

Laboratory Investigation on Utilization of Maximum Percentage of Reclaimed Asphalt Pavement Material in Bituminous Concrete Mix with VG-10 Grade Bitumen

Sambasivarao Konakanchi¹, K Giridhar, M.S (USA)², Dr.T.Sureshbabu. M.Tech, Ph.D³

Post Graduate Student, Dept. of Civil Engg, Visvodaya Engineering College, Kavali, AP, India¹

Assistant Professor, Dept. of Civil Engg, Visvodaya Engineering College, Kavali, AP, India²

Principal & Head, Dept. of Civil Engg, Visvodaya Engineering College, Kavali, AP, India³

ABSTRACT: RAP is old bituminous pavement that is milled up or ripped off the roadway. This material can be reused in new bituminous mixtures because the components of the mix (the bitumen binder and aggregate) still have value. The main objective of this study aims to determine the maximum amount of reclaimed asphalt pavement material percent that can be used in BC mix with Virgin VG-10 Grade bitumen. The present laboratory investigation carried out on Bituminous Concrete (BC) mixes prepared with control mix with virgin aggregates and VG-30 Grade bitumen, and Mixes with variable % of RAP from 10 % to 80% with VG-10 Grade bitumen. The experimental process involves determination of characteristics of the materials procured. All the characteristics were found to be within specified specifications as per MoRT&H and IS standards. Firstly, the quantity of RAP and new aggregates are to be blended in such a way that the resultant gradation of aggregates conforms to the BC Grading-1 as per MoRT&H. The optimum Bitumen content is the percentage of bitumen corresponding to 4% of Air Voids was determined from Marshall graphs. Density-void analysis, Marshall Stability, flow and water sensitivity tests were carried out on the specimens prepared at OBC in all mixes. Inclusion of minimum 20% and maximum upto 60% of RAP in Bituminous Concrete (BC) mixes with VG-10 Grade bitumen was found to be suitable for construction and rehabilitation of flexible pavement, without compromising specifications and standards as specified.

KEYWORDS: Reclaimed Asphalt pavement, Bituminous concrete, VG-10 Grade bitumen, Marshall Stability, Water sensitivity.

I. INTRODUCTION

Recycling of bitumen pavements is a Nobel approach in terms of technical, economical, preservation of natural resources and environmental issues. These materials are generated when bituminous pavements are rehabilitated, resurfacing, removed for reconstruction, or to obtain access to buried utilities. Incorporating RAP in fresh materials has been favoured in the light of the increasing cost of bitumen, scarcity of quality aggregate, scarcity of bitumen and pressing need to preserve the environment. RAP can be used in new hot mix bitumen concrete by several recycling techniques, such as hot mix recycling, hot in-place recycling, cold mix recycling, cold in-place recycling, and full depth reclamation. The most common method involves a process in which RAP is combined with virgin aggregate and virgin bitumen in a central mixing plant to produce new hot mix paving mixture. Control mix done with virgin aggregates and VG-30 Grade bitumen. In the present investigation an attempt has been made to combine 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80 % of RAP material with virgin aggregate and virgin bitumen VG-10 grade. In this investigation RAP to new aggregate ratio has been adopted as 10:90, 20:80, 30:70, 40:60, 50:50, 60:40, 70:30, 80: 20. The major advantages of use of RAP are (a) Lower cost (b) Reduction in use of natural resources (c) Reduction of damage to other roads for transportation of materials from quarry site, (e) Less dependence on diesel due to energy crisis, (f) Preservation of the Environment

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

1.1 Objectives of the Present Project

1. Marshall Mix design with Virgin aggregates and VG-30 Grade Bitumen (Control mix).
2. Marshall Mix design with Virgin aggregate and VG-10 Grade bitumen added with various proportions of the RAP from 10% to 80%
3. Evaluation of the properties of the bituminous mix with various proportions of the RAP.
4. Minimum and Maximum amount of RAP that can be used in BC-1 with VG-10 grade bitumen was investigated
5. Cost analysis.

1.2 Scope

1. Characterization of the Virgin bitumen grades of VG-30, and VG-10 and aggregates.
2. Characterization of the Reclaimed bitumen and aggregate.
3. Marshall Method of mix design for virgin aggregates and determination of optimum binder content and Marshall Properties for control mix.
4. Laboratory investigation on Marshall Properties using the reclaimed asphalt pavement materials at variable percentages from 10% to 80 %.
5. Performance Evaluation by Moisture susceptibility

II. LABORATORY INVESTIGATION

The first step is collecting the study materials. These materials are the virgin aggregate and the RAPs as well as bitumen binder

2.1 Aggregates: Aggregate samples of sizes 20mm, 16 mm, 10 mm and stone dust are collected from the crusher site near Medarametla, Prakasam district, AP State, India and sampled aggregates are characterized for the following properties as per MORTH specification. The type of Rock was Igneous and Petrological name "DIORITE"

2.2 Bitumen: Source of the Bitumen used for the project work is CPCL Chennai, Grade selected is VG-30 for control mix and VG-10 for variable mixes of RAP 10 % to RAP 80 %. The bitumen is tested in the laboratory as per the procedure laid in the relevant IS codes

2.3 Reclaimed asphalt pavement (RAP): is a reusable mixture of aggregate and bitumen binder, source of the RAP material is collected from NH-16 near Ongole.

Table-1 Physical Properties of Aggregates

Property	Test	Code of Practice	Specification Requirement as per MORTH	Result Obtained for Virgin Aggregates	Result Obtained for RAP Aggregates
Particle Shape	Flakiness and Elongation Index (FI & EI)	IS: 2386 (P-1)	Max 35%	26%	29%
Strength	Aggregate Impact Value (AIV)	IS: 2386 (P-4)	Max 24%	16%	17.0%
	Los Angeles Abrasion Value (LAA)		Max 30%	18%	19.5%
Water Absorption	Coarse aggregates	IS: 2386 (P-3)	Max 2%	0.40%	0.49%
	Fine aggregates		Max 2%	0.97%	1.04%
Specific Gravity	Specific Gravity for Coarse aggregate	IS: 2326 (P-3)		3.068	2.921
	Specific Gravity for fine aggregate			3.006	2.903

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

Test	Code of Practice	Specification requirement as per IS-73 for VG-30 Grade bitumen	Result Obtained for Virgin VG-30 Grade bitumen	Result Obtained for Virgin VG-10 Grade bitumen	Result obtained for Residual bitumen from RAP
Softening Point	IS: 1205	Min. 47 ^o C	50	46	82
Ductility at 27 ^o C (cm)	IS: 1208	Min. 40 cm	> 75 cm	> 75 cm	27 cm
Penetration at 25 ^o C, 100g, 5s, 0.1 mm	IS: 1203	Min 45mm	60 mm	90 mm	21 mm
Specific Gravity	IS: 1202	Min. 0.99	1.04	1.035	1.05
Residual Bitumen in RAP	ASTM:D2172				4%

2.4 Individual Aggregate Gradations

Individual aggregate gradations trials were conducted for all sizes of aggregates and RAP Material and the results are summarized in the following Table 3

IS Sieve mm	Individual % Passing of Aggregate					Specification Limits for BC Grading-I	
	RAP	20 mm	16 mm	10 mm	Stonedust	Lower Limit	Upper Limit
26.50	100.00	100.00	100.00	100.00	100.00	100.00	100.00
19.00	97.14	60.73	99.11	100.00	100.00	90.00	100.00
13.20	84.99	0.93	46.57	100.00	100.00	59.00	79.00
9.50	75.24	0.40	6.90	93.60	100.00	52.00	72.00
4.75	50.25	-	1.30	6.04	95.82	35.00	55.00
2.36	36.89	-	0.94	0.59	75.48	28.00	44.00
1.18	28.14	-	-	-	60.13	20.00	34.00
0.60	20.74	-	-	-	44.95	15.00	27.00
0.30	14.77	-	-	-	31.26	10.00	20.00
0.15	9.00	-	-	-	17.26	5.00	13.00
0.075	3.80	-	-	-	6.77	2.00	8.00

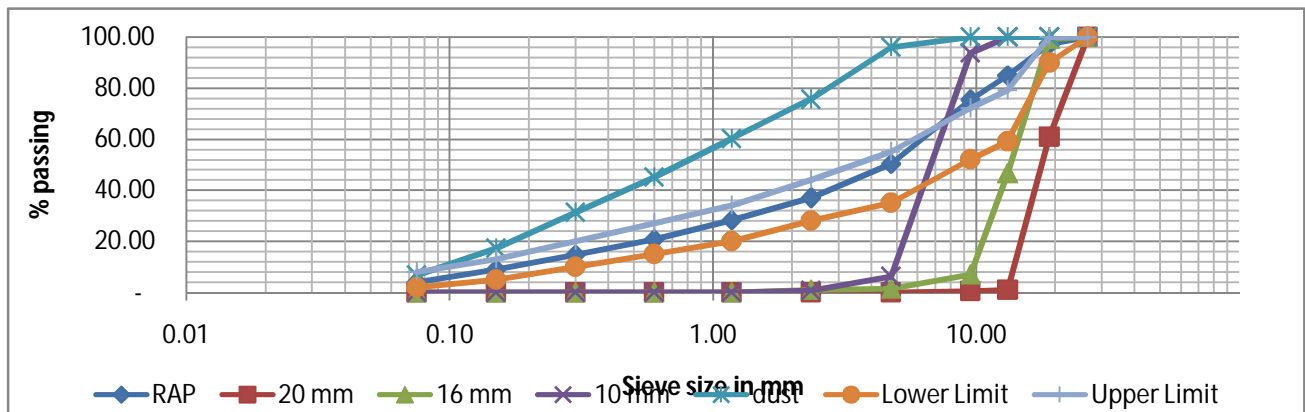


Fig-1 Gradation curve for the Individual Material

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

2.5 Combined Gradations

The Combined Gradation of virgin Aggregates and different percentage for RAP such as 0%, 10%,20%, 30%, 40%,50%,60%,70% and 80% are meeting the desired Gradation of BC Grading-1 mix as per MORT&H Table 500-17 Grading-1 and the typical Grading-curve for BC mix gradation for different RAP mix is shown in Figure 2.

