Case Study on Marshall Characteristics of Bituminous Mixes with Partial Replacement of Aggregate and Filler Material by Reclaimed Asphalt Pavement and Fly Ash

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Abstract - *Bituminous surfacing on flexible pavement is one of the expensive kinds of flexible pavement layers utilized in surface course. Despite of high-cost specifications, the bituminous mixes are properly designed to satisfy the design requirement of stability and durability. The mixes contain coarse aggregate, fine aggregate, mineral filler coated with bituminous binder. The aggregate of different grades and filler material performs a very important role in bituminous mixes. The aim of the project presents the optimization of the use of RAP and fly ash as coarse aggregate and filler mineral in surface courses such as Bituminous Concrete. From the past research papers, it has been observed that there's no specific optimum. The percentage for using RAP and fly ash varies from project to project. This is because an optimum percentage of RAP depends upon many factors like RAP materials, fly ash, binder content, and availability of RAP, the viscosity of binder, and the extent of deterioration. During the study, various properties like Marshall Stability, Flow value, and Density of bituminous mixes using RAP and fly ash with varying percentage of 20% to 40% were compared to that of the fresh bituminous mix. One virgin bituminous mix and four different percentages of RAP were selected and samples were prepared at four different percentages of bitumen at each bitumen percentage 3 samples were prepared and tested. Test results showed that a blend prepared with 40% RAP and fly ash gave nearly the identical physical and strength parameters as a virgin bituminous mix.*

Key Words: Reclaimed asphalt pavement, Fly ash, Marshall Mix design, Optimum binder content, Aggregate.

1. INTRODUCTION

The traditional practice of laying bituminous surfacing in flexible pavement requires massive energy for the assembly of bituminous binder, laying of aggregate, and subsequent bituminous mix production at Hot Mix Plant(HMP), which releases an immense amount of greenhouse gases and harmful pollutants. For every 10^{o} C increase in bituminous mix production temperature, the amounts of eviction of harmful pollutants become doubled. For an instance, around 6 liters of fuel is employed to heat up and dry one ton of aggregates, which may grow massively to vast quantities in view of plenty of aggregates that are utilized for the construction of road per annum. Also, there's a vast scantiness of good-quality material, which results in the hauling of material from long distances. Using diesel to drive the truck to haul the material from long distances also leads to the emission of pollutants, which account for 30 percent of global air pollution and greenhouse gases, 22 percent of global energy consumption, and 25 percent of fuel combustion. The bituminous mixture can remove these inadequacies by the evaluation and usage of modified bitumen. But the process involves very expensive due to the cost of equipment, the cost of modified bitumen polymer, and trained experts.

Therefore, an attempt has been made to reduce these expenses consumption of fuel and aggregates by adopting alternative technologies which can be achieved by replacing filler and aggregate with RAP and Fly ash waste. Recycling of waste material for pavements, particularly RAP (from HMA) and fly ash recycling is one such technology that may be adopted for Indian conditions (Ministry of Finance, Govt. of India,200),(Dipu Sttradhar, et, al, 2015). The most frequent waste material is Reclaimed pavement (RAP) and Fly ash. Reclaimed Asphalt Pavement (RAP) and Fly ash is such sort of waste material, which are obtained in huge amount from distressed pavement and waste from coal thermal power plant

Figure-1: Dumped RAP material

Figure-2: Fly ash

1.1. LITERATURE REVIEW

G. M. Harun-Or-Rashid, Mohd. Abdus Sobhan, Nafiur Rahman, Bulbul Ahmed. Marshall Characteristics of Bituminous Mixes Using Reclaimed Asphalt Pavement. The bituminous mixture of RAP material and 1% additional bitumen content provide maximum stability that satisfies Marshall Design standards. On the consideration of test results and aggregate properties, waste aggregate collected from RAP is suitable for a bituminous mix when it is combined with fresh aggregate at 40%.

Ahmed Ebrahim Abu El-Maaty, Abdulla Ebrahim El-Moher. Evaluation of Hot Asphalt Mixtures Containing Reclaimed Asphalt Pavements. The laboratory investigations of the study demonstrated that when the mix is properly designed, new conventional HMA mixtures, will provide better performance compared to those by 50%-100% of RAP replacement mix, also 45-64% of material cost is reduced by the cost analysis.

T.Anil Pradyumna, Abhishek Mittal Dr.P.K.Jain. Characterization of Reclaimed Asphalt Pavement (RAP) for Use in Bituminous Road Construction. Based on laboratory tests on fresh mixes and partially replaced mixes containing 20% RAP, it is concluded that the addition of RAP improved all properties of the bituminous mix. It shows that under similar conditions, the mixture containing 20% RAP performs better than the fresh mixture.

