EXPERIMENTAL STUDY ON MODIFIED ASPHALT PAVEMENT BY USING WASTE MATERIALS

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***Abstract*—India is one of the rapid urbanizing country. Due to increase in vehicular amount of tyre waste originated in range of 15-20% each year and it causes a great problem while disposing them into the environment. The first aim of this study is to minimize the cost and increase the efficiency of roads by using different waste materials as additives like scrap tires, waste engine oil and coal fly ash. In the present paper, the property of bitumen has to be modified by adding crumb rubber at the levels 5%, 10% and 15%. The crumb rubber gives the additional binding strength, increases elastic property, stability and flow of bitumen mix. The coal fly ash is used as filler in order to improve workability and durability of asphalt mix. Due to this conventional bituminous mix includes stone aggregate and 4%, 8%, 12% of fly ash has to be modified as fillers by weight of the aggregate. The second aim of this study is to overcome the cracks, waste engine oil is one of the waste material used as an additive of improving the self-healing capacity, age resistance and fatigue life of bituminous mix. This modified asphalt mix performances are carried out by Marshall Stability method. The rheological properties of asphalt binder are carried out by DSR test. The properties and performances will be compared among conventional asphalt mix and modified asphalt mix.**

Intex terms— Crumb rubber, Fly ash, Waste engine oil, Marshal Stability test and DSR test.

I. INTRODUCTION

The Road network of India is second largest road network in the world with total length of around 4,320,000 kilometers. Indian road network is consists of 1000 km of Expressways, 79,243 km of National Highways, 1,31,899 km of State Highways and Other major district and rural roads. Due to low initial cost and maintenance cost, flexible pavement type of construction is preferred over the rigid pavement type of construction. Construction and subsequent maintenance of pavements in good condition has become quite problematic especially in areas where soft or expansive soils are met with. In India, such soils covered more than one sixth of the area and it is estimated that over 33 lakh kilometers of road exists. The road transport carries close to 90% of passenger traffic and 70% of freight traffic. Bitumen is used as binder and water proofing materials for construction of roads, pavements and air field surfacing for several years. The demand of bitumen has increased tremendously because of rapid urbanization in recent years. Even though the importance of surface transport, most of the roads are poorly managed and badly maintained, this leads to rapid damage in pavement construction. In order to improve the performance standard of pavement,

- Bitumen is modified with the incorporation of certain additives like crumb rubber, waste engine oil.
- Coal fly ash is used as fillers in asphalt mix.

The advantages of modified bitumen can include one or more of the following for road works:

- Lower susceptibility to daily & seasonal temperature variations.
- Better age resistance properties.
- Higher fatigue life of mix.
- Better adhesion between aggregate & binder.
- Prevention of cracking & reflective cracking.
- Overall improved performance in extreme climatic conditions & heavy traffic conditions.

SCOPE OF THE PROJECT

- The properties of bituminous mixes get improved.
- Life of pavement gets enhanced, particularly, where high traffic loads are expected.

- The total construction cost of the flexible pavement to be reduced.
- The disposal of waste materials becomes easy.

A. CRUMB RUBBER

Crumb rubber is recycled rubber produced from automotive and truck scrap tires. During the recycling process, steel and tire cord (fluff) are removed, leaving tire rubber with a granular consistency. When dealing with asphalt overlays, reflection cracks can arise and cause an unwanted crack pattern beneath the pavement. Rubber-modified asphalt uses stress absorbing membranes that reduce the reflective cracking because of its elastic properties. With fewer cracks, there are fewer repairs, so crumb rubber assists in reducing maintenance costs. The pavement has an increased lifespan because after multiple uses and exposure to different elements, regular asphalt loses elasticity over time. The use of the artificial rubber resists the formation of cracks and has an anti-aging effect that keeps the asphalt in a better condition.

Fig 1.1 Crumb rubber (30 mesh)

B. COAL FLY ASH

Coal fly ash or Pulverised Fuel Ash (PFA) has been used for many years in road construction as a fill material, in concrete, lean mix sub-bases and in more recent years as a binder and aggregate in hydraulically bound materials. Its use reduces material being sent to landfill and preserves virgin aggregate stocks and is a major mineral resource for future generations. There are many environmental and sustainability reasons for using PFA in preference to virgin aggregates, reducing the overall greenhouses gas emissions.

