International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 05 | May 2019 www.irjet.net p-ISSN: 2395-0072

Experimental Analysis of Partial Replacement of Natural Aggregates with Recycled Concrete Aggregates

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Abstract - *The road network is a mixture of paved roads, unpaved roads and highways. More than 50% of Indian road is of paved roads. However, aggregates form the major portion in the road construction. Aggregates are used in granular sub base, Wet mix macadam, wet bound macadam, dense bound macadam, bituminous concrete layer, in cement concrete and in much other road construction. Aggregate is the natural resource which is of limited quantity and is being depleting as it is used widely in all the construction works. We have to search for the alternatives to get rid of this problem. Though large amount of waste is generating from during construction and demolition of various structures.*

Key Words: *Wet Mixed Macadam, Recycle, Aggregation, Energy Conservation, Eco Friendly Mixes.*

1. INTRODUCTION*)*

The road network of India is greater than 5 million kilometers. India ranks in 3rd position in the world in terms of road network. The road network is a mixture of paved roads, unpaved roads and highways. More than 50% of Indian road is of paved roads. However, aggregates form the major portion in the road construction. Aggregates are used in granular sub base, Wet mix macadam, wet bound macadam, dense bound macadam [9][11], bituminous concrete layer, in cement concrete and in much other road construction. Aggregate is the natural resource which is of limited quantity and is being depleting as it is used widely in all the construction works. We have to search for the alternatives to get rid of this problem. Thus, large amount of waste is generating from during construction and demolition of various structures. These demolished structures are non-biodegradable and it's been a quite challenge to dispose it. Also, disposal of this concrete demolished structure is hazardous to environment. With development of Science and technology these construction and demolished structures can be converted into recycled concrete aggregate. These recycled concrete aggregates can be effectively used as an alternative source for natural aggregates which will be not only economical but also economical**.**

In the present investigation Recycled Concrete Aggregates (RCA) has been produced from the Construction and demolished aggregates. These recycled aggregates are used as a partial replacement for coarse aggregates in bituminous mixes. Investigation has been carried out by replacing 12 mm down natural aggregates and 6 mm down natural aggregates with recycled concrete aggregates. Laboratory investigation has been done to evaluate Marshall Properties and performance study for Bituminous Concrete grade II layer. 7 trial mixes were prepared in which trial 1 is done for conventional mix and remaining trials are done for 10%, 20%, 30%, 40%, and 50% replacement of natural aggregate with recycled aggregate. Investigation Recycled Concrete Aggregates (RSA) [1] in Partial Replacement for Coarse Aggregates in Bituminous Mixes.

1.1 Advantages of Using Recycled Aggregate

- Construction of pavement at low cost.
- Conservation of energy.
- Environment pollution can be reduced.
- Aggregate can be conserved.

1.2 need for the Present Study

- Environmental pollution can be reduced by the use of recycled aggregate in bituminous mix.
- Dumping is the major problem due to the demolition of buildings which can be reduced by the use of these demolished aggregates.
- Depletion of natural aggregates can be reduced with the use of recycled aggregates as a replacement of natural aggregates.
- Material cost can be saved by the replacement of natural aggregates with recycled aggregates.

1.3 Objectives of Present Study

- To characterize the use of recycled concrete aggregates for the use in bituminous concrete layer.
- To examine the effect of recycled concrete aggregate as partial replacement for natural aggregates in bituminous concrete (grade –II).
- To examine the optimum percentage replacement of recycled aggregates with natural aggregates.
- To examine the Indirect Tensile Strength and tensile strength ratios on Bituminous Concrete mix layer before and after replacement of recycled aggregates for Optimum binder content.
- To inspect the Fatigue life with and without replacement of recycled aggregates for BC layer for the obtained OBC.
- To examine the Retained Marshall Stability of the BC mix before and after replacement of recycled aggregates for Optimum Binder Content.
- To justify the amount of cost for bituminous concrete layer with and without replacement recycled aggregates.

