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RESEARCH ARTICLE

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USE OF WASTE ENGINE OIL AS A REJUVENATING AGENT IN RECLAIMED ASPHALT BINDER TO IMPROVE PAVEMENT RECYCLABILITY

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ABSTRACT

Pavement construction needs a high amount of bitumen, which is a non-renewable material. The usage of Reclaimed Asphalt Pavement (RAP) can be considered as a Sustainable option, which offers economic benefits and conservation of natural resources. The high stiffness of RAP which causes cracking has propelled the use of Rejuvenator .The exploration of Waste Engine Oil (WEO) as the rejuvenator has gained interest and research is being carried out on it in many international laboratories. Huge amount of waste product from the automotive industry can impose detrimental impact if not disposed properly. The effects of addition of waste engine oil to the binder and mixture performance were investigated. The aim of this project is to study the feasibility of using waste engine oil as a rejuvenating agent to improve the recyclability of pavements containing Reclaimed Asphalt Binder (RAB). It is observed that these tests claim that waste engine oil can be used as a rejuvenating agent to restore the properties of RAB. In this study, the maximum utilization of RAB and WEO was considered through a rigorous experimental investigation on various combinations of both components.

Keywords: Reclaimed Asphalt Pavement, Reclaimed Asphalt Binder, Recyclability, Rejuvenator, Waste Engine Oil

I. INTRODUCTION

Due to increase in road network, demand for bitumen is increasing day by day. As bitumen is extracted from petroleum products which are non-renewable, existing deposits of petroleum products are depleting. Thus reuse of bitumen has become the necessity. Bitumen is a byproduct obtained from petroleum distillation. Bitumen is primarily used in road making industry for construction and maintenance purpose.It decreases the consumption of virgin binder. Asphalt industries are compelled to find another alternative source to construct economical and sustainable roads without compromising on their quality due to fast depletion of natural material sources. Due to less waste produced the use of reclaimed asphalt pavement (RAP) is seen as a viable option.

1.1 Reclaimed Asphalt Pavement (RAP): Recycled Asphalt Pavement refers to reclaimed and reprocessed pavement material containing asphalt binder and aggregates. There are mainly two methods of obtaining RAP that are Milling and Full Depth Removal. Milling involves machines that grind, pick up, and load RAP into a truck.In Full-depth Removal the pavement structure is broken in to slabs and then transported to a location where they are crushed. Recycling of asphalt pavements is one of the effective and proven rehabilitation processes. Aging and reduction in the performance of binder will occur afteryears of exposure toclimate change and traffic loads.Aging of Pavement makes the binder stiffer and more Brittle than virgin binder which makes the roads more susceptible to cracking paved with unmodified reclaimed asphalt pavement (RAP).

1.2 Rejuvenating agent: In order to improve the properties of aged binder some chemical additives, known as recycling agents are merge into the asphalt mixture. Recycling Agents are usually made out of a petroleum product composed of either highly polar or aromatic oils The purpose of using recycling agents is to restore asphalt consistency. Addition of rejuvenating agent to RAB helps in restoring the binder properties. Waste engine oil is one of the materials which can be used as rejuvenating agent. The production of waste automotive engine oil (WO) is estimated at 24 million tons each year throughout the world, posing a significant treatment and disposal problem for modern society.One gallon of used oil can create an eight-acre slick on surface water, threatening fish, waterfowl and other aquatic life. The preferred disposal option in most countries is incineration and combustion for energy recovery, though vacuum distillation and hydro-treatment have been researched to recycle this waste. The cost associated with Regeneration of waste engine oil is also known to be high. Thus,considering the above shortcomings related to WEO, the most practical and eco-friendly way is to adopt it as a construction material such as in pavement construction.