Table -4: Combined Gradation for RAP Material and Fresh Aggregate in BC Mix

IS Sieve size in mm	Virgin Aggregates	10% RAP	20% RAP	30% RAP	40% RAP	50% RAP	60% RAP	70% RAP	80% RAP	Specification Limits
26.50	100	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100
19.00	92.75	92.86	92.60	92.71	92.45	92.20	91.94	91.69	92.21	90-100
13.20	71.48	70.97	71.07	70.56	70.67	71.30	71.40	72.04	74.12	59-79
9.50	62.24	61.01	61.46	60.23	60.68	61.99	62.50	63.75	66.06	52-72
4.75	42.61	42.60	42.68	42.67	42.74	42.86	43.84	43.06	43.25	35-55
2.36	32.76	32.65	32.52	32.42	32.29	32.16	32.79	31.91	31.80	28-44
1.18	25.86	25.66	25.47	25.28	25.09	24.89	25.30	24.51	24.32	20-34
0.60	19.33	19.16	18.98	18.81	18.63	18.46	18.74	18.11	17.94	15-27
0.30	13.44	13.36	13.27	13.19	13.10	13.01	13.24	12.84	12.76	10-20
0.15	7.42	7.46	7.50	7.53	7.57	7.61	7.82	7.68	7.72	5-13
0.075	2.91	2.95	2.99	3.04	3.08	3.12	3.23	3.20	3.24	2-8
Proportion***	0%, 18%, 20%, 19%, 43%	10%, 17%, 20%, 15%, 38%	20%,17 %,17%, 13%,33 %	30%,16 %,17%, 9%,28 %	40%,16 %,14%, 7%,23 %	50%,16 %,10%, 6%,18%	60%,16 %,7%,3 %,14%	70%,16 %,3%,3 %,8%	80%14 %,0%, 3%,3%	

Note: *** Percentages of RAP, 20mm, 16mm, 10mm and stone dust respectively

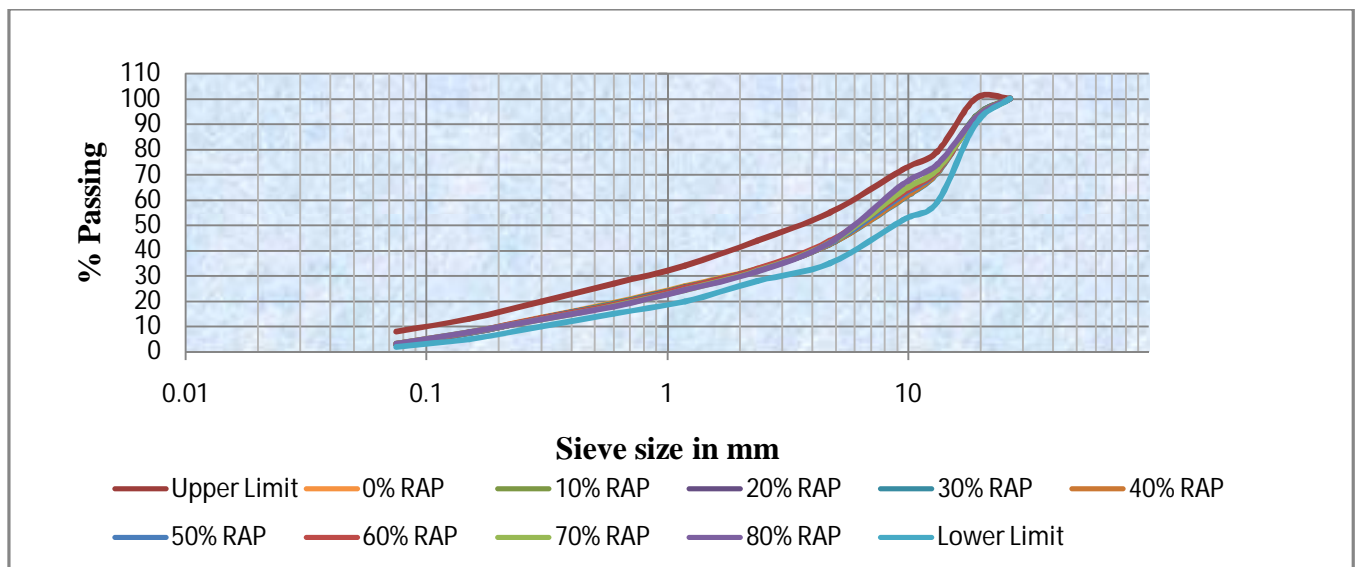


Fig -2: Gradation Curve for Combined Gradation of RAP Material and virgin Aggregates for BC Mix Grading-1

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

2.6 Marshall Method of Mix Design

Mixture Designs will be performed using the Marshall method by casting Marshall specimens for each type of mix by varying the RAP proportion from 10 to 80 % with Bitumen content from 3.5 % to 5.5 % in each proportion with the increment of 0.5% and three specimens has been casted for each bitumen content.

2.7 Density-Void analysis, Marshall Stability - Flow and Retained tensile strength of the mixes

The optimum Bitumen content was chosen as the bitumen content that produced 4 % air voids. Bitumen content corresponding to all other parameters are checked for that binder content so as to confirm that whether all other parameters such as VMA, VFB, Stability and flow falls within the MORT&H specified limits. The specimens to be tested are kept immersed in water in a thermostatically controlled water bath at 60⁰C for 30 minutes. The specimens are taken out one by one placed in a Marshall setup and the Marshall Stability (maximum load carried in KN by the specimen before failure) and the flow values are noted. The corrected Marshall Stability values of each specimen are calculated by applying the appropriate correction factor. Marshall Graphs were plotted for different % of RAP materials i.e.0%, 10%, 20%, 30% , 40% ,50% ,60%, 70% and 80% was obtained OBC at 4 % Air voids and then find out Properties like VMA, VFB, Density, Stability, Marshall quotient ,and flow from Marshall graphs at OBC. Water sensitivity tests were carried out on the specimens prepared at OBC in all mixes. The values along with the MORT&H Specifications are given in Table 5.

Mix Properties for Virgin materials and varying different % of RAP

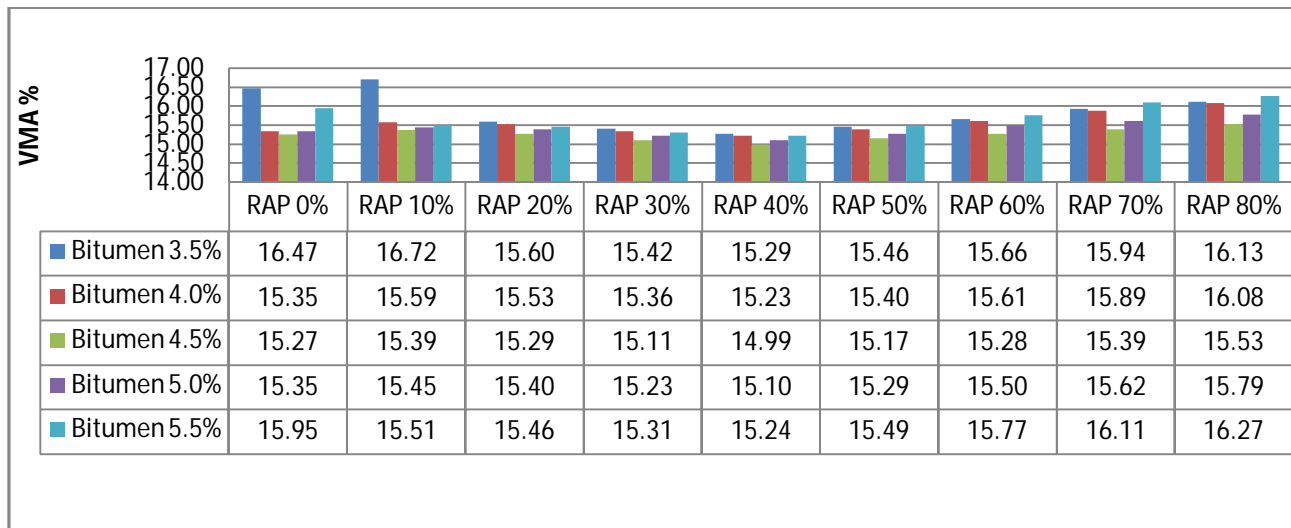


Fig-3 Comparison of VMA % for different percentage of RAP Mixes for varying Binder Content with VG-10 Grade bitumen