2. LITERATURE REVIEW

In most of the studies laboratory investigation of Recycled Concrete Aggregates which are obtained from the construction and demolished waste is investigated. Many studies are conducted for hot mix asphalt for the suitability to use in the base course. Evaluation is done by replacing RCA [1] of 0%, 5%, 10%, 20% and 30% with natural aggregates. 22 mm size was the maximum aggregate size of aggregate used in the test along with 4 % mineral filler was used. Good moisture sensitivity was obtained by using RCA and Construction and Demolished waste. RCA can be used to produce an HMA [2] mix with acceptable abrasion resistance. Deformation found to increase with increase in the percentage of RCA content. Maximum of 30% of RCA can be replaced adequately. Marshall Stability, Rutting properties Fatigue and Indirect tensile strength test given satisfactory results up to 30 % replacement of RCA [4].

Replacement for dacite [12][14] including replacement of coarse aggregate, fine aggregate and filler. Marshall Properties were evaluated by preparing two series of Marshall specimens [2][15][16]. One set of specimens contained various percentage of binder content to evaluate OBC [3][4]. Another series was prepared at OBC to determine the HMA properties. The results concluded that OBC increased with the increase in the percentage of RCA. Bituminous concrete mix using RCA as fine aggregate with dacite as coarse aggregate and filler was found to be the optimal mix. The addition of RCA in fines and filler aggregate increased the Marshall Stability, fatigue and resilient modulus [5][6]

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It was advisable to use modified bitumen as binders as it seems to increase the bitumen mixtures performance values.

Many tests such as Standard proctor compaction test, permeability test, CBR [7][8] test was conducted. The test results concluded that the basic properties were within the limits. By conducting tests on GSB mix and by comparison of the test results it was concluded that Recycled aggregates can be effectively replaced with natural aggregate up to 50%.

3.1 EXPERIMENTAL INVESTIGATIONS

There are two parts included here, where first part deals with the studies carried out on the materials used such as aggregates, bitumen and recycled aggregates and the second part dealing with the studies carried out on the bituminous mixes.

3.1 Methodology

After referring the literatures, research work is recognized. Flow chart of methodology on which current investigation is worked out is shown in the Flow chart Fig.1.

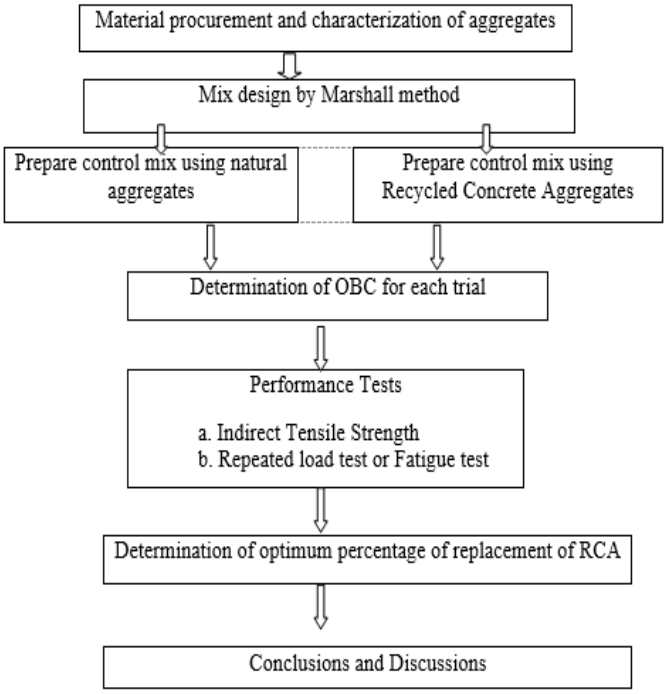

Fig - 1: Flow chart of the project

3.2 Test Conducted on Materials

3.2.1 Test on Virgin Aggregates

In pavement structure foremost part is formed by coarse aggregates and this is the key material which is used in the construction of pavement. Load stresses which occur on the pavement have to be taken by these aggregates. Hence the quality, strength of the aggregates is of major importance in the construction of pavement section. The virgin aggregates are procured from the Manjunatha Crushers near Bidadi, Bengaluru. The tests were conducted as per MORTH section 500 5th revision, confirming to the table 500-35 and results are shown in Table-1.