II. Need of Study: In present study Disposal of waste engine oil is a major problem. Waste engine oil is a non-biodegradable. Burning of these waste engine oil causes high environmental pollution. India is highest producer of fly ash in the present world which is the waste material. Use of waste engine oil in Bituminous Road construction really impressive job, this material dumped into land leads to wastage ofland. In this study, use of waste engine oil as a rejuvenating agent in reclaimed asphalt pavement to improve properties of aged asphalt binder and to find its utility in bituminous mixes for road construction. Improvement in properties of bituminous mix provides the solution for disposal in a useful way.Recycling old asphalt reduces the amount of new petroleum needed and may reduce dependence on foreign petroleum.

2.1Objective:

Study has been carried out to satisfied following objectives:

1. To study the feasibility of using waste engine oil as rejuvenating agent in RAB for Indian roads.
2. To study the different proportions of Virgin Bitumen& RAB.
3. To carry out bituminous mix design for Virgin Bitumen (VG-30).
4. To compare the mix design values of VG-30 and RAB plus VG-30 & WEO.

II. Methodology

1] In this study bituminousmix has been designed for Bituminous Concrete (Grade -2). The Aggregate used in the study is crushed Aggregate from Quarry Site located at Sidhivadi (Pune,MH) and VG-30 grade of Bitumen used as binder obtained from BPCL.

2] First, Laboratory testing has been carried out to find the physical properties of Aggregate by conducting tests like Grain size analysis, Aggregate Impact value, Abrasion Test, Crushing value test, Flakiness and Elongation Index (combined), Water absorption, Specific Gravity etc.

3] Similarly, The Bitumen test for VG-30 has been done including Penetration test , Softening Point test, Ductility test ,Viscosity, Specific Gravity etc. which satisfied the requirement of IS:73-2006.

4] The above tests were conducted on a] virgin bitumen b]RAB c] Different Proportions of Virgin binder plus RAB by adding different percentages of Waste Engine Oil (WEO)

5] Marshall Mix Design was performed to compare different properties of the samples.

III. Test Conducted On Materials

3.1 Aggregate

Table 1. Properties of Aggregate

Test	Result	MORTH Specification
Specific gravity Coarse aggregate Fine aggregate	 2.89 2.87	 2.5-3.0 2.5-3.0
Water Absorption Test Coarse Aggregate Fine Aggregate	 1.01% 1.36%	Max 2%
Impact Value Test	11.84	Max 24%
Los Angeles abrasion value Test	16.20	Max 30%
Crushing value Test	10.45	Max 45%
Stripping value Test	99%	Min 95%
Flakiness and Elongation Index Test(combined)	21.84%	Max 30%

3.2 Bitumen:

Table 2: Properties of VG-30

Test	Result	Specification IS:73-2006	BIS code for Testing
Penetration Test	65mm	50-70	IS :1203
Ductility Test	70cm	Min 40	IS :1208
Softening Point Test	52.4ºC	Min 47ºC	IS :1205
Viscosity Test	2711 Poise	Min 2400 Poise	IS :1206 (Part 2)
Specific gravity	1.03	Min 0.99	IS :1202

Table 3: Properties of VG 30+RAB+WEO

Test	Penetration Test (mm)			Ductility Test (cm)			Softening point Test (ºC)			Viscosity Test (sec)		
Oil%/Proportions	30-70	40-60	50-50	30-70	40-60	50-50	30-70	40-60	50-50	30-70	40-60	50-50
5%	56.3	42.2	33.5	39.5	60.1	22.1	52.5	51.2	53.1	4.2	4.8	6.1
10%	62.9	50.4	45.8	50.8	63.6	37.5	51.3	50.4	52.3	6.3	8.1	10.6
15%	64.1	55.6	53.8	64.6	67.9	52	48	49	51.8	9.4	12.2	14.6
20%	76	67.8	64.3	75	75	70	48	48.2	50.2	15.1	16	18.3

3.3 Marshall Mix Design: The mix design should aim at an economical blends, with proper gradation of aggregate and adequate proportion of bitumen so as to fulfil the desired properties of the mix bituminous concrete is the one of the highest and costliest types of flexible pavement layer used in surface course the desirable properties of a good bituminous mix are stability, flexibility, skid resistance, durability, workability.