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

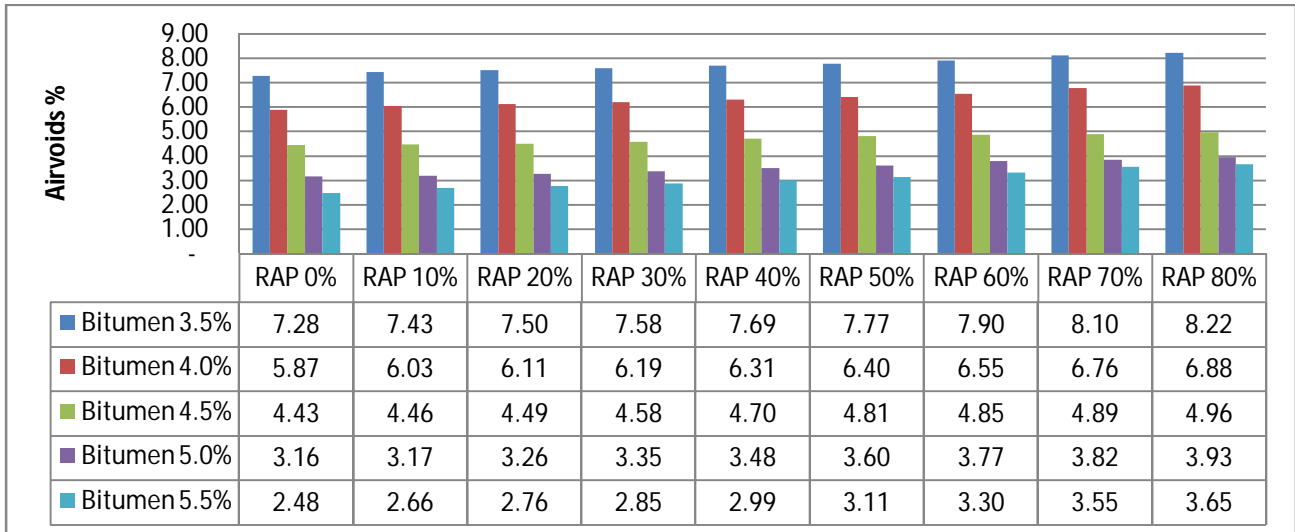


Fig-4 Comparison of Airvoids % for different percentage of RAP Mixes for varying Binder Content with VG-10 Grade bitumen

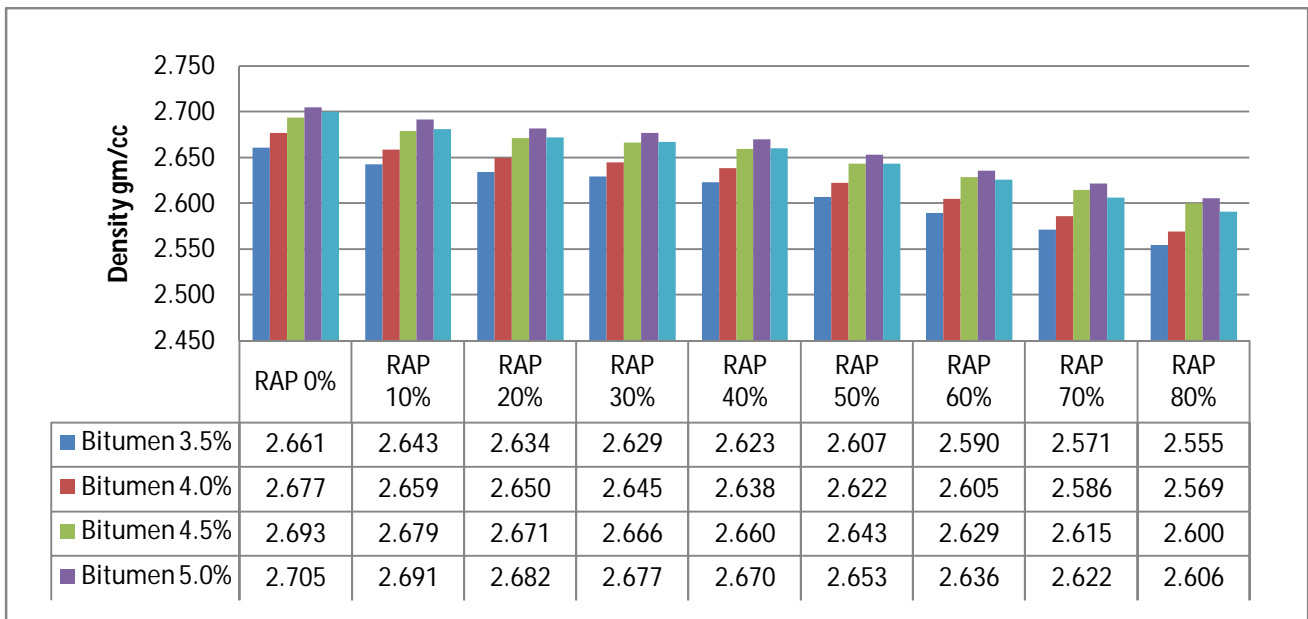


Fig-5 Comparison of Bulk density of compacted mix values for different percentage of RAP Mixes for varying Binder Content with VG-10 Grade bitumen

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

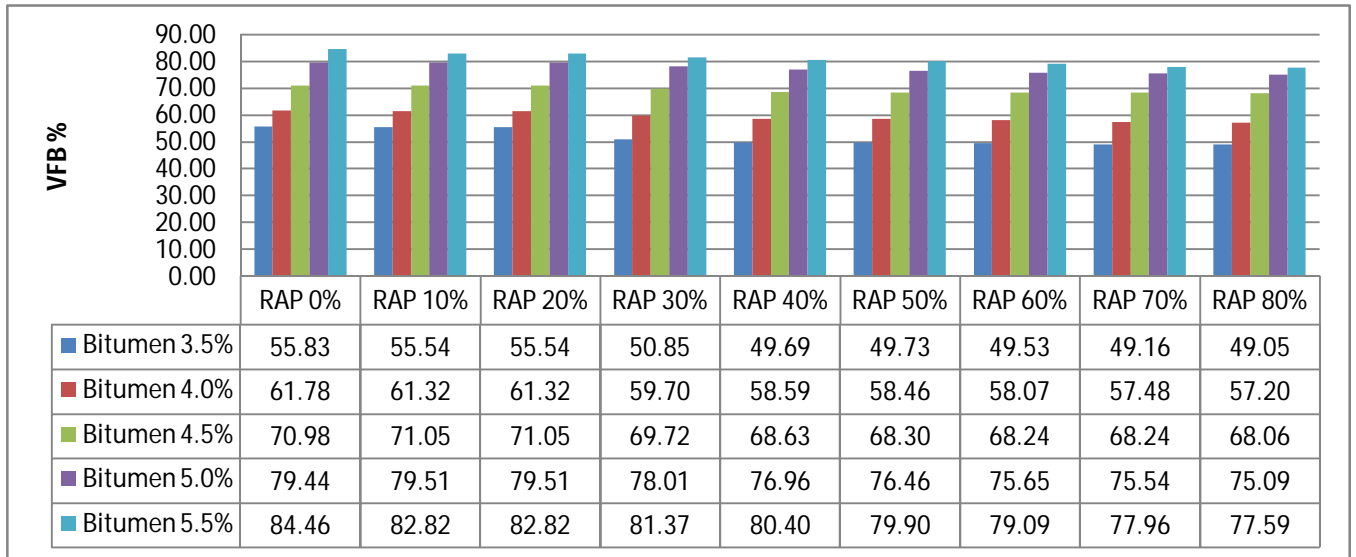


Fig-6 Comparison of VFB % for different percentage of RAP Mixes for varying Binder Content with VG-10 Grade bitumen

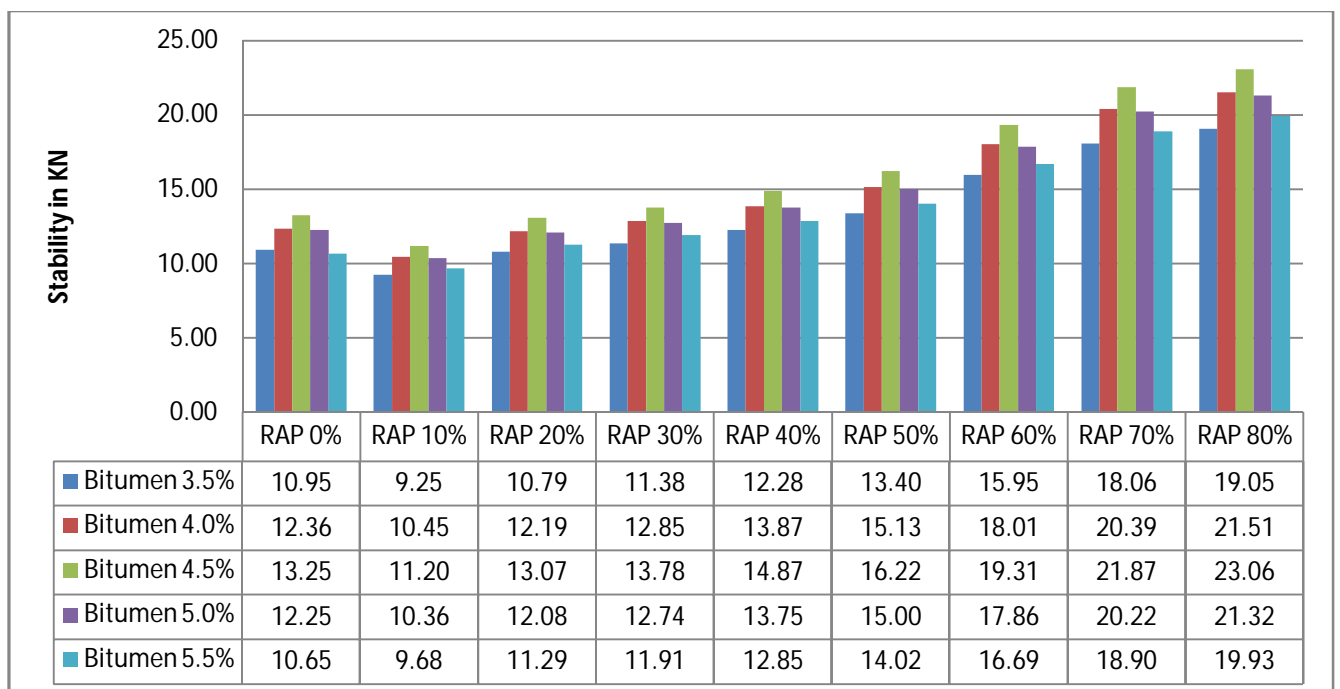


Fig-7 Comparison of Stability values for different percentage of RAP Mixes for varying Binder Content with VG-10 Grade bitumen

