliable-performance of the In-service Highway pavement can be "Achieved". Two Points are to be taken for the major considerations in the "flexible-pavement" & the Mix-design. "The heating of The bitumen-binder, aggregate & the production of high quantity"(HMA)" releases a some high amount of the "green-house-gases &the harmful-pollutants. The Quantity of the Emissions become the(twofold) for the {every-10.0°. increment in the mix-production temp &the 'increasingly', high-temp. is normally being-used for the manufacture of the 'HMA' with the "modified-binders". The diesel used for running the trucks leads to the "Emission of Pollutants".

THE RECLAIMED-ASPHALTE- PAVEMENT",'(RAP)'

The Use of RAP in pavement rehabilitation project has advantages over virgin materials due to the Due to day by day Increasing the cost of asphalte, insufficiency of quality aggregates and the necessity to Save 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 1996-97, it has calculated nearly 33.0% of the asphalte-pavement in the US was (recycled) into the "HMA".

"Hot-mix asphalte" with the "RAP-material" shows to have the equal Quality as with {hot mix asphalte without the use of "RAP" in the terms of (rutting, raveling, weathering & fatigue cracking). This Recycled pavement has also shown to age- slower & are high resistant to the water than conventional(hot mix asphalte). After more than 30years since its first trial in Nevada and Texas, it appears that the use of RAP will not only beneficial alternative in the future but will also become a requirement to assure economics of flexible pavement construction.

The 'RAP' has become the major Resource to Makenew-asphalte & is recently the main recycled material in the "world". Recycled asphalte uses {old-resources} to cut the (cost & material) for the New asphalte- pavement. 'RAP' is being used widely as the technology with the RAP is high. So, there are Strict-specification for The "RAP" use which limits the quantity that can used as each of the mix-design. Recent Studies shows that the National avg. of the "RAP" which is to be used in the "new mixes" are nearly around 12.0% to 15.0%.

2. ADVANTAGES OF THE ASPHALTE RECYCLING

- Conservation of The "non-renewable" energy sources & its reuse.
- Reduction in land filling reduction & Environment friendly.
- The Improved "pavement smoothness".
- Economical than "traditional-rehabilitation" method.
- Improved pavement physical & chemical properties by the modification of the – (Existing aggregate gradation)& asphalte binder property.

Demolished Asphalt Pavement

3. TYPE OF TESTS WHICH ARE BASED ON THE MATERIALS USED

AGGREGATES

To make Bitumen mix (BC) aggregate a/c to'. MORTH.' grade shown in T-3.5 and A "Particular-type" of The Binder' in the needed quantities should be taken/c to the Marshall's - Procedure.

(JOB-MIX FORMULAA)"AGGREGATE GRADATION

The design mix was performed using job mix formula according to table 500-17 as given in"SPECIFICATIONS FOR R&B WORKS", MORTH (fifth revision), 2012. Following is the grading table-depicting the gradation of various aggregates and filler used for bituminous concrete(fresh materials) of sizes 13.2 mm, 6 mm, Stone dust and Filler.

Table combined gradation for bituminous mix

Graph combined gradation for bituminous mix

COMBINED GRADATION

Bituminous Concrete Gradation of Table 500-17, Grade - II

Average Individual Grading Material		% by weight passing IS sieve accordingly									
		19mm	13.2mm	9.5mm	4.75mm	2.36mm	1.18mm	0.600mm	0.300mm	0.150mm	0.075mm
13.2 MM		100.00	98.88	47.46	0.53	0.19					
6 MM		100	100.00	100.00	62.51	16.02	0.89				
STONE DUST		100	100	100.00	100.00	96.01	72.41	56.15	37.41	25.43	7.38
Lime		100	100	100	100	100	100	100	100	100	99.32
Theoritical Combined Aggregates in % by weight											
13.2 MM	30	30.00	29.66	14.24	0	0	0	0	0	0	0
6 MM	18	18.00	18.00	18.00	11.25	2.88	0	0	0	0	0
STONE DUST	50	50.00	50.00	50.00	50.00	48.01	36.21	28.08	18.71	12.72	3.69
Lime	2	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.99
Theoritical Combined Aggregates Gradation	100	100.00	99.66	84.24	63.41	52.95	38.37	30.08	20.71	14.72	5.68
Specified Gradation Limits		**100**	**90-100**	**70-88**	**53-71**	**42-58**	**34-48**	**26-38**	**18-28**	**12-20**	**4-10**