Marshall Stability test carried out to find stability, flow value, air voids, voids fill with bitumen, density. Finally consist of finding Optimum Binder Content (OBC).

3.4 Graduation Requirement of Aggregate: Grading of aggregate has been carried out before mix design. For this purpose sieve analysis of aggregate has been done for Grade 2. Grading requirement of BC for this study should satisfy the MORTH section 509 Table 500-18 for Grade 2.The aggregate has been sieved and final blend of aggregate has to be obtained by trials.Grading requirement of aggregate shown in Table below.

Grading	1	2
Nominal aggregate size	19 mm	13 mm
Layer Thickness	50-65 mm	30-45 mm
IS Sieve(mm)	Cumulative aggregate passing %	Cumulative aggregate passing %
45	-	-
37.5	-	-
26.5	100	-
19	79-100	-
13.2	59-79	100
9.5	52-72	90-100
4.75	35-55	35-51
2.36	28-44	24-39
1.18	20-34	15-30
0.6	15-27	-
0.3	10-20	9-19
0.15	5-13	-
0.075	2-8	3-8
Bitumen content % by mass of total mix	5.00-6.00	5.00-6.00
Bitumen grade (Penetration.)	65	65

3.5 Marshall Stability Test: This test has been carried out to determine the Optimum Binder content for BC mixes. The properties incorporate with the test are stability, flow value, Bulk specific gravity, Air voids, Voids filled with bitumen and Voids in mineral aggregate. Marshall Requirement of bituminous mixes shown in Table 4.The Voids in mineral aggregate must satisfied the requirement as shown in Table 5.

3.5.1 Bulk Density of mix: It is the ratio of weight in air of sample to difference in weight of sample in air and water and is denoted by G_m.

3.5.2 Air Voids: It is the total volume of the small pockets of air between coated aggregate particles throughout a compacted paving mixture, expressed as percentage of the total volume of the compacted paving mixture.

$V_v = \underline{G_t - G_m} \times 100 G_t$

Where, Vv = Air voids (%)

Gt = Theoretical specific gravity

G_m = Bulk density of mix (g/cc)

3.5.3 Voids in Mineral Aggregate: It is the volume of inter granular void space between the uncoated aggregate particles of a compacted paving mixture that includes the air voids and effective bitumen content. VMA is expressed as percentage of the total volume of the compacted paving mixture.

$VMA = V_v + V_b$

Where V_v= Air voids (%)

V_b= Volume of bitumen

3.5.4 Voids Filled with Bitumen

It is the percentage of VMA that is occupied by the effective bitumen.

$$VFB = \frac{V_b}{VMA} \times 100$$

Where, Vb= Volume of bitumen

VMA= Voids in mineral aggregate.

3.5.5 Marshall Requirements of Bituminous Concrete:

Table 4

Properties	Requirement as per MORTH
Marshall Stability (Kg)	900
Flow (mm)	2-4
Compaction Level (Number of Blows)	75 blows on both side of the specimen
Percent Air Voids	3-6 %
Percent Voids filled with Bitumen (VMB)	65-75 %
Percent Voids in Mineral Aggregate (VMA)	Minimum 16%

Table 5: Requirement of Voids in Mineral Aggregate

Nominal Maximum Particle Size(mm)	Minimum VMA% Air Voids Related to Design Air Voids (%)		
	3.0	4.0	5.0
9.5	14.0	15.0	16.0
12.5	13.0	14.0	15.0
19.0	12.0	13.0	14.0
25.0	11.0	12.0	13.0
37.5	10.0	11.0	12.0

Source: MORTH section 500 clause 509, Table 500-12

By performing different trials following proportion was selected for the aggregate.

Aggregate Size	Blending Percentage Passing
22mm	12%
14mm	31%
6.3mm	55%
Filler	2%

Three specimens were prepared at each of binder content of 4.75%, 5.25%, 5.75%, 6.25%, and 6.75% by weight of mix.

From the volumetric properties of the mix at eachbitumen content plot the following graphs:

1] Binder content versus corrected Marshall Stability.