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

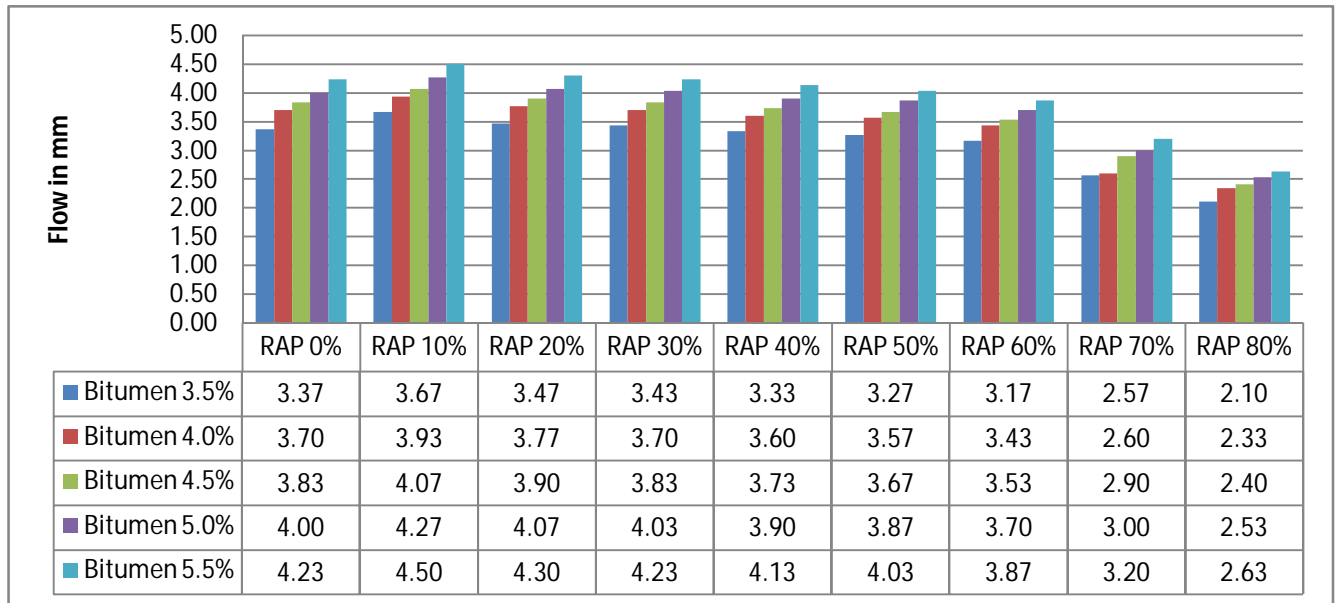


Fig-8 Comparison of Flow values for different percentage of RAP Mixes for varying Binder Content with VG-10 Grade bitumen

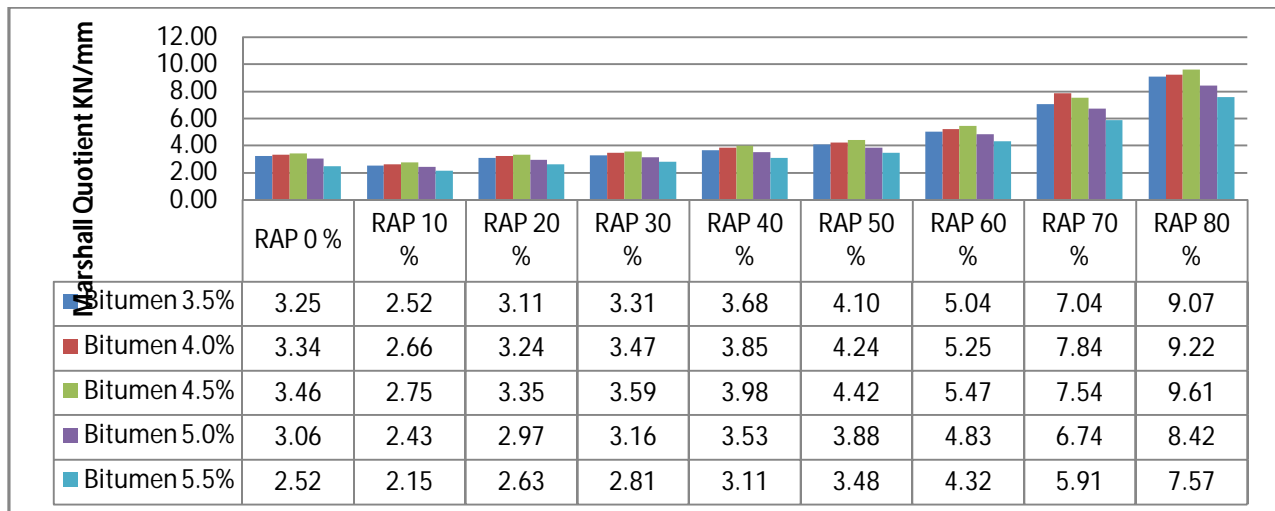


Fig-9 Comparison of Marshall quotient values for different percentage of RAP Mixes for varying Binder Content with VG-10 Grade bitumen

2.8 Retained Tensile strength Test: Retained tensile strength test, which was used to measure mix durability by evaluating the resistance of the investigated mixes to moisture damage. This test is intended to measure the loss of stability resulting from the action of water on compacted bitumen mixtures by comparing the stability of dry specimens which have been immersed in water bath at 60°C for certain times, 0.5 and 24 hours

- . Water Sensitivity (Retained Tensile Strength)

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

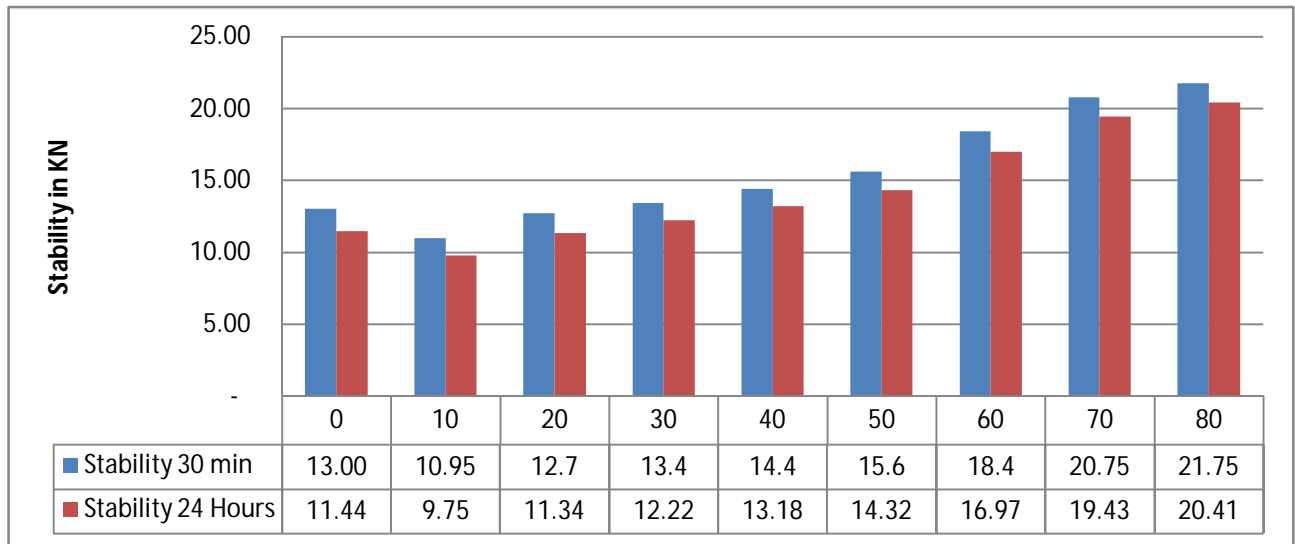


Fig-10 Comparison of Stability values at 60°C in 30 min and 24 hours for different percentage of RAP Mixes for varying Binder Content with VG-10 Grade bitumen

III. ANALYSIS OF TEST RESULTS AND DISCUSSION

3.1 Comparison of Marshall Properties at different RAP Percentages at OBC

After finding the OBC at 4 % Airvoids at the various percentages of the RAP material i.e. 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80% .the percentage reduction in the bitumen content is 0.400%, 0.790%, 1.190%, 1.590%, 1.990%, 2.380%, 2.770 %, and 3.160% respectively.