Table – 1: Test Results for Natural Aggregates

Property	Test	Test Result	Specification	Test Method
Cleanliness	Grain size analysis	3.2	Max 5% passing on 0.075 mm sieve	IS:2386 Part I
Particle shape	Combined Flakiness and Elongation Indices	12%	Max 35%	IS:2386 Part I
Strength	Los Angeles Abrasion Value	20.76%	Max 30%	IS:2386 Part IV
	Aggregate Impact Value	12.42%	Max 24%	IS:2386 Part IV

Water Absorption	Water Absorption	0.49%	Max 2%	IS:2386 Part III
Specific Gravity	20 mm down 12 mm down 6 mm down Stone dust	2.63 2.65 2.67 2.73	2.5-2.8	IS:2386 Part III
Stripping	Coating and Stripping of Bitumen Aggregate mix	99%	Minimum retained coating 95%	IS : 6241

3.3.2 Test on Recycled Aggregates

Construction and Demolished waste aggregates are procured from Rock Crystals, Uttanahalli, Vidyanagar near Yelahanka, Bengaluru. All the tests were conducted as per MORTH section 500, confining to the Table 500-35 and results are shown in Table 2.

Table – 2: Test Results fo Recycled Aggregates

Property	Test	Test Result	Specification	Test Method
Cleanliness	Grain size analysis	4.2	Max 5% passing on 0.075 mm sieve	IS:2386 Part I
Particle shape	Combined Flakiness and Elongation Indices	8.31 %	Max 35%	IS:2386 Part I
Strength	Los Angeles Abrasion Value	27.9%	Max 30%	IS:2386 Part IV
	Aggregate Impact Value	17.60%	Max 24%	IS:2386 Part IV
Water Absorption	Water Absorption	0.49%	Max 2%	IS:2386 Part III
Specific Gravity	20 mm down 12 mm down 6 mm down Stone dust	2.63 2.65 2.67 2.73	2.5-2.8	IS:2386 Part III
Stripping	Coating and Stripping of Bitumen Aggregate mix	99%	Minimum retained coating 95%	IS : 6241

3.3.3 Test on Binder

Selection of bitumen is the most important job in the highway construction. Bitumen of viscosity grade VG 30 is used all over the India as the temperature in India is moderate. In the present investigation VG 30 is used. Bitumen is procured from the Bharat road builders near Yelahanka, Bengaluru. All the tests were conducted on binder VG 30 as per IS 73:2013-Paving Bitumen Specification. The experimental test results are tabulated in the Table 3.

Table – 3: Test Result for Binder – VG 30

Test	Method	Result	Specification as per IRC ;SP :53,:2010
Penetration test (mm) at 25 ° C	IS 1203-1978	68	60-70
Softening point ° C, minimum	IS 1205-1978	51.2 °	47 ° minimum
Specific Gravity	IS 1202-1978	1.02	0.97-1.02
Flash Point ° C	IS 1209-1978	270	220 minimum

3.3.4 Aggregate Gradation

The distribution of particle size is termed as aggregate gradation. Various properties of bituminous mix such as density and stability are dependent on aggregates and gradation of aggregates. Maximum density is obtained by the best gradation. Distribution of particle sizes is expressed as a percentage of total weight.