2] Binder content versus Flow Value.

3] Binder content versus Air void (V_v) in the Total Mix.

4] Binder content versus voids filled with Bitumen (VFB).

5] Binder content versus Unit weight or Bulk Density (G_m).

Optimum Binder Content for mix is determined by average of the following three parameters:

1] Binder content corresponding to Maximum Stability.

2] Binder content corresponding to maximum Unit weight.

3] Binder content corresponding to 4.0% Air voids (V_v) in the total mix.

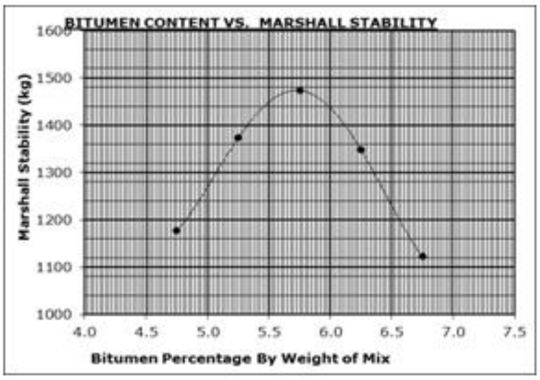
3.5.7 Bitumen Content

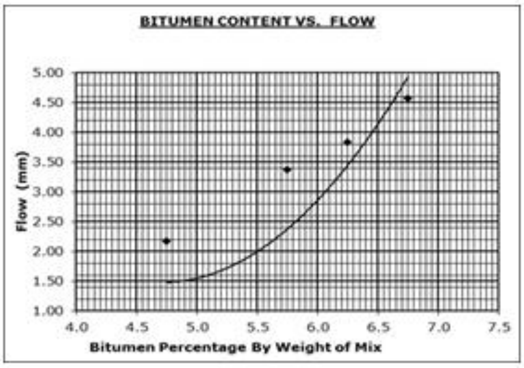
Sr. No.	% Of Bitumen Mix	Weight in air (gms)	Weight in Water (gms)	SSD Weight(gms)	Volume (Cm^3)	Unit Weight (gm/cc)	Gmm	Vv	VMA	VFB	Stability (Kg)	Flow (mm)
1	4.75	1239.5	741	1239.5	498.5	2.486	2.690	7.57	16.67	54.60	1007	2.1
2	4.75	1236.5	742	1236.5	494.5	2.501	2.690	7.04	16.20	56.50	944	2.3
3	4.75	1231	739	1231.5	492.5	2.499	2.690	7.08	16.23	56.36	1101	2.1
4	5.25	1246	756	1246.5	490.5	2.540	2.660	4.50	15.31	70.60	1196	2.9
5	5.25	1246	753	1246	493	2.527	2.660	4.99	15.74	68.32	1101	2.4
6	5.25	1243.5	754	1244.5	490.5	2.535	2.660	4.69	15.48	69.68	1164	3.3
7	5.75	1230.5	748	1231	483	2.548	2.630	3.13	15.51	79.81	1259	3.4
8	5.75	1230	746	1230	484	2.541	2.630	3.37	15.72	78.55	1277	3.5
9	5.75	1241	754	1241.5	487.5	2.546	2.630	3.21	15.58	79.41	1277	3.2
10	6.25	1227	741	1227.5	486.5	2.522	2.603	3.11	16.80	81.50	1101	3.6
11	6.25	1227	743	1227	484	2.535	2.603	2.61	16.37	84.07	1164	3.8
12	6.25	1229	740	1229	489	2.513	2.603	3.45	17.09	79.84	1133	4.1
13	6.75	1231	739	1233	494	2.492	2.575	3.23	18.24	82.30	944	4.7
14	6.75	1222	736	1223.5	487.5	2.507	2.575	2.65	17.75	85.05	975	4.8
15	6.75	1228.5	740	1230.5	490.5	2.505	2.575	2.73	17.82	84.66	912	4.2