Advantages

- Reduced potential for asphalt stripping due to hydrophobic properties of fly ash.
- Lime in some fly ashes may also reduce stripping.
- May afford a lower cost than other mineral fillers.

Fig 1.2 Fly ash (Class F)

C. WASTE ENGINE OIL

The waste engine oil consists of non-degradable components that are hard to be decomposed (Vazquez-Duhalt 1989). If improperly disposed, the pollution of used engine oil may cause irreparable damage to the environment. Waste engine oil contains higher percentages of polycyclic aromatic hydrocarbons (PAHs) which are very dangerous to health. As a petroleum-based product, waste engine oil has similar molecular structures as asphalt binder (DeDene 2011). Some researchers investigated the potentials of applying waste oil as a modifier for asphalt. Some studies reported the changes in physical and chemical properties of asphalt binders/mixtures when waste oil is added. Results from rheological tests indicated that inclusion of waste oil will significantly soften asphalt.

Fig 1.3 Used Engine oil

II. OBJECTIVES

- To explore the effective use of waste materials in road construction.
- To study the effect of crumb rubber, waste engine oil and fly ash in increasing the stability of modified asphalt mix.
- To study the effect of waste engine oil in increasing the rheological properties of modified asphalt binder.

- To compare the strength of bitumen and additives of modified asphalt mix with conventional asphalt mix.

III. COMPONENTS OF ROAD CONSRUCTION MATERIALS

1) BINDER : Bitumen grade VG 30
2) MODIFIER : Crumb rubber
3) AGGREGATE MIX : Coarse aggregate
4) FILLER : Coal Fly ash
5) ADDITIVES : Waste engine oil

IV. EXPERIMENTAL WORK

Following test were conducted to investigate the material properties used in asphalt mix

A. TESTS ON AGGREGATE

Tests which are generally carried out for judging the desirable properties and suitability of stone aggregates are listed below

Table 4.1 Physical Properties of Coarse aggregate

PROPERTY TESTED	TESTS METHOD	MORTH SPECFICATION	RESULTS
Aggregate impact test	IS:2386 (Part 4)	20-24%	21.36%
Los Angeles Abrasion value test	IS:2386 (Part 4)	30% max	25%
Specific gravity test	IS:2386 (Part 3)	2.5-3.0	2.72
Water absorption test	IS:2386 (Part 4)	2% max	1.15%
Flakiness and Elongation Index test	IS:2386 (Part 1)	30% max	22.03%
Aggregate crushing test	IS:2386 (Part 4)	45% max	20%

B. TESTS ON BITUMEN

Bitumen is available in a variety of types and grades. To judge these binders various physical tests have been specified by agencies like Bureau of Indian Standards (BIS), American Society for Testing and Materials (ASTM) and the British Standards Institution. Various tests that are generally carried out to evaluate the properties of bitumen binders are

Table 4.2 Physical Properties of Bitumen

PROPERTY TESTED	TESTS METHOD	PERMISSIBLE LIMIT	RESULTS
Specific gravity test	IS:1202	0.97-1.02	1.02
Penetration test	IS:1203	50-70mm	65mm
Ductility test	IS:1208	40cm(min)	92cm
Softening point test	IS:1205	35-70^0 C	49^0 C
Absolute viscosity test	IS:1206 (Part 2)	2400(min)	2450
Kinematic viscosity test	IS:1206 (Part 3)	350(min)	360

C. MAJOR TESTS

- Marshall Stability test
- DSR test

V. TEST RESULT AND DISCUSSION

All the respective samples are collected and various tests were conducted in laboratory. The result obtained from the test are tabulated and discussed as follows:

Table 5.1 Physical Properties of Bitumen with Crumb Rubber

PROPERTY TESTED	TESTS METHOD	RESULTS		
		5% of Crumb Rubber	10% of Crumb Rubber	15% of Crumb Rubber
Specific gravity test	IS:1202	1.05	1.09	1.11
Penetration test	IS:1203	62mm	48mm	39mm
Ductility test	IS:1208	75cm	61cm	43cm
Softening point test	IS:1205	60^0 C	67^0 C	71^0 C
Absolute viscosity test	IS:1206 (Part 2)	2308	2361	2398
Kinematic viscosity test	IS:1206 (Part 3)	397	409	418