Ahmed Mohamady, Ashraf Elshahat, Mahmoud Fathy Abd-Elmaksoud, Ph.D.; ENG Mohamed Hoseny Abdallah. Effect of Using Reclaimed Asphalt Pavement on Asphalt Mix Performance. As a result of these analyses a conclusion is drawn that 30% of RAP ensure superior field performance after construction, also recommended to conduct more experiments by considering more cases with different mixing components and at different conditions.

Gnanamurthy P B, Suthan S S, Comparative Study on Design of Bituminous Mixes Containing Recycled Asphalt Pavement Materials. In laboratory it is observed that bituminous mixes containing RAP material perform the same or even better than the conventional mix and stability value almost increase linearly with increase in RAP

1.2. OBJECTIVE

1. The main objective of the research is to assess the impact of replacing RAP and Fly ash with fresh aggregate partially.
2. To characterize the untreated RAP and Fly ash which is partially replaced with Fresh aggregate by the addition of bitumen content at the rate of 0.5% and to investigate its stability and suitability through Marshall mix criteria.
3. To derive optimum binder content at different percentages of RAP and Fly ash with fresh aggregate.
4. To carry a comparative study on test results of a bituminous mix of RAP and fly ash at different percentages with fresh aggregate.
5. To study feasible and effectual use of RAP and fly ash as a renewable resource.

1.3. SCOPE

- The merits associated with pavement recycling are the conversation of energy, conservation of aggregate, and binder.
- Optimizing the use of available waste recourses.
- Reducing environmental impact by safeguarding it.
- Increase in restrictions on the dumping of reusable materials.
- Reduction in material cost, energy cost, and total construction cost.

2. MATERIALS AND METHODOLOGY

1. AGGREGATES

- **Fresh aggregates**

Coarse aggregates 20 mm down size (20mm pass) as well as fine aggregate (M- sand) (pass 4.75 mm) were used from locally available source.

- **RAP**

For this study, coarse aggregates of 20mm down size (20mm pass) were used along with fine aggregate (pass 4.75mm) from RAP. RAP material was collected from Davangere to Chitradurga state highway SH-2. where the old road is being reconstructed. RAP here comprise of mix of old surface course and bituminous base course. The removal of RAP was done using excavator. RAP being mix of base and old surface layer, the binder content found in RAP was 4.5 % and the original percentage at the time of construction was 5.5%. This RAP material is used with a Fresh aggregate as partial replacement.

Table -1: PHYSICAL PROPERTIES OF AGGREGATES

SI NO	Test	MORTH Specification	Fresh aggregate	RAP
1	Flakiness and elongation index	Max 30%	29.845%	9.92%
2	Aggregate impact test	Max 27%	18.05%	20.12 %
3	Crushing test	Max 30%	20.17%	7.05%
4	Water absorption	Max 2%	0.19%	0.22%

5	Specific gravity 20mm down 4.75mm down	3.0 2.67	2.9 2.64	2.83 2.36

Table-2: MORTH Specifications for gradation of BC layer.

IS sieve(mm)	Grade -2	Upper limit	Lower limit	Mid grade	Obtained grade
19	100	100	100	100	100
13.2	79-100	100	79	89.5	86
9.5	70-88	88	70	79	77
4.75	53-71	71	53	62	65
2.36	42-58	58	42	50	49
1.18	34-48	48	34	41	38
0.6	26-38	38	26	32	30
0.3	18-28	28	18	23	22
0.15	12-20	20	12	16	15
0.075	4-10	10	4	7	4

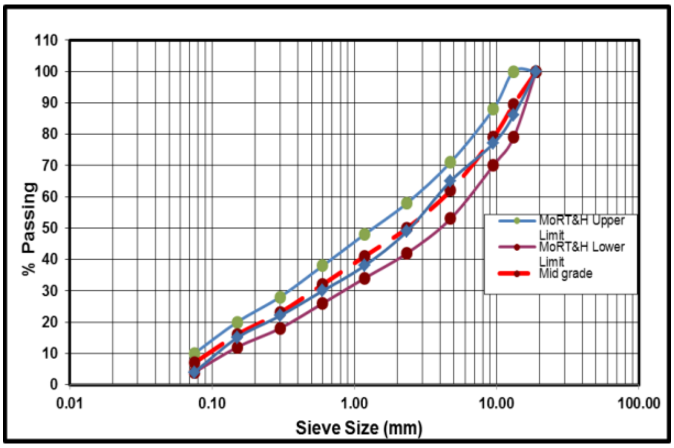

Figure-3: The grading curve of the aggregates used is shown in Graph

2. FILLER

Rock dust, hydrated lime, cement or fly ash are finely divided mineral matter which shall make up the filler.