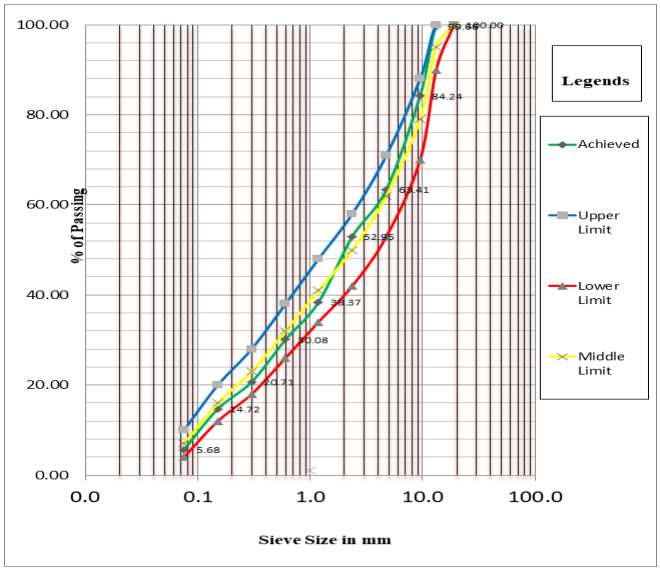


Table Marshall Test Data for Virgin Bituminous Concrete

BITUMINOUS CONCRETE
Marshall Test Data (As per AASHTO T 245)

Grade of Bitumen :- VG-30
Gsb:- 2.682 Gse:- 2.802
Sp. Gravity of Bitumen 1.021
Proving Ring Facto 5.77(kgf)

S.No	Type of Mix	% Bitumen by weight of total mix	% Agg by weight of total mix	Weight In Air	Weight In S.S.D	Weight In Water	Volume (cm³)	Bulk Spec Gravity of Mix	Max. Spec Gravity of Mix	Air Voids (%)	Voids in mineral aggregate	Voids filled with Bitumen (%)	Stability - KN Reading Dir	Load (KN)	Correction Factor	Corrected Load (KN)	Flow (mm)
1	B.C	5.4	94.6	1200	1202	700	502	2.390	2.561	6.75	15.77	57.22	156	900.12	1.04	936.12	2.30
				1194	1195	694	501	2.383					145	836.65	1.04	870.12	2.30
				1200	1202	700	502	2.390					150	865.50	1.04	900.12	2.40
								2.388						ΔLQ= 3.07		902.12	2.33
2	B.C	5.6	94.4	1201	1202	706	496	2.421	2.553	5.17	14.79	65.08	175	1009.75	1.04	1050.14	2.70
				1197	1199	703	496	2.413					169	975.13	1.04	1014.14	2.80
				1192	1194	703	491	2.428					183	1055.91	1.09	1150.94	2.40
								2.421						ΔLQ= 4.07		1071.74	2.63
3	B.C	5.8	94.2	1203	1204	712	492	2.445	2.545	3.99	14.19	71.89	196	1130.92	1.09	1232.70	3.20
				1202	1203	710	493	2.438					186	1073.22	1.09	1169.81	3.30
				1196	1198	709	489	2.446					206	1188.62	1.09	1295.60	3.30
								2.443						ΔLQ= 3.77		1232.70	3.27
4	B.C	6.0	94.0	1196	1199	708	491	2.440	2.537	3.85	14.52	73.49	160	923.20	1.09	1006.29	4.50
				1201	1203	710	493	2.436					168	969.36	1.09	1056.60	4.20
				1191	1192	704	488	2.441					153	882.81	1.09	962.26	4.30
								2.439						ΔLQ= 2.32		1008.38	4.33
5	B.C	6.2	93.8	1193	1195	703	492	2.425	2.529	4.14	15.23	72.80	144	830.88	1.09	905.66	5.40
				1202	1203	705	498	2.414					156	900.12	1.04	936.12	5.30
				1197	1198	706	492	2.433					139	802.02	1.09	874.21	5.20
								2.424						ΔLQ= 1.71		905.33	5.30