Aggregates satisfying the physical requirements for bituminous concrete are used for the aggregate gradation. Sieve analysis is done to carry out the aggregate gradation. Aggregate gradation can be done by Rothfuch's method as well as trial and error method to obtain individual percentages of different aggregate sizes that can be used in the bituminous concrete mix confining to the upper and lower limits specified as per MORTH table 500:17.

About 4000 gm of aggregates were taken to conduct the sieve analysis. 20 mm down size.12 mm down size, 6 mm down size and dust of weight 2 kg, 1 kg, 500 g and 500 g are taken respectively to obtain the proper blend. The gradation was carried out for both conventional mixes and combined mix of virgin aggregates and recycled aggregates. The gradation for combined mix is carried out for various percentage replacements of recycled aggregates.

4. ANALYSIS AND DISCUSSION OF TEST RESULTS

4.1 Marshall Properties

Initially the Marshall Test specimens are prepared and are tested as discussed in the section 3.2. Three number of specimens are prepared for each bitumen content. Marshall Parameters has been calculated for each specimen. Average value of 3 specimens is tabulated. Tests have been conducted on Marshall Specimen to determine optimum binder content for conventional BC mix and mix which has been replaced with recycled aggregates. Later, Marshall Properties are evaluated for both Conventional BC mix and BC mix that has been replaced with recycled aggregates. Thereafter, Water Sensitivity Test and Repeated load test are carried out based the results that are obtained from the previous tests. OBC for each mix is calculated considering average binder content corresponding to maximum stability, mid-range of flow value and maximum density.

4.1.1 Conventional BC Mix

Optimum binder content and Marshall Properties is determined for conventional mix from Marshall test. The specimens are prepared for the obtained blend of aggregates of BC-II mix by varying bitumen content. Bitumen is varied at a interval of 0.25%. Specimens are prepared for bitumen content of 5.0%, 5.25 %, 5.5%, 5.75%, 6.0% and 6.25%. The graphs are plotted for Marshall Parameters based on the obtained test results. Table 4 shows the details of the test.

Table – 4: Marshall Properties for conversion Mix

Bitumen Content	Height of the Sample	Volume of the Sample	Weight in Air	Weight in Water	Bulk Specific Gravity G_b	Avg G_b	Theoretical Specific gravity G_t	Air voids V_v%	Volume of bitumen Vb	VMA %	VFB %	Flow mm	Marshall Stability	Corrected Marshall Stability
5.0	67.69	548.88	1244	704	2.30	2.30	2.50	7.87	11.29	19.16	58.94	2.24	15.72	13.99
	68.37	554.36	1240	702	2.30							2.16	18.21	16.2
5.25	68.30	553.82	1252	713	2.32	2.32	2.49	6.97	11.93	18.90	63.14	2.56	16.34	14.54
	69.13	560.53	1243	706	2.31							2.69	19.88	17.09
5.5	68.40	554.58	1263	724	2.34	2.33	2.48	6.00	12.59	18.59	67.72	2.9	18.56	16.51
	68.96	559.15	1261	719	2.33							2.93	20.88	18.58
5.75	68.01	551.47	1267	728	2.35	2.35	2.48	4.89	13.27	18.16	73.07	3.26	20.27	18.04
	65.70	532.69	1264	728	2.36							3.64	21.04	20.19
6.0	66.18	536.63	1266	729	2.36	2.35	2.47	4.80	13.81	18.61	74.22	3.68	18.72	17.4
	67.71	549.01	1259	721	2.34							3.82	18.13	16.13
6.25	67.22	545.04	1246	720	2.37	2.34	2.46	4.78	14.34	19.13	75.00	4.17	15.56	14.47
	66.85	542.01	1238	703	2.31							3.95	16.92	15.73

Table - 5: Marshall Properties for BC mix with Recycled Aggregate Concrete replacement