- **Stone dust**

For this study stone dust from the locally available source was used as filler.

- **Fly ash**

For this study waste fly, ash of class c type from the coal plant was collected and used as filler as a partial replacement with stone dust which is available locally.

Table-3: CHEMICAL COMPOSITION OF FLYASH

Chemical component	Class C
SiO_2	40%
Al_2O_3	16%
Fe_2O_3	6%
CaO	24%
MgO	2%
SO_2	3%
LOI	6%

Table-4: PHYSICAL PROPERTIES OF FILLER

Tests	Stone dust	Fly ash
Specific gravity	2.73	2.57
Finess	2.3%	4%

Table-5 GRADING REQUIREMENTS FOR MINERAL FILLER

IS Sieve (mm)	Cumulative per cent passing by weight of total aggregate	Obtained grade
0.6	100	100
0.3	95 – 100	97
0.075	85 – 100	85

3. BITUMEN OF GRADE VG-30

Bituminous binder used in pavement construction works includes both bitumen and tar. Bitumen is a petroleum product obtained by the distillation of petroleum crude. Coal tar is produced from coal or wood both have similar appearance, black in colour through they have different characteristics. Both of this can be used as pavement works.

Table-6: GRADING OF BITUMEN

Tests	VG-30
Softening point	49
Ductility	56
Specific gravity	0.98
Penetration test	65

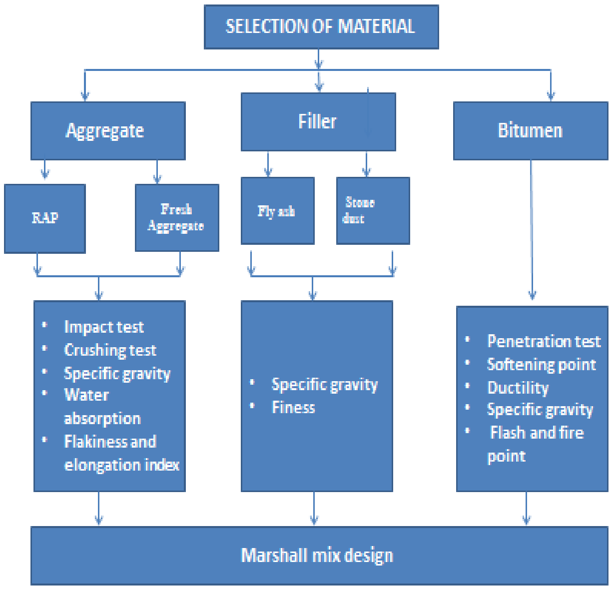

Figure-4:Methodology

3. MARSHALL MIX DESIGN

The major steps involved in the material mix design procedure are material mix design and its assessment. The reprocessed bituminous mixture must be designed suitably to get superior performance..

Figure-5: Weighing of aggregate

Figure-6: Heating of Aggregate & RAP mix

Figure-7: Mixing with Binder

Figure-8: Compacting with 75 Blows on each side

Figure-9: Compacted moulds

Figure-10: Weight in water

Figure-11: Testing on Marshall Test machine

4. RESULTS AND ANALYSIS

The major aim of a material assessment is to find the fundamental engineering properties of constituent material to attain an optimum blend of material so that to meet the mix requirements, also to find out the percentage and type of bituminous binder by the compacted specimen. The test conducted on the specimen and its results is analyzed here. The main results are stability and flow value.

Table-7:100%FA+0%(RAP &FLY ASH)

Percentage	100%			0%	
Mix A	Fresh aggregate with stone dust			RAP with fly ash	
Binder content(%)	4.5	5	5.5	6	6.5
Height (m)	6.4	6.45	6.4	6.5	6.4
Diameter (mm)	101	101	101	101	101
Weight in air (g)	1253.1	1258.9	1265.1	1270.8	1272.85
Weight in water (g)	683.6	697.75	708.5	714.5	711.7
SSD (g)	1267.2	1272.1	1277	1280.35	1288.7
Bulk volume(cm^3)	512.758	516.764	512.758	520.77	512.758
Bulk density (Gmb)	2.14722	2.19187	2.22542	2.24591	2.20602
Theoretical bulk density (Gmm)	2.42185	2.39316	2.36514	2.33777	2.31102
Vv (%)	11.3397	8.41103	5.90737	3.92939	4.54352
Vb (%)	10.5313	11.6114	12.8716	13.8257	15.2118
VMA(%)	21.871	20.0224	18.7789	17.7551	19.7554
VFB(%)	48.1666	57.9927	68.6077	77.9462	77.05656
Stability (kN)	16.835	21.5	24.435	22.045	17.99
Flow value(mm)	1.94	2.53	3.28	3.88	4.57