Specified Limits as per MORTH
Stability (kg) - 900 min. Flow (mm)- 2-4 Va (%)- 3-5 VMA (%)- 13 min. VFB (%)- 65-75 Marshall Quotient- 2-5

Table Summary for Marshall Test Data for Virgin Bituminous concrete

Summery for physical & volumetric characteristics of Virgin Bituminous concrete						
VG-30						
Bitumen, %	Density, Gm/cc	Stability, Kg	Flow, mm	VA, %	VMA, %	VFB, %
5.4	2.388	902.12	2.33	6.75	15.77	57.22
5.6	2.421	1071.74	2.63	5.17	14.79	65.08
5.8	2.443	1232.70	3.27	3.99	14.19	71.89
6.0	2.432	1008.38	4.33	3.85	14.52	73.49
6.2	2.424	905.33	5.30	4.14	15.23	72.80

4. PROPORTION OF BITUMEN PRESENT IN RAP

Percentage of bitumen was determined using centrifugation method. The removal of RAP was done using excavator. The

material is 3 year old. RAP being mix of base and old surface layer, the binder content found in RAP was 4.8% and the original percentage at the time of construction was 5.5%. For this study, aggregates of 13.2mm, 6mm, Stone dust and Lime were used. Along with RAP material was collected from the nearby vicinity where the old road is being reconstructed. RAP here comprise of mix of old surface course and bituminous base course. The aggregates needed to be separated slightly.

Determination of Bitumen % of RAP on Centrifuge Extractor

Theoretical combined gradation with RAP 10%

COMBINED AGGREGATES GRADATION

Bituminous Concrete Gradation of Table 500-17, Grade - II

Average Individual Grading Material		%by weight passing IS sieve accordingly									
		19mm	13.2mm	9.5mm	4.75mm	2.36mm	1.18mm	0.600mm	0.300mm	0.150mm	0.075mm
RAP		100.00	93.25	70.41	59.07	53.21	47.23	35.62	28.15	17.89	9.65
13.2 MM		100.00	98.88	47.46	0.33	0.19					
6 MM		100	100.00	100.00	62.51	16.02	0.89				
STONE DUST		100	100	100.00	100.00	96.01	72.41	56.15	37.41	25.43	7.38
Lime		100	100	100	100	100	100	100	100	100	99.32
Theoretical Combined Aggregates in % by weight											
RAP	10	10.00	9.33	7.04	5.91	5.32	4.72	3.56	2.82	1.79	0.97
13.2 MM	20	20.00	19.78	9.49	0	0	0	0	0	0	0
6 MM	18	18.00	18.00	18.00	11.25	2.88	0	0	0	0	0
STONE DUST	50	50.00	50.00	50.00	50.00	48.01	36.21	28.08	18.71	12.72	3.69
Lime	2	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.99
Theoretical Combined Aggregates Gradation	100	100.00	99.10	86.53	69.26	58.25	43.09	33.64	23.52	16.50	6.64
Specified Gradation Limits		100	90-100	70-88	53-71	42-58	34-48	26-38	18-28	12-20	4-10

5. RESULTS AND DISCUSSIONS

This chapter deals with the Result and Observation of test carried out in previous chapter is presented, analyzed and discuss. This chapter deals with parameter used for analysis, (calculation of OBC of BC), Marshall Properties of bituminous concrete with or without using RAP, Results of Static indirect tensile stress and fatigue life cycle index.

BITUMEN PRESENT IN RAP

Percentage of bitumen was determined using centrifugation method in bitumen centrifuge extractor. It shows 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 & "(Optimum Binder Content)" which are shown in (Table-3.4).It is observed that stability value increases with increase binder content up to certain binder content; then stability value decreases which is 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 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 shows 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 VALUEVs BITUMEN AND RAP 10%, 20%, 30%, 40%.

It shows that the 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 shows 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 FORTHE RB WORKS", MORTH (fifth revision), published by Indian Roads Congress.(2mm - 4mm) as specified in table 500-11.

VOIDS IN AGGREGATE (VA %).

It shows 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 shows that the 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 THE RB WORKS", MORTH (fifth revision), published by Indian Roads Congress. The requirement is 3-5% as specified in table 500-11.