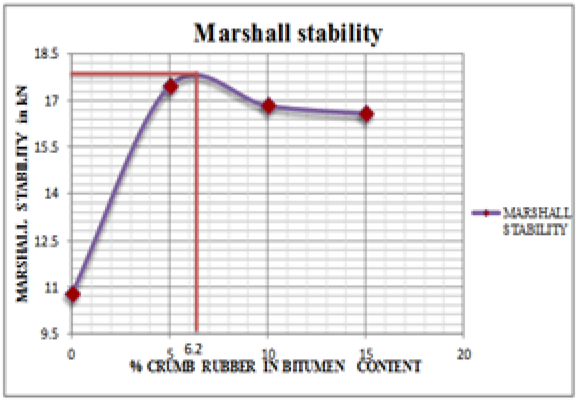
Table 5.2 Physical Properties of Bitumen with waste engine oil

PROPERTY TESTED	TESTS METHOD	RESULTS	
		2% of Engine oil	5% of Engine oil
Specific gravity test	IS:1202	0.99	0.97
Penetration test	IS:1203	86mm	93mm
Ductility test	IS:1208	83cm	89cm
Softening point test	IS:1205	54^0 C	48^0 C
Absolute viscosity test	IS:1206 (Part 2)	2245	2206
Kinematic viscosity test	IS:1206 (Part 3)	372	358

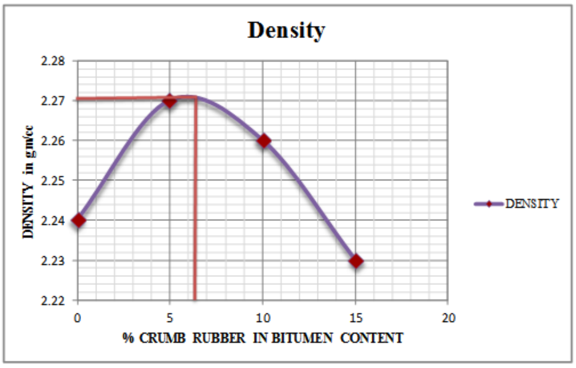
MARSHALL STABILITY TEST

Table 5.3 Results of Dense Bituminous Mix with varying percentages of Crumb rubber

S.NO.	PARAMETER	RESULTS		
		5% of crumb rubber	10% of crumb rubber	15% of crumb rubber
1	Stability (kN)	17.49	16.83	16.58
2	Air voids (%)	56.59	54.05	51.66
3	Voids filled with bitumen (%)	14.65	20.62	26.24
4	Flow value (mm)	3.11	3.52	3.96
5	Density (gm/cc)	2.27	2.26	2.23



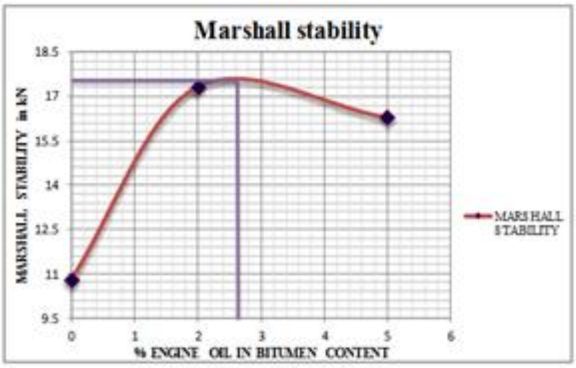
Graph 5.1 Shows variation of Marshall Stability with Bitumen content



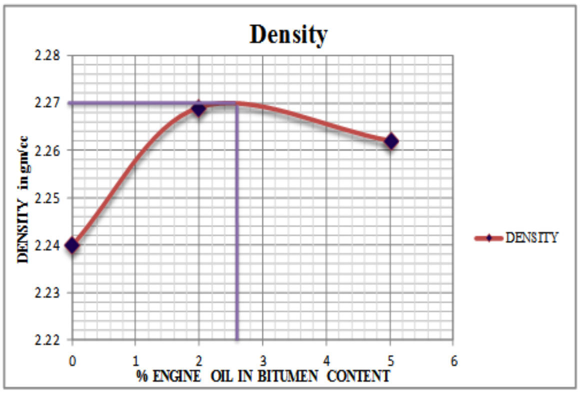
Graph 5.2 Shows variation of Density with Bitumen content