Mix Design parameters	Recycled Concrete Aggregate %						MORTH Requirements
	0	10	20	30	40	50	
Marshall Stability , KN	20.19	18.89	17.19	16.40	15.89	15.36	Min 9.0 KN
Marshall Flow ,mm	3.64	3.24	3.28	3.22	3.05	2.78	2-4
Bulk Specific gravity	2.35	2.34	2.34	2.31	2.29	2.28	
% Air voids	4.89	4.9	4.95	4.98	5.09	5.19	3-5
Voids filled with bitumen, VFB in %	73.07	72.93	72.79	72.74	72.31	72.08	65-75
Binder Content %	5.67	5.73	5.83	5.93	5.96	6.06	Min 5.4

5. COST ANALYSIS

Cost analysis is the methodological approach to evaluate the strengths and flaw of alternatives to determine the option that provides the finest approach to obtain the benefits. In this chapter cost analysis for BC mix is evaluated for both conventional mix and mix with optimized percentage of recycled concrete aggregate. Cost of the materials required for 1 km road with 2 lane of 40 mm thickness BC layer is evaluated.

From the previous chapter Marshall Properties for 40% of recycled aggregate showed better results. Hence an attempt has been made to evaluate the cost of the materials required to for the construction of 1 km road with 2 lane of 40 mm thickness. Later the cost of conventional mix and optimized mix of recycled aggregate for BC mix is compared. Table shows the cost analysis of conventional mix and optimized mix of recycled aggregate.

Table - 6: Cost Analysis of Conventional Mix

Materials	Materials Quantity %	Specific Gravity	Quantity in tons per m^3	Cost of materials per ton, Rs	Cost of mix per m^3, Rs	Cost of mix per km, Rs
Bituminous mix		2.35	2.35			
Bitumen	5.67	1.02	0.133	31777	4234.12	1185555
Aggregates			2.217			
20 mm	9	2.62	0.200	600	119.70	33517.34
12 mm	23	2.65	0.510	400	203.94	57103.61
6 mm	22	2.68	0.488	400	195.07	54620.84
Stone dust	46	2.73	1.020	400	407.88	114207.2
Total cost of mix per km, Rs					5160.73	1445004

Total cost of materials per m^3 is Rs. 5160.73

Total cost of materials for 1-km 2-lane road of 40 mm thickness is Rs.14,45,004.

Table – 7: Cost analysis of Optimized 40% RCA mix

Materials	**Materials Quantity %**	**Specific Gravity**	**Quantity in tons per m³**	**Cost of materials per ton, Rs**	**Cost of mix per m³, Rs**	**Cost of mix per km, Rs**
Bituminous mix		2.35	2.35			
Bitumen	5.96	1.02	0.133	31777	4355.99	1219678
Aggregates			2.217			
20 mm	9	2.62	0.195	600	116.79	32703.35
12 mm	23					
a)Natural aggregates	60%	2.65	0.298	400	119.39	33430.09
b)Recycled aggregates	40%	4.4	0.199	220	43.77	12257.7
6 mm	22					
a)Natural aggregates	60%	2.68	0.286	400	114.20	31976.01
b)Recycled aggregates	40%	2.45	0.190	220	41.87	11724.76
Stone dust	46	2.73	0.995	400	397.97	111433.6
Total cost of mix per km, Rs					5190.01	1453204

Total cost of materials per m^3 is Rs. 5190.01

Total cost of materials for 1-km 2-lane road of 40 mm thickness is Rs.14,53,204.

6. CONCLUSIONS

Values of Marshall Parameters for Conventional and Optimized RCA Mix are found to be satisfying the MoRTH Requirements. The effective replacement of Recycled Concrete Aggregate with natural aggregates is found to be 40%.

The ratio of Indirect Tensile Strength of RCA Mix is found to be 83.37% which is more than the required 80%.

Retained Marshall Stability Test is found to be satisfied.

From Fatigue Test it is found that Conventional BC Mix showed higher resistance for cracking than RCA Mix.

Cost Analysis of both mixes indicated almost same cost for materials.

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