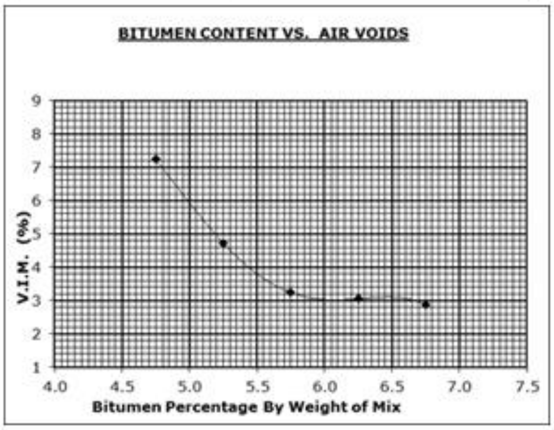
The optimum bitumen content was found out to be 5.30 % by weight of the mix. This OBC value was then used in the Marshal testing of the VG-30 with RAP sample. The following table compares the two samples:

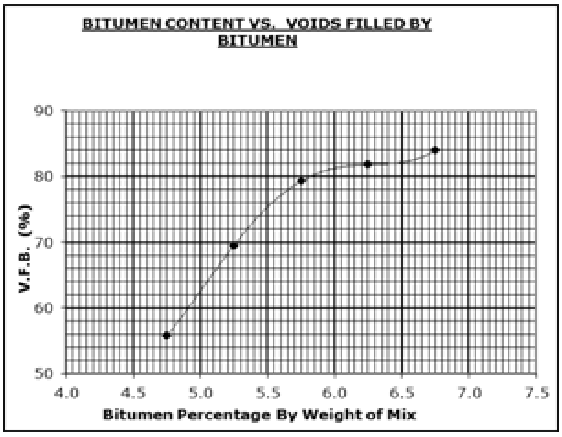
1. Virgin Bitumen (VG-30)
2. VG-30(50%) + RAB (50%) + WEO (20%)

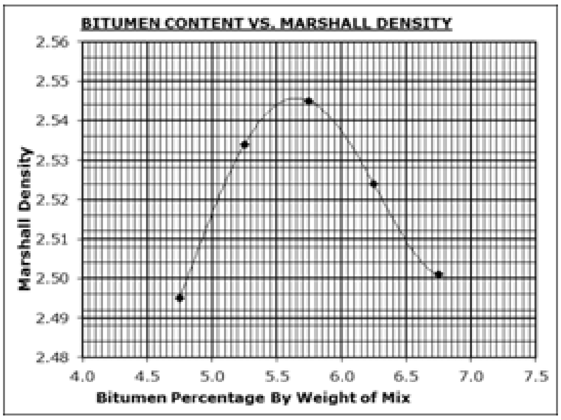
Properties	VG-30	VG-30(50%)+ RAB(50%) + WEO (20%)	MORTH Specification
OBC (%)	5.30	5.30	Min-5
Bulk density (gm/cc)	2.54	2.53	-
Stability (kg)	1400	1697	900kg
Flow (mm)	3.0	2.9	2-4
Air Voids (%)	4.62	5.24	3-6
VMA (%)	15.55	15.93	Min-16
VFB (%)	72.00	67.10	65-75











IV. DISCUSSIONS:

- The addition of WEO to RAB improved its physical properties like penetration,ductility, softening,viscosity and match with the standard values.
- By studying the results of the tests we concluded that 50%-50% of virgin bitumen& RAB with 20% of WEO can be used for the BC Design.
- The Marshal Design results showed a significant

improvement in the stability value of the selected proportion (50%-50%-20%) without affecting the Air voids content of the mix.

V.CONCLUSION

Following conclusions can be made:

- The above study indicated consistent increase in the physical properties (Penetration, Ductility, softening point etc.) of the aged bitumen when rejuvenated with waste engine oil and VG-30.
- By Marshall Mix Design it is found that waste engine oil can be used effectively to make pavement with stability and flow values comparable to that of virgin bitumen.
- In this present project work, based on the laboratory studies it can be concluded that RAP content as high as 50% can be suitably adopted in Pavement Construction.

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