3.2 Analysis of Marshall Test Results. Table 5 shows the results of Marshall test of the investigated mixes.

Table-5 Mix Properties for Control mix with VG-30 Grade bitumen, and Mixes with varying different % of RAP from 10% to 80% with VG-10 Grade Bitumen@ 4 % Air Voids

Parameter	RAP%									Criteria as per MORTH
	0	10	20	30	40	50	60	70	80	
Aggregate Bulk Specific Gravity (Gsb)	3.036	3.024	3.011	3.000	2.988	2.975	2.963	2.952	2.939	
Apparent Specific Gravity of Aggregate (Gsa)	3.098	3.087	3.075	3.063	3.052	3.040	3.029	3.017	3.006	
Aggregate Effective Specific Gravity (Gse)	3.065	3.050	3.041	3.038	3.033	3.016	2.999	2.982	2.965	
Bitumen specific Gravity Gb	1.040	1.036	1.038	1.039	1.040	1.041	1.042	1.043	1.044	
Maximum theoretical Specific Gravity of loose mixture(Gmm)	2.814	2.805	2.797	2.796	2.792	2.779	2.765	2.750	2.745	
Bulk Specific Gravity of Compacted Mixture (Gmb)	2.697	2.683	2.675	2.670	2.663	2.648	2.632	2.617	2.600	
Optimum Binder Content (%) by total weight of mix	4.650	4.680	4.700	4.750	4.800	4.880	4.950	5.000	5.050	Min 5.2% *
% of Residual bitumen in RAP by Weight of total mix	-	0.400	0.790	1.190	1.590	1.990	2.380	2.770	3.160	

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

% of Virgin bitumen VG-30 Grade by Weight of total mix	4.650	4.280	3.910	3.560	3.210	2.890	2.570	2.230	1.890	
Absorbed Binder (Pba) (%)	0.329	0.290	0.332	0.431	0.522	0.467	0.417	0.361	0.309	
Effective Binder (Pbe) (%)	4.337	4.404	4.383	4.339	4.303	4.436	4.553	4.657	4.757	
Dust-Binder Ratio	0.626	0.630	0.636	0.640	0.642	0.639	0.653	0.640	0.642	0.6 to 1.2
Voids in Mineral Aggregate (VMA) (%)	15.20	15.30	15.40	15.20	15.100	15.500	15.50	15.70	15.80	Min 12
Voids Filled with Bitumen (VFB) (%)	73.00	73.00	74.00	74.00	74.000	74.000	74.00	74.00	75.00	65-75
Stability (KN at 60 ⁰ C, 30 minutes)	13.00	10.95	12.70	13.40	14.400	15.600	18.40	20.75	21.75	Min 9 KN
Flow (mm at 60 ⁰ C, 30 minutes)	3.750	4.200	4.000	3.950	3.850	3.800	3.700	3.000	2.550	2-4 mm
Marshall Quotient	3.47	2.61	3.18	3.39	3.74	4.11	4.97	6.92	8.53	2-5
Water Sensitivity (Retained Tensile Strength) (%)	88.00	89.00	89.30	91.20	91.50	91.80	92.25	93.65	93.85	minimum 80%
*As per IRC: 111-2009, Cl: 3.5.2, Note-2 and Foot note of Clause 507.2.5 of MORT&H , The bitumen content specified corresponds to Specific gravity of aggregate being 2.7 ,In case of aggregate specific gravity more than 2.7,the minimum bitumen content can be reduced proportionately										

3.2.1 Analysis of Optimum Bitumen Content Results

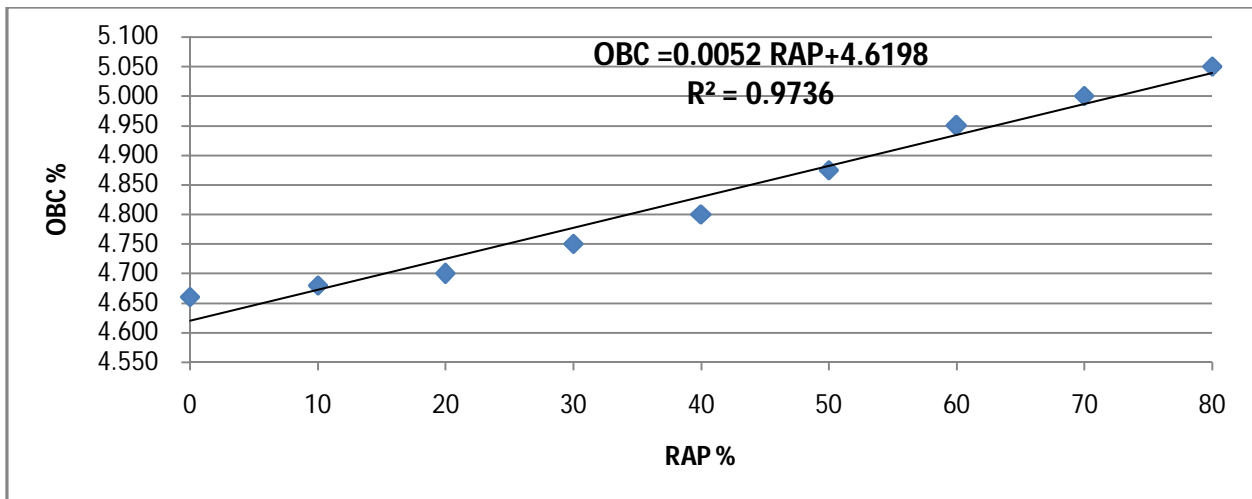


Fig-11: Relationship between % of RAP Vs OBC %

Aggregate gradation is directly related to OBC. The finer the mix gradation, the greater the surface area of aggregate and the greater the binder that will be required to uniform coat the particles. Fig-11 is plotted based on Marshall test results presented in table (5) to show the optimum bitumen content percent for the investigated mixtures. From the fig-11 it can be noticed that the optimum bitumen content is slightly increased as the RAP percent increases. The relationship between optimum bitumen content % (O.B.C) and RAP % in mix is as follows:

$$OBC = 0.0052 \text{ RAP} + 4.6198$$

3.2.2 Analysis of Bulk density Results

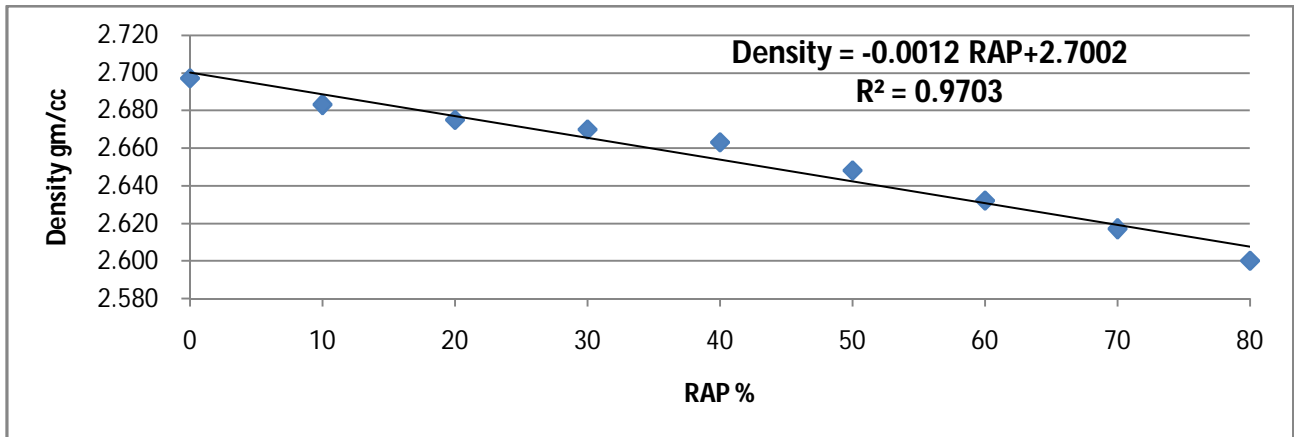


Fig-12: Relationship between % of RAP Vs Density at OBC

Investigating the effect of using RAP on the density of bitumen mixtures. RAP has unpronounced effect on the mix unit weight. However unit weight is decreased as reclaimed percent increases. It must be noticed that, increasing RAP percent from zero to 80% reduce the unit weight by only 3.596%. To examine the relationship between mix density content and RAP percent figure (12) was plotted. The relationship between mix density content and RAP % in Mix is as follows:-

Mix Density = - 0.0012 RAP + 2.7002

3.2.3 Analysis of Mix Stability Results

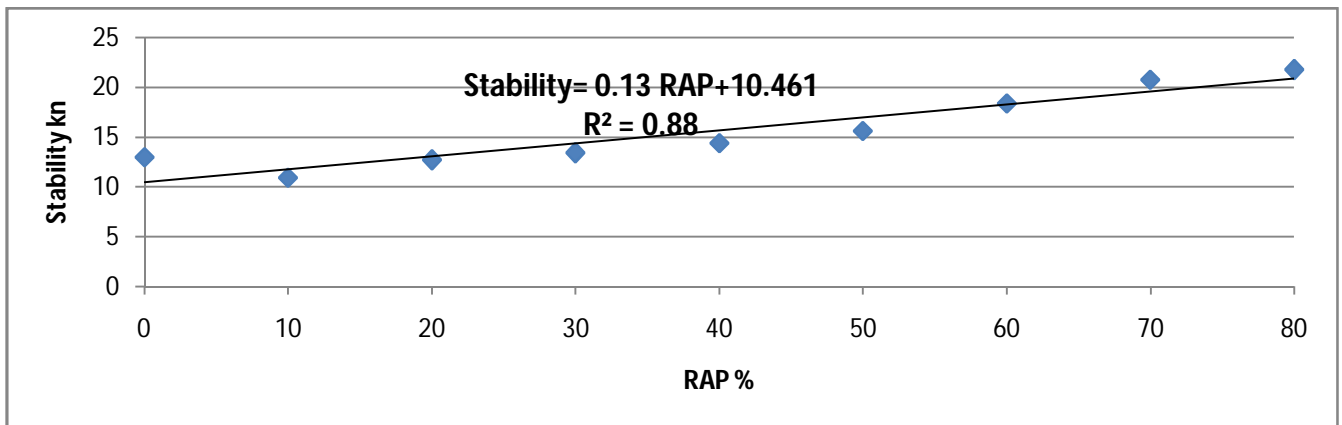


Fig-13: Relationship between % of RAP Vs Stability at OBC

One of the most important properties of bitumen mix is the stability. The mix stability is an important indicator for resisting pavement distresses. The stability of the investigated mixtures is presented in the table 5. Referring to the table it can be noticed that, the mix stability is less than control mix at 10% and 20% RAP mixes, from 30% onwards the stability of mix is increased as RAP percent increases. It can be also noted that, increasing RAP percent from zero to 30% increase the stability value from 13 KN to 13.4 KN i.e. increased by about 3.07% only, when the RAP percent increases from 30% to 80% the increase in the stability value from 13.4 KN to 21.75 KN i.e. increased by about

