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Study on Mechanical Performance of Asphalt Mixture using Waste Wood Bio-Oil

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***Abstract*— The present study evaluates the effects of using bio-oil derived from waste wood biomass on physical and mechanical properties, of base binder. A base binder (Viscosity Grade VG30) was blended with 0%, 2% and 4% of bio-oil by total weight of the binder. Along with physical properties tests (penetration, softening point and ductility, specific gravity of the bio-oil modified binder was evaluated. .The results showed that the blending of bio-oil increased the penetration, flash and fire point and decreased the softening point, ductility and specific gravity test of the basebinder. Based on Indian Standard 73:2013 specification, it was observed that blending of 0%, 2% and 4% bio-oil satisfies VG30 binder properties, respectively. Marshall Stability Test was conducted on the base binder and the following conclusions are drawn: Using the Asphalt Institute Procedure, optimum binder content for virgin bitumen mixture was obtained at 4.08%. Similarly when 2% and 4% of bio oil was blended respectively, optimum binder contents were obtained at 4.16% and 4.58% respectively.**

***Keywords*— Bio-oil,Bitumen(VG30),Aggregates**

I. INTRODUCTION

The high demand for petroleum products, including bituminous binder, has resulted in depleted petroleum reserve and increased energy cost. This results in higher cost of pavement construction. Researches and engineer have been seeking approaches to reduce the use of petroleum asphalt. Recently researcher have found that bio-oils can be generated from several biomass materials.

In our study, we are using waste wood bio-oil to modify or partially replace the petroleum asphalt binders in the asphalt pavement structure. Utilizing these waste materials from other industries to partially substitute asphalt, can not only reduce asphalt consumption but also improve the pavement performance of asphalt. Their works indicated that the addition of bio-oil increased the high temperature performance of asphalt binder, reduced the mixing temperature of the asphalt mixture, and it had adverse effects on the medium and low temperature performance of the asphalt binder.

II. OBJECTIVES

1. To investigate the effects of bio-oil on the physical, mechanical properties of VG30 grade bitumen.
2. To determine physical properties of aggregate.
3. To determine the optimum binder content and optimum dosage of bio-oil in asphalt mixture.

III. MATERIALS

Table. 1 shows the fundamental properties of the collected base binder graded as viscosity grade VG30 and satisfied the requirements as per IS 73: 2013. The bio-oil was produced from waste wood biomass using the fast pyrolysis process. In this process, waste wood biomass was subjected to the polymerization process at higher temperature to produce bio-oil. The characteristic properties of binders were evaluated as per Indian Standard test methods (IS 73:2013). The grade of a binder with specific value requirement as per IS 73:2013 specification. Four different viscosity grade (VG) of binder: VG10, VG20, VG30, and VG40 are recommended. The grading of the binder is done based on absolute viscosity test measured at 60°C.Table. 2 shows the fundamental properties of aggregates required for the Marshall mix design.

SI NO	Physical Properties	Bio-oil Content		
		0%	2%	4%
1	Penetration	67.6	79.6	127.6
2	Softening point	47.75	44.25	41.2
3	ductility	79	75.25	71
4	Specific gravity	0.99	0.9899	0.9898

Table. 1 - Fundamental properties of bitumen

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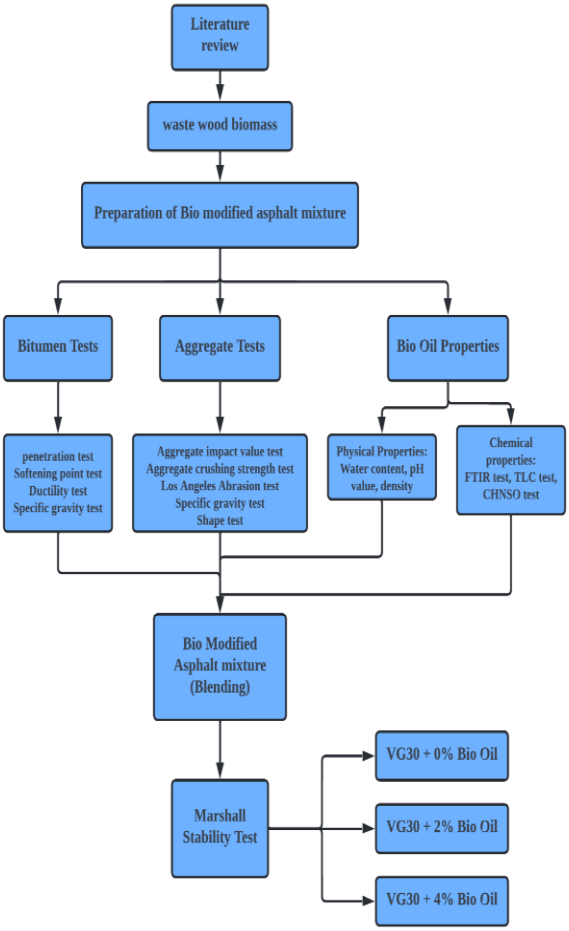
SI NO	Fundamental properties	values
1	Aggregate impact value	13.092
2	Aggregate crushing value	15.415
3	Aggregate loss angeles	12.75
4	Specific Gravity	2.66
5	Shape test	34.64

Table. 2 – fundamental properties of aggregates

IV. METHODOLOGY



The above flow chart gives us a complete skeletal structure of the project.

- Initially we obtain the bio-oil by waste wood biomass through pyrolysis process.
- The preparation of bio modified asphalt mixture is carried out by adding 0%, 2%, 4%, 6% and 8% of waste wood bio-oil into the conventional asphalt mixture.
- The physical and mechanical properties on bitumen and aggregates are tested by the following tests-

i. Bitumen tests

- Penetration test
- Softening point test
- Ductility test
- Specific gravity test

ii. Aggregate tests

- Crushing test
- Abrasion test
- Shape test
- Impact test

- The aggregate, bitumen (VG30) grade and bio-oil at different dosages are blended together