VOID IN THE MINERAL AGGREGATES ('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 shows that the Voids in The Mineral aggregates 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 FORTHE RB WORKS", MORTH (fifth revision), published by Indian Roads Congress.

VOIDS WHICH CAN BE FILLED WITH BITUMEN ('VFB' %).

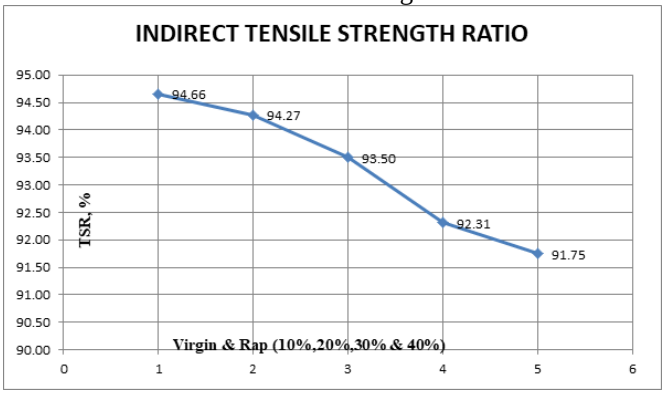
It is observed that VFB value at OBC 5.8% is 71.89 % and VMA in RAP 10 % is 56.84%,RAP 20% is 63.92%, RAP 30% is 70.17% and RAP 40% is 66.56 % against the requirement is 65-75 % as given in Table.3.2 and Table no.3.14 for virgin mix and different percentage of RAP. From the above it Shows that the Voids 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 500-11as specified in "SPECIFICATIONS FOR the RB WORKS", MORTH (fifth revision), published by Indian Roads Congress.

INDIRECT TENSILE STRENGTH TEST

Test was performed for newly and different percentage of Reclaimed asphalte pavement with OBC of 5.8% which was found after Marshall Stability testing. The –"(ASTM T283)" code specify the 80% Should be the min. value of The "Indirect Tensile Strength) ratio. The Results were tabulated in table

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

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 m3 of bituminous concrete is 12000/m3.

31The Cost of aggregate /m3 is 1175.{CPWD SOR 2014 – Page No.8}

The Cost of 30% aggregate is 352.50/m3.

The density of mix is 2.434gm/cc.

4.8 % bitumen available in RAP, i.e., 4.8% is 116.83 kg/m3 bitumen is available in RAP.

32The rate of bitumen at site is 52/kg.{MPPWD SOR 2014, Page 1 - General Notes Road Work}

We have 116.83×52=6075.16/m3.

Then the total reduction in cost is 6075.16+352.50=6427.66/m3.

The saving is with 30% RAP @ 12000/m3-6427.66/m3=5573/m3

Total saving in percentage is 46.44 %.

6. CONCLUSIONS AND RECOMMENDATION

GENERAL

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 "RECLAIMED ASPHALTE PAVEMENT PERCENTAGE"

A/Cto(MORTH) "Specifications" Mix-Design requirement of the "bitumen mix" which is shown in table 5.1.

Table MORTH Specification (section 500) Mix-design requirement of a Bitumen 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 the road and RB 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. Similarly 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 THE RB WORKS", MORTH (fifth revision), published by Indian Roads Congress.

The matured bituminous mix shows the present Paving Material with more DIFFERENT % of "newly Binder", there is consistently increment in Physical properties like: (Penetration., Ductility., softening point., etc..) of an Old Bitumen when it will Invigorated with "Virgin VG-30".

The proportion of the aggregate with some Reclaimed Aggregates all specified percentages of "(10,20,30 and 40)" Gives Correct Blending of aggregate which meets all the specification and 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 shows that more than 30% RAP can be suitable to adopt in making the new roads with the RAP. This % of 'RAP" provides an Insight to a (Research and field persons) to take effectively with full technological alignment for "milling. Mixing. Transporting. Laying and compacting".

Overall from this study it was concluded that RAP 30 % showed results same as that of newly bituminous mix in its "OBC"& its performance was best amongst other RAP percentages. Also with using the RAP, 30 % the cost of project was reduced by 46.44 % and the result is qualifying the all requirements of "SPECIFICATIONS OF (RB) WORKS", MORTH (fifth revision), published by Indian Roads Congress.

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