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

62.31%. To deduce the relationship between mix stability and recycled aggregate percent figure (13) was plotted. The relationship between mix stability and RAPpercent in mix is as follows:
Stability = 0.13 RAP+10.461

3.2.4 Analysis of Mix Flow Results

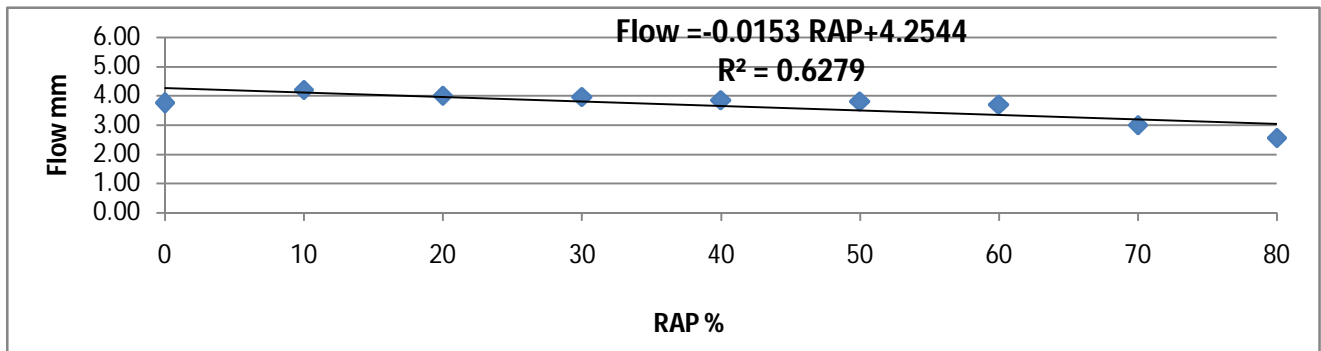


Fig-14: Relationship between % of RAP Vs Flow at OBC

Mix flow value gives an indicator for the resistance to permanent deformation. Based on the flow values obtained for all the investigated mixtures, table (5) was prepared. The mix flow is decreased as the RAP percent increases, but the flow values are greater than the control mix upto the mixes with 10% to 50% RAP, at RAP 10% with VG-10 grade bitumen, the flow value increases from 3.75 mm to 4.2mm. i.e. increased by about 12%. This flow value is out of specification limits. When the RAP percent increases from 20%, 30%, 40%, 50%, 60%, 70% and 80% the corresponding flow values of mix are 4.00, 3.95, 3.85, 3.80, 3.70, 3.00, 2.55 mm respectively, decreases of flow value from 20% RAP to 80 % RAP by about 36.25%. It is noted from the above upto 20% RAP with VG-10 Grade bitumen the mix falling out of specification limits, hence minimum RAP 20% should be used when VG-10 Grade bitumen used in Bituminous concrete mix. To derive the relationship between mix flow and RAPpercent, fig-14 was plotted. The relationship between mix flow and RAP % in Mix is as follows.
Mix flow = -0.0153 RAP+4.2544

3.2.5 Analysis of Marshall Quotient of Mix Results

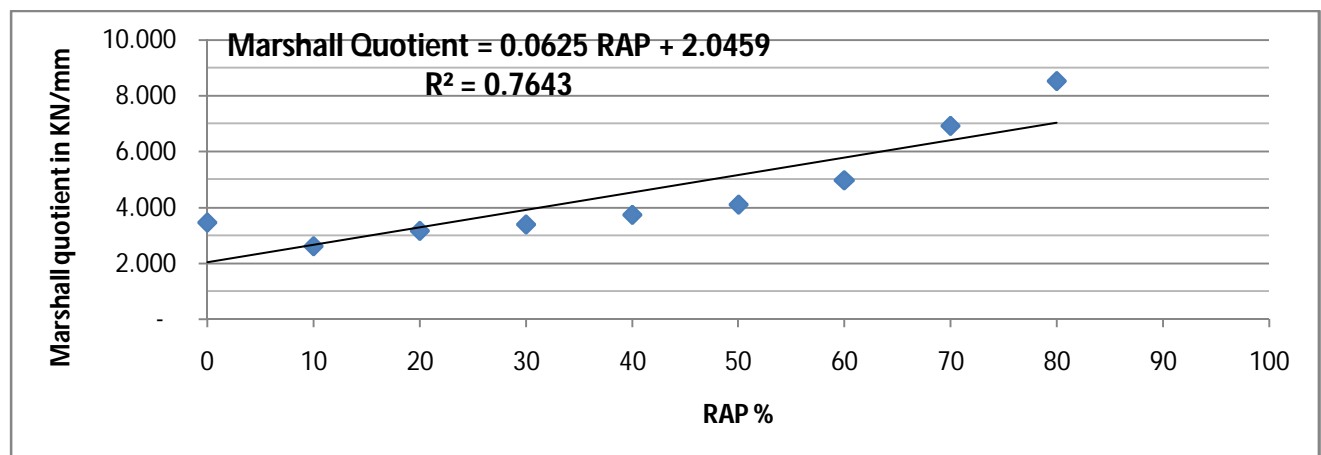


Fig-15: Relationship between % of RAP Vs Marshall Quotient at OBC

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

Marshall Quotient (MQ) also known as rigidity ratio is the ratio of stability to flow value of the mixture and the Marshall Quotient values of Bituminous concrete mix with different RAP contents are shown in Fig.15. It is observed that Marshall Quotient (MQ) increases with increase of RAP content. It can be also noted that, increasing RAP percent from zero to 40% increase the Marshall Quotient (MQ) value from 3.47 KN/mm to 3.74 KN/mm i.e. increased by about 7.8%. ,when the RAP percent increases from 40% to 80% the increase in the Marshall Quotient (MQ) value from 3.74 KN/mm to 8.53 KN/mm i.e. increased by about 128%..It must be noted that the mix Marshall Quotient value reaches a value of 6.92 KN/mm as the RAP percent reaches to 70%. This value is out of specification limits. **Therefore, it is recommended to use RAP with VG-10 Grade bitumen up to the maximum percent of 60 only.** To derive the relationship between Marshall Quotient (MQ) and RAP present, fig-15 was plotted. The relationship between Marshall Quotient (MQ) and RAP percent in Mix is as follows.

$$\text{Marshall Quotient} = 0.0625 \text{ RAP} + 2.0459$$

3.2.6 Analysis of Air voids results

The air voids is an important factor that must be considered when designing bitumen Concrete mixture. The air voids limits are in the range 3-5 % of the total mix volume. When air voids lower than 3% bleeding of bitumen will occur specially with higher temperature. On the other hand for air voids percent greater than 5% of the mix, the pavement will be weak and unstable. For these considerations the bitumen binder is a very sensitive element in pavement design. It is observed that from Fig-4 the Air Voids value goes on slightly increased while increasing the RAP content. Analysing the data in the Fig-4, it can be seen that virgin bitumen may not perfectly blended partly with the RAP binder as its percentage increases. This may be due to the ineffective old bitumen in the aggregate pores which prevent partly the virgin bitumen from occupying deeply the aggregate pores. The results of the investigated mixes are shown in table-5 were Based on the 4 % air voids.

3.2.7 Analysis of Voids in Mineral Aggregate Results

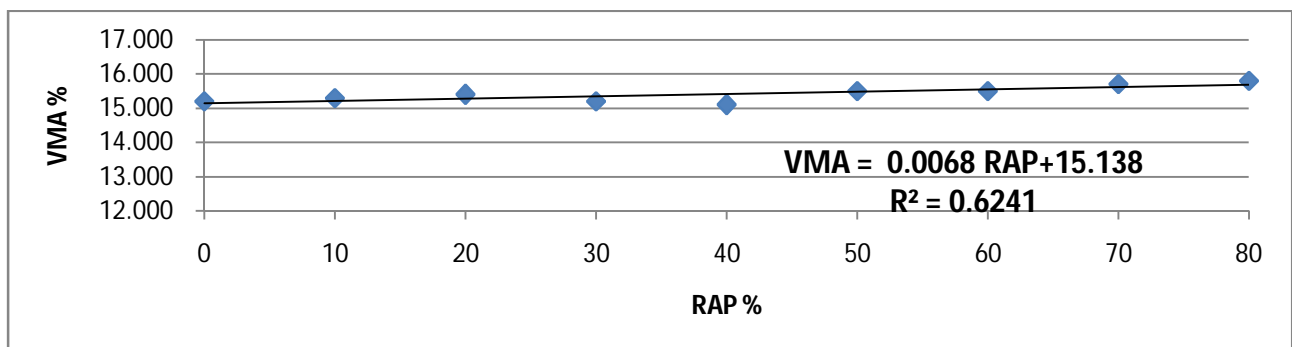


Fig-16: Relationship between % of RAP Vs VMA at OBC

VMA must be high enough to achieve an adequate bitumen film thickness, which results in a durable pavement. Bituminous mixes with below minimum VMA values will have thin film of bitumen and will provide bituminous pavement with low durability. Table (5) presents the voids in mineral aggregate for all the investigated mixes. VMA is satisfying in all mixes of Variable % of RAP from 10 to 80% and its value is more than the minimum value of 12 as specified. From the table it can be noted that, the VMA of mix is 15.3% at RAP 10% and it reaches 15.1 when RAP percentage in mix is 40% there after it is increasing to 15.8% when RAP reached in the mix to 80%..The decrease in VMA is of low rate up to RAP % of 40%, when the RAP % increases from 40% to 80% the VMA is slightly increased by about 5.4%. To derive the relationship between the voids in mineral aggregate and the RAP% in mix, figure (16) was plotted and the relationship is as follows: $VMA = 0.0068 \text{ RAP} + 15.138$