Table-8: Table-7:80%FA+20%(RAP &FLY ASH)

Percentage	80%			20%	
Mix B	Fresh aggregate with stone dust			RAP with fly ash	
Binder content(%)	4.5	5	5.5	6	6.5
Height (m)	6.5	6.5	6.5	6.5	6.5
Diameter (mm)	101	101	101	101	101
Weight in air (g)	1248.23	1255.33	1262.2667	1267.96	1274.26
Weight in water (g)	676.8	692.933	706.767	713.533	714.29
SSD (g)	1253.6	1259.26	1268.067	1274.9	1286.5
Bulk volume(cm^3)	520.77	523.441	523.441	520.77	520.77
Bulk density(Gmb)	2.16463	2.21706	2.24891	2.2588	2.229
Theoretical bulk density (Gmm)	2.42185	2.39316	2.36514	2.3377	2.3110
Vv (%)	10.6208	7.35851	4.91415	3.37788	3.53581
Vb (%)	10.3709	11.465	12.6095	13.8279	14.9802
VMA(%)	20.9917	18.8235	17.5237	17.2057	18.516
VFB(%)	49.6058	61.1486	72.0398	80.5048	80.9319
Stability (kN)	16.1	18.433	23.2333	20.2	17.1
Flow value(mm)	2.0067	2.82	3.51667	4.4233	5.17667

Table-9: Table-7:60%FA+40%(RAP &FLY ASH)

Percentage	60%			40%	
Mix C	Fresh aggregate with stone dust			RAP with fly ash	
Binder content(%)	4.5	5	5.5	6	6.5
Height (m)	6.4	6.6	6.4	6.5	6.4
Diameter (mm)	101	101	101	101	101
Weight in air (g)	1252.2	1257.7667	1263.8333	1270.633	1274.5
Weight in water (g)	691	704.733	715.067	721.933	716.86
SSD (g)	1263.033	1268.033	1273.6	1280.333	1284
Bulk volume(cm^3)	515.429	528.782	512.758	520.77	512.75
Bulk density (Gmb)	2.18906	2.233	2.26284	2.27075	2.2476
Theoretical bulk density (Gmm)	2.42185	2.39316	2.36514	2.33777	2.3110
Vv (%)	9.361237	6.69238	4.32525	2.86676	2.7442
Vb (%)	10.4773	11.3468	12.8716	13.8257	15.211
VMA(%)	20.0896	18.0392	17.1968	16.6927	17.956
VFB(%)	52.1664	63.0877	74.912	82.8369	85.114
Stability (kN)	15.0667	17.1883	21.1417	18.7333	16.893
Flow value(mm)	2.0067	2.82	3.75667	4.80333	5.1766

Table-10: Table-7:50%FA+50%(RAP &FLY ASH)

Percentage	50%			50%	
Mix D	Fresh aggregate with stone dust			RAP with fly ash	
Binder content (%)	4.5	5	5.5	6	6.5
Height (m)	6.4	6.5	6.4	6.5	6.4
Diameter (mm)	101	101	101	101	101
Weight in air (g)	1252.9	1259.2	1264.3	1270	1275
Weight in water (g)	698.7	709.8	719.4	724.9	725
SSD (g)	1264.2	1268.2	1273.2	1279.9	1289
Bulk volume(cm^3)	512.758	520.77	512.758	520.77	512.758
Bulk density (Gmb)	2.21556	2.25501	2.28295	2.28829	2.26064
Theoretical bulk density (Gmm)	2.42185	2.39316	2.36514	2.33777	2.31102
Vv (%)	8.51798	5.7726	3.47494	2.11659	2.18021
Vb (%)	10.5313	11.5214	12.8716	13.8257	15.2118
VMA(%)	19.0493	17.294	16.3465	15.9423	17.3921
VFB(%)	55.2845	66.6208	78.742	86.7234	87.4643
Stability (kN)	14.2	16.2	17.5	15.1	13.2
Flow value(mm)	2.92	3.89	4.8	5.87	6.9

Table-11:MORTH SPECIFICATION AND REQUIREMENTS FOR BITUMINOUS CONCRETE PAVEMENT LAYERS (GRADING-2)