Table 5.4 Results of Dense Bituminous Mix with varying percentages of Waste engine oil

S.NO.	PARAMETER	RESULTS		
		0% of Engine oil	2% of Engine oil	5% of Engine oil
1	Stability (kN)	10.79	17.33	16.29
2	Air voids (%)	59.04	57.5	55.26
3	Voids filled with bitumen (%)	8.52	11.85	16.65
4	Flow value (mm)	2.7	3.02	3.8
5	Density (gm/cc)	2.24	2.269	2.262



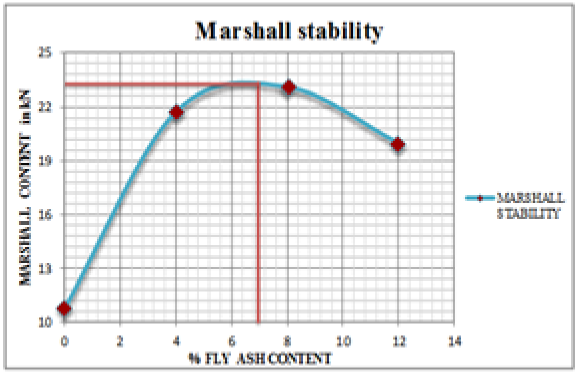
Graph 5.3 Shows variation of Marshall Stability with Bitumen content



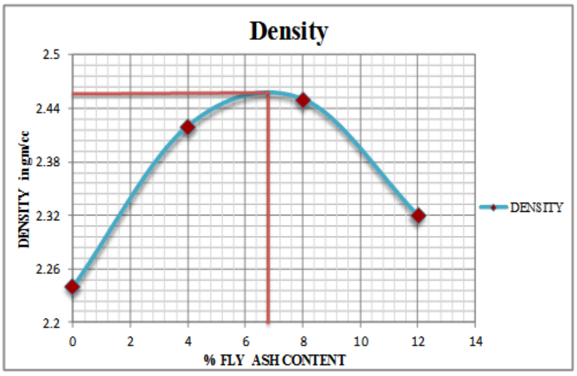
Graph 5.4 Shows variation of Density with Bitumen content

Table 5.5 Results of Dense Bituminous Mix for Varying Percentages of Coal fly ash

S.NO.	PARAMETER	RESULTS		
		4% of coal fly ash	8% of coal fly ash	12% of coal fly ash
1	Stability (kN)	21.73	23.08	19.96
2	Air voids (%)	58.54	57.85	57.32
3	Voids filled with bitumen (%)	8.58	8.68	8.76
4	Flow value (mm)	3.5	4.3	5.4
5	Density (gm/cc)	2.42	2.45	2.32



Graph 5.5 Shows variation of Marshall Stability with Bitumen content



Graph 5.6 Shows variation of Density with Bitumen content

Discussion

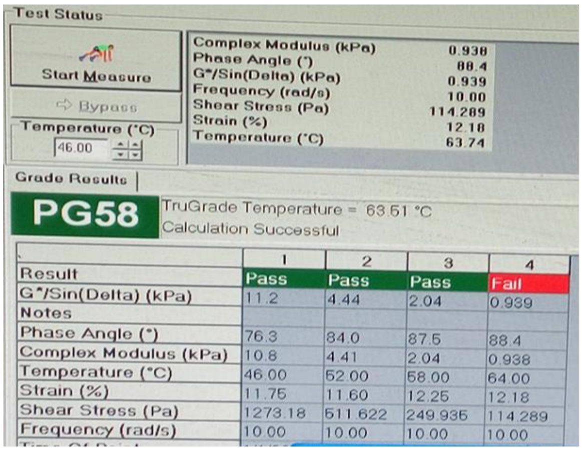
From the above graphs maximum stability, bulk density occurs when adding 6.2% of crumb rubber with bitumen content. From the calculation 6.5% of crumb rubber is taken as optimum content. By adding crumb rubber to the bituminous pavements the voids present in the aggregates are better filled and thus yield better results.