3.2.8 Analysis of Voids Filled with Bitumen Results

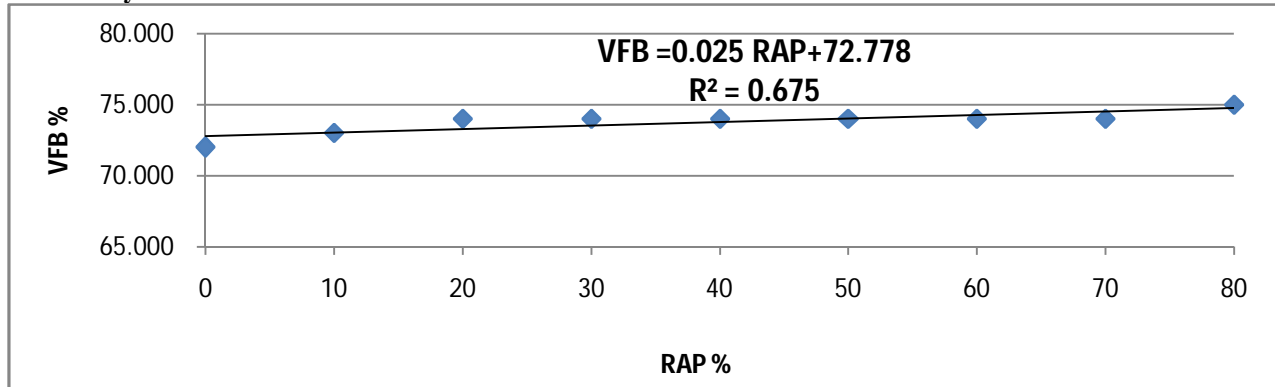


Fig-17: Relationship between % of RAP Vs VFB at OBC

VFB criteria help to avoid those mixes that would be susceptible to rutting in heavy traffic situation. The main effect of the VFB criteria is to limit maximum levels of VMA, and subsequently, maximum levels of Bitumen content. VFB is used to ensure proper asphalt film thickness in the mix, if it is too low the mix will have poor durability or if it is too high, the mix can be unstable. Table (5) presents the voids filled with the bitumen for all the investigated mixes. VFB is satisfying in all mixes of Variable % of RAP from 10 to 80% and its value is in the range of 73 to 75% at OBC. From the table it can be noted that, the VFB of mix is 74% from the mix of 20% RAP to up to 70% of RAP at OBC there after it is slightly increasing to 75% when RAP reached to 80%. No change is noted in VFB values at OBC from 20% to up to 70% of RAP with VG-10 Grade bitumen. To derive the relationship between the voids filled with bitumen and the RAP% in mix, figure (17) was plotted and the relationship is as follows: $VFB = 0.025RAP + 72.778$

3.2.9 Analysis of Retained Tensile Strength Test Results

The loss of stability test was conducted on bitumen concrete specimens prepared at the optimum bitumen content obtained in Marshall Test. This test is considered an important measure of mix durability by evaluating the resistance of the investigated mixes to moisture damage. The results of the Retained tensile strength test are presented in table (5) and it can be noted that Retained tensile strength is satisfying in all mixes of Variable % of RAP from 10 to 80% and its value is more than the minimum value of 80% as specified. It is clear that increasing of recycled material percent decreases the loss of stability of mix. It is noticed that, increasing RAP percent from 10 to 30% resulted decrease in loss of stability value from 11 % to 8% i.e. by about 27.3 % of its original value. But when the RAP percent reaches from 30% to 80%, the decreasing in loss of stability value reaches from 8% to 5%; i.e. by about 37.5%. To derive the relationship between the Retained Tensile Strength and the recycled percent, figure (18) was plotted and the relationship is as follows

Retained Tensile strength = $0.0007 RAP + 0.8825$

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

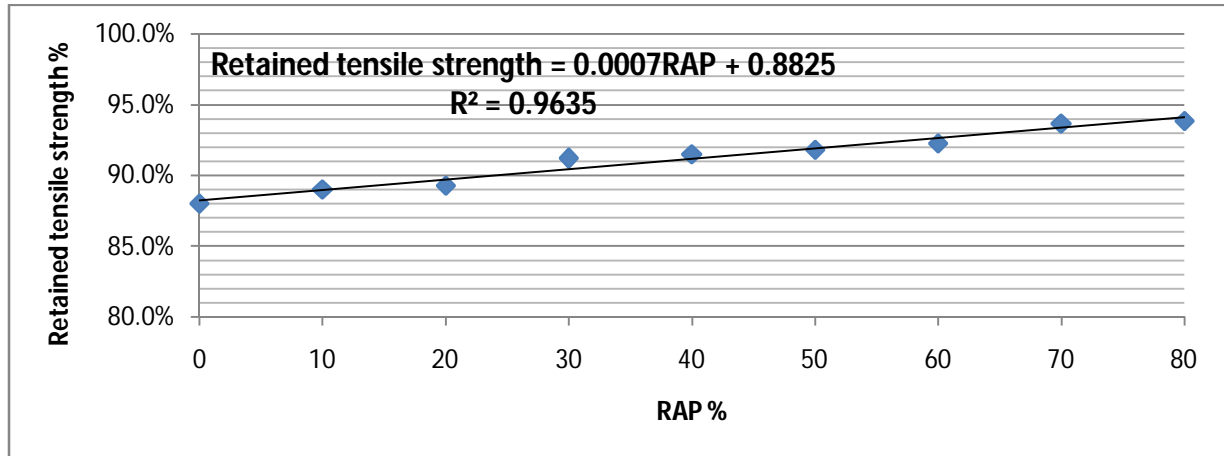


Fig-18: Relationship between % of RAP Vs Retained tensile strength at OBC

IV. COST ANALYSIS

The primary saving in central hot mix recycling comes from savings in the cost of virgin bitumen materials and aggregates. Fig-19 shows cost of control mix with VG-30 Grade bitumen and by using Variable percentages of Reclaimed bitumen pavement (RAP) 10% to 80% with VG-10 Grade bitumen per MT. Based on AP SSR Rates 2016-2017 it is obtained Average rate of Virgin aggregates is Rs 660 per MT and the rate of VG-30 Grade bitumen is Rs 32600 per MT, VG-10 Grade bitumen is Rs 31600 per MT, the cost of a 100 percent virgin mix with OBC at 4.65 percent VG-30 Grade bitumen the material cost worked out to Rs 2145 per MT of Mix. The cost of milling machine and hauls the RAP back to the Central hot mix plant, the total cost for RAP is worked out to Rs 708/MT

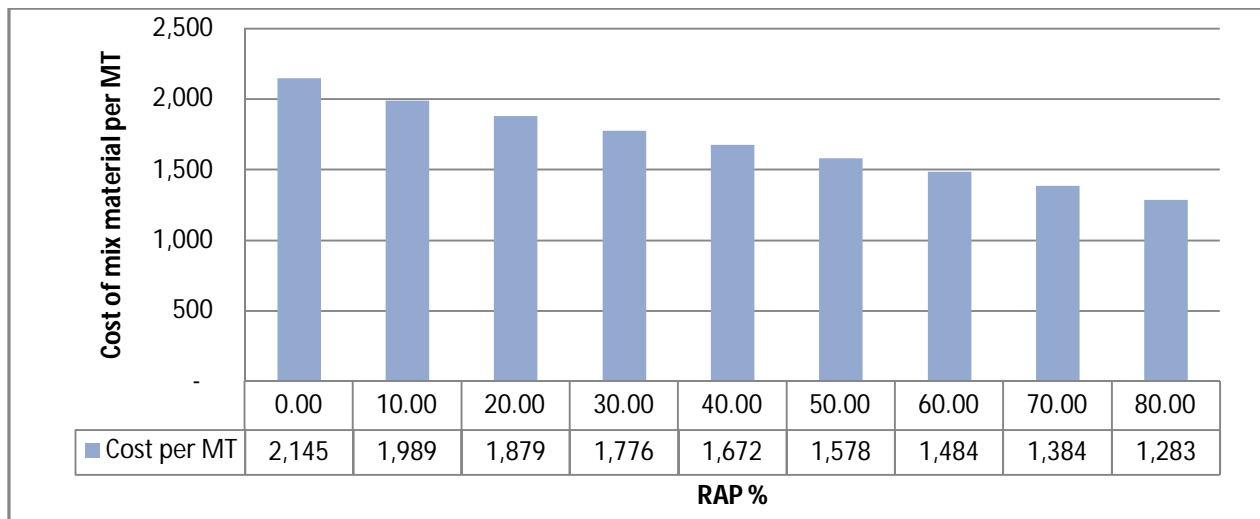


Fig-19: Comparison of Cost in RS per 1 MT of Mix materials for different percentage of RAP with VG-10 Grade bitumen

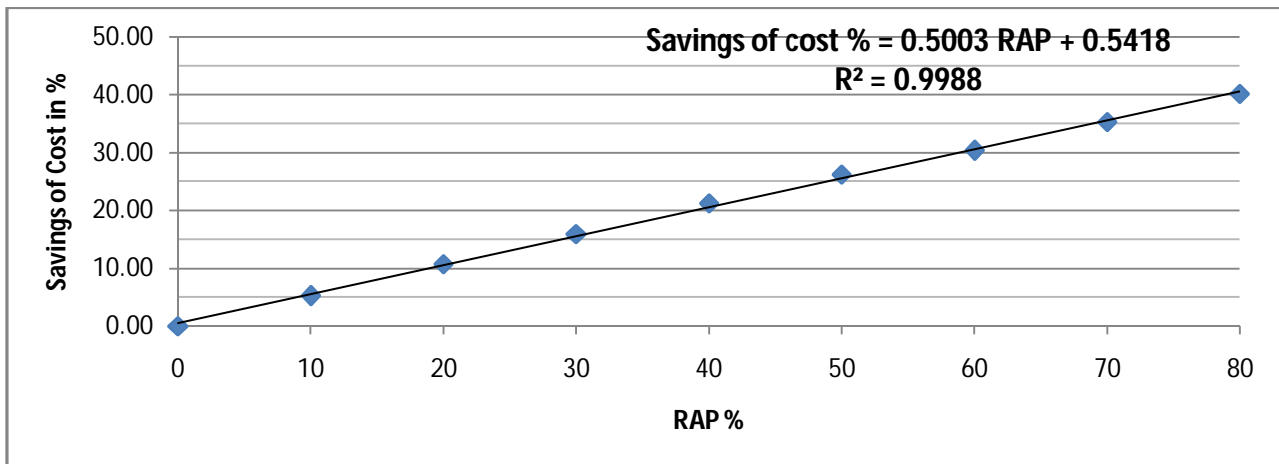


Fig-20: Savings % by using different percentages of RAP with VG-10 Grade bitumen

V. CONCLUSIONS

The following conclusions were determined based upon the experimental results obtained from a laboratory investigation of mixes of Control mix with Virgin materials (0% RAP) with VG-30 Grade bitumen and mixes with Variable % of RAP from 10 to 80% with Virgin VG-10 Grade bitumen in Bituminous Concrete Grade-I.