	MORTH SPECIFICATION	% RAP			
		0%	20%	40%	50%
OBC (%)	5-7	5.75	5.7	5.63	5.5
Maximum stability(KN at 60 ^{0}C)	9.0	24.435	23.233	21.141	17.5
Flow value (mm)	2-4	3.28	3.51	3.75	4.8
Compaction level (Number of blows)	75 blows on each of the two faces of the specimen	75 blows on each of the two faces of the specimen			
Per cent air void	3-6	5.9	4.9	4.3	3.4
Minimum Per cent voids in mineral aggregate (19mm down size) (VMA)	12	18.77	17.52	17.19	16.34
Percent voids filled with bitumen (VFB)	65-75	68.60	72.03	74.91	78.74

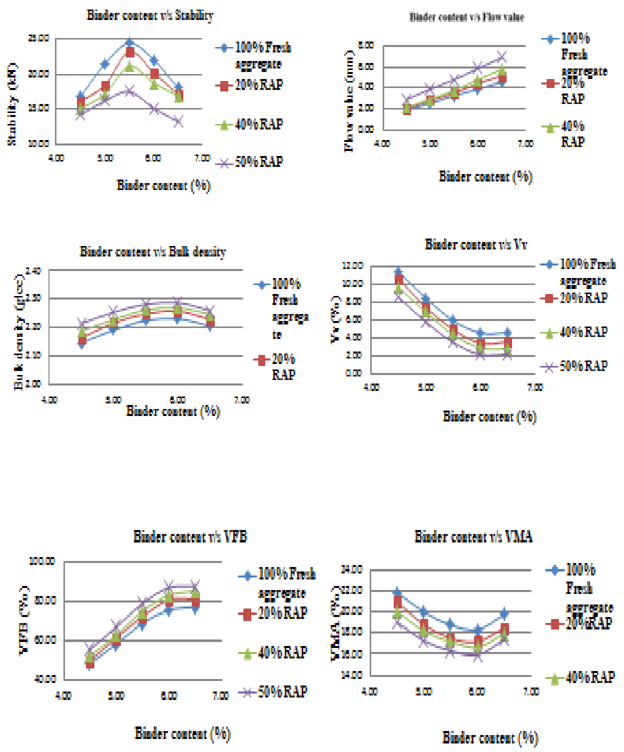

Figure-12: Comparative graphs showing the variation in Marshall Properties with variation of % of Binder content

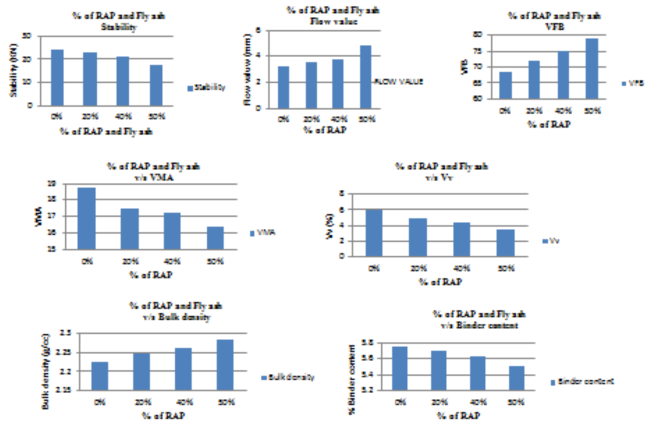

Figure-13: Comparative graphs showing the variation in Marshall Properties with increase in % of RAP and Fly ash

5. CONCLUSIONS

Following conclusions are drawn by comparing obtained experimental results with the specifications that are specified in MORTH (2012) table 500-11 "SPECIFICATIONS FOR ROAD AND BRIDGE JOBS", 5th revision.

- RAP and fly ash (along with fresh aggregate) with additional bitumen content in the bituminous mix gives the maximum stability and satisfies the Marshall Design criteria.
- On account of properties of aggregate and mineral filler, partially replaced RAP aggregate and fly ash with fresh material are well suited up to 40% for a bituminous mix.
- The optimum binder content for RAP and fly ash was found at 5.63% (at 40% replacement) which is lower than optimum binder content. Obtained results clearly show that as decreases in an optimum binder with an increase in the percentage of RAP.
- Although the stability of compacted specimens decreases with increase RAP and fly ash as aggregate and mineral aggregate in bitumen mix with fresh aggregates, which satisfy the Marshall mix criteria.
- Therefore, in the area especially where RAP and fly ash are often disposed of, they can be used as a substitution for aggregates and mineral filler to assure global sustainability. Hence, the use of recyclable material help in reducing carbon footprint, depletion of fossil fuel conserving nonrenewable and also reduce the price of HMA and enhance its performance particularly in the place where aggregate is in short of supply or where it should be hauled from long-distance tom remote location is long.

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