From the above graphs maximum stability, bulk density occurs when adding 2.6% of engine oil with bitumen content. The stability curve gets decreased when increasing the percentage of engine oil content. In the addition of 5% of engine oil gives some poor results compared with the addition of 2% of engine oil with the bitumen content. From the calculation 2.6% of engine oil is taken as optimum content.

From the above graphs stability, bulk density reaches maximum at 6.8% of coal fly ash with bitumen content. The Stability gets decreased when adding the excess amount of fly ash content. From the above study we adopt 7% of coal fly ash is an optimum content.

DSR TEST RESULTS

The 2.6% optimum content of engine oil mixed with bitumen and that sample is treated in this test. The results obtained from DSR test is given below



	1	2	3	4
Result	Pass	Pass	Pass	Fail
G*/Sin(Delta) (kPa)	11.2	4.44	2.04	0.939
Notes				
Phase Angle (°)	76.3	84.0	87.5	88.4
Complex Modulus (kPa)	10.8	4.41	2.04	0.938
Temperature (°C)	46.00	52.00	58.00	64.00
Strain (%)	11.75	11.60	12.25	12.18
Shear Stress (Pa)	1273.18	511.622	249.935	114.289
Frequency (rad/s)	10.00	10.00	10.00	10.00

Fig 5.1 Rheological properties of Modified Asphalt binder

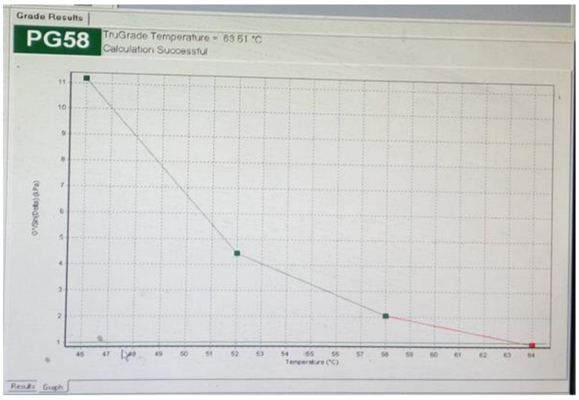


Fig 5.2 Graph obtained from DSR test

From the data gathered in DSR testing of the PG 58 binder and the blends of waste engine oil, a comparison of the high temperature performance grades of the asphalt binders can be made, as shown in Figure 5.1. Initially the binder caused an increase in PG because it increased the G*/Sin (δ) parameter to a point where it was less than 1.0 kPa at the test temperature. The increase in PG corresponds to an increase in stiffness and rutting resistance. With subsequent percentages of oil added, that stiffening was reduced and ultimately the binder was softened beyond the initial PG.

Figure 5.2 is a plot of the G*/Sin (δ) parameters obtained from the DSR test results. These results are for the PG 58 binder that was then blended with 2.6% of waste engine oil for subsequent testing. The original binder, shown in gray, fails specification at 76ºC, which is expected for a PG 52 binder. The blend with 2.6% waste engine oil experienced an upward shift for all data points, and had an overall PG increase to PG 58, indicating an improved resistance to rutting.

VI. COMPARISION

The comparison of results of physical property and Marshall Stability tests between the Conventional and Modified Bitumen.

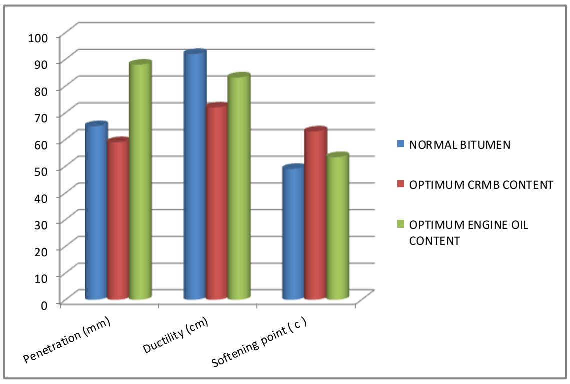


Fig 6.1 Comparison of Physical Properties between Conventional & Modified bitumen