The results obtained showed that there were no significant difference in Volumetric Properties of mix, between Control mix with Virgin aggregate (0% RAP) with VG-30 Grade bitumen and mixes with Variable % of RAP from 10 to 80% with VG-10 Grade bitumen. But there are significant effect noted on the Marshall stability, flow of mix, Marshall Quotient and water sensitivity test values

5.1 The optimum binder content for Control Mix was at 4.65% bitumen, OBC for RAP 20% Mix is 4.700% and for RAP 60% Mix is 4.95%. It was also observed that the optimum binder content for RAP mixes was slightly increased as the RAP percentage increases. This may mainly be due to the decrease in bulk specific gravity of compacted mix as the percentage of RAP increases, and the mix gradation is very slightly finer when RAP is increased, causing a slight increase in the surface area of aggregate, thus requiring a slight increase in the binder to uniformly coat the particles.

$$\text{OBC} = 0.0052 \text{ RAP} + 4.6198$$

5.2 At optimum binder content the density of Control mix (RAP 0%) was 2.697 g/cc which is slightly higher than that of RAP 60% mix which had a density of 2.632 g/cc by 2.41%. Increasing RAP has an unpronounced effect on the mix unit weight. However, increasing RAP from zero to 80% decreases the mix density by 3.6% only,

$$\text{Mix Density} = -0.0012 \text{ RAP} + 2.7002$$

5.3 At optimum binder content the Marshall Stability value of control mix was 13 KN, found to be slightly less than RAP 30% 13.4 KN by 3.07%. Mix stability increases as the RAP percentage increases. However, the increase in stability of bitumen mix is more significant when the percent of RAP is higher than 30%. Increase of RAP from zero to 30% the mix stability increases by 3.07%, whereas from an increase of RAP from 30% to 60% the increase in the mix stability is 37.31%

$$\text{Stability} = 0.13 \text{ RAP} + 10.461$$

5.4 At optimum binder content the mix flow value of control mix was 3.75 mm, found to be less than RAP 30% 3.95 mm by 5.33%. At optimum binder content flow values of RAP mixes were more than the control mix up to a RAP percentage in the mix of 50%. The mix flow decreased as the RAP percentage increased. However, the decrease in flow of bitumen mix is more significant when the percent of RAP is higher than 50%. Increase of RAP from 50% to 80% the mix flow decreases by 32.89%. The flow values of mixes with RAP 30% to 80% are meeting the specification requirements. It is also noted that mixes of 10% and up to 20% RAP with VG-10 Grade bitumen

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

the mix falling out of specification limits, hence minimum RAP 20% should be used when VG-10 Grade bitumen used in Bituminous concrete mix.

Mix flow = -0.0153 RAP + 4.2544

- 5.5 At optimum binder content the mix Marshall Quotient of control mix was 3.47KN/mm found to be more than upto RAP 30% .It is observed that Marshall Quotient (MQ) increases with increase of RAP content. It can be also noted that, increasing RAP percent from 30% to 60% increase the Marshall Quotient (MQ) value by about 46.60%. ,when the RAP percent increases from 60% to 80% the increase in the Marshall Quotient (MQ) value from 4.97 KN/mm to 8.53 KN/mm i.e. increased by about 71.63%. It must be noted that the mix Marshall Quotient value reaches a value of 6.92 KN/mm as the RAP percent reaches to 70%. This value is out of specification limits. Mixes having Marshall Quotient (MQ) value more than 5 KN/mm are not acceptable because pavements with such mixes tend to be less durable and prone to cracking prematurely under heavy volumes of traffic. Therefore, it is recommended to use maximum RAP in BC mixes with VG-10 Grade bitumen up to 60% only. The relationship between mix Marshall Quotient (MQ) and RAP percent in mix is as follows.

Marshall Quotient = 0.0625 RAP + 2.0459

- 5.6 Specimen prepared with Control Mix (0% of RAP) sample has slightly less Air Voids value than specimen prepared with RAP mixes it indicates that Air Voids value goes on slightly increased while increasing the RAP content. It can be seen that virgin bitumen may not perfectly blended fully with the RAP binder as its percentage increases. This may be due to the ineffective old bitumen in the aggregate pores which prevent partially the virgin bitumen from occupying deeply the aggregate pores. To this effect there was no significant differences found in the test results of density and void analysis. The results of the investigated mixes are shown in table-5 were Based on the OBC at 4 % air voids.

- 5.7 At optimum binder content the VMA of control mix was 15.2 % found to be same in RAP 30%. VMA is satisfying in all mixes of Variable % of RAP from 10 to 80%. There were no significant changes noted in VMA values with variable % of RAP from 10 % to 80 %.

VMA = 0.0068 RAP + 15.138

- 5.8. It was found that VFB at optimum binder content for control mix was 73%. It was also observed that at optimum binder content for RAP mix 20% to 70% the VFB values were same and no change was noted. VFB is satisfying in all mixes of Variable % of RAP from 10 to 80%.

VFB = 0.025 RAP + 72.778

- 5.9. At optimum binder content Retained tensile strength of control mix was 88 % found to be less than RAP 30% mix value of 91.2% by 3.63%. Increasing of RAP percent decreases the loss of stability of bitumen mix and there by increases the percentage of Retained Tensile strength. it can be noted that Retained tensile strength is satisfying in all mixes of Variable % of RAP from 10 to 80% and its value is more than the minimum value of 80% as specified

% of Retained tensile strength = 0.0007 RAP + 0.8825

In this present Paper, based on the laboratory studies it was concluded that minimum 20% RAP and Maximum upto 60% RAP with VG-10 Grade bitumen satisfy the Volumetric properties of compacted mix, stability, Flow, Marshall quotient, and Retained tensile strength Hence maximum RAP of 60% can be used in the Bituminous concrete mix with VG-10 Grade Bitumen. It was also noted that the use of 60% RAP in Bituminous concrete will save 31% of initial cost of Bituminous mix materials.

VI. SCOPE FOR FURTHER STUDY

- 6.1 A large scale study can be carried out taking into considerations of several parameters like age of RAP materials, Residual binder content in RAP, availability of RAP, viscosity of binder etc and corrections also need to be established with respect to age of RAP and other factors example residual binder, percentages etc.
- 6.2 Performance based test methods can be carried out are Static or Creep, Dynamic loading and Rutting tests to provide accurate and realistic relationship under the actual traffic loading and environmental conditions.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

REFERENCES

- [1] MaulikRao, Dr.N.C.Shah, Utilisation of RAP (Reclaimed Asphalt Pavement) Material Obtained By Milling Process: With Several Options in Urban Area at Surat, Gujarat, India, Int. Journal of Engineering Research and Applications ISSN: 2248-9622, Vol.4, Issue 7 (Version 4), July 2014, pp.01-04.
- [2] Khushbu M. Vyas, Shruti B. Khara, Technical viability of using reclaimed asphalt pavement in Ahmedabad BRTScorridor for base course
- [3] Saurabh S Mahankale, Satish R Patel, Vishal A Patil, Abhishek A Dalvi, Prof. Kaustubh. U. Saraf, Use of RAP material in Bituminous Pavement
- [4] Brajesh Mishra, U.P. Cane Development Department, Lucknow, India, A Study on Use of Reclaimed Asphalt Pavement (RAP) Materials in Flexible Pavements
- [5] Jaspreet Singh, Jashanjot Singh, A.K Duggal, A REVIEW PAPER ON RECLAIMED ASPHALT PAVEMENT (RAP)
- [6] T. Anil Pradyumna, Abhishek Mittal, Dr. P.K. Jain, Characterization of Reclaimed Asphalt Pavement (RAP) for Use in Bituminous Road Construction
- [7] S.K Khanna and C.E.G. Justo, Highway Material Testing (Laboratory Manual), Nemchand and Bros, Roorkee (1997).
- [8] Mix Design Methods, Asphalt Institute, Manual Series No.2, Sixth Edition, USA.
- [9] Asphalt Hot-Mix Recycling, Asphalt Institute, Manual Series No. 20, Sixth Edition, USA.
- [10] Specification of Road & Bridge Works – Fifth Revision, Ministry of Road Transport & Highways.
- [11] Tentative Guidelines for The Design of Flexible Pavement, IRC-37:2012, Indian Road Congress, New Delhi.
- [12] Specification for Dense Grade Bituminous Mixes, IRC:111-2009 Indian Road Congress, New Delhi