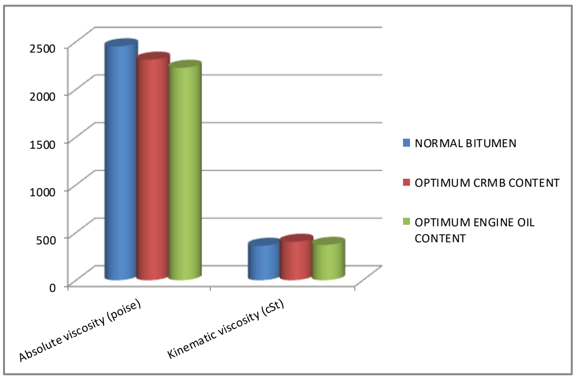


Fig 6.2 Comparison of Physical Properties between Conventional & Modified bitumen

In comparison 6.5% optimum content of crumb rubber in bitumen specific gravity, softening point, are increasing and ductility, penetration are decreasing. Hence it gets more harden compared with conventional bitumen. Due to the high hardness of bitumen gives more stability and less flexibility to the pavement. It increases the age resistance properties. By adding 2.6% optimum content of engine oil penetration, ductility, softening point are increasing due to this water resistance become low. It is not suitable for heavy rain fall areas.

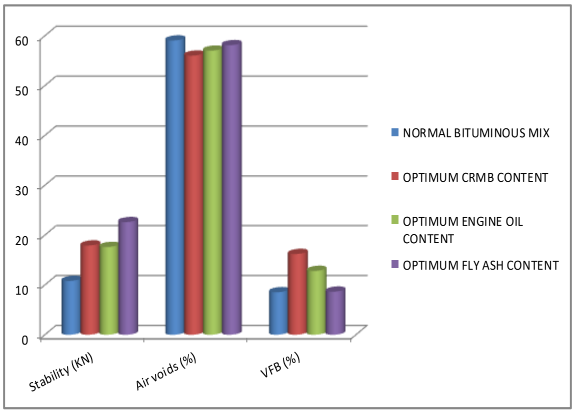


Fig 6.3 Comparison of Marshall Properties between Conventional & Modified bituminous mix

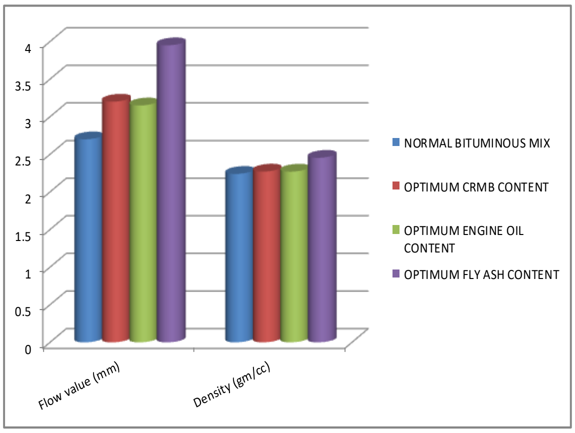


Fig 6.4 Comparison of Marshall Properties between Conventional & Modified bituminous mix

Crumb rubber gives the more Marshall Stability value (1824.66 kg sample) by using 6.2% of crumb rubber powder with bitumen mix, which is 1.658 times greater than the Marshall Stability value of conventional bitumen mix. Bituminous mix with engine oil gives high Stability value (1794.08kg sample) by using 2.6% engine oil with mix which is 1.63 times greater than normal mix. Coal fly ash high stability value occurs (2303.77kg sample) by using 7% of fly ash content with bituminous mix which is 2.09 times greater than the Marshall Stability value of conventional bituminous mix.

VII. CONCLUSION

CRUMB RUBBER: The addition of the Crumb rubber powder benefits, such as reduced sensitivity to temperature, greater flexibility at low temperatures, reducing the percentage of sand in the mix, improve the impact resistance of asphalt mixtures.

WASTE ENGINE OIL: From the test results the addition of used waste engine oil was shown to lower the carbonyl and sulfoxide indices which, in effect, mean the oil is adding maltenes to the binder structure. Since the maltenes contribute to the ability to flow and softness of binder, when oil is added the viscosity should be decreasing as well as the increase in rutting potential.

COAL FLY ASH: The feasibility of using coal fly ash to significantly improve asphalt mix performance. Coal fly ash appears to improve the aging resistance of pavement, thereby increasing the life of pavement infrastructure by reducing aging-related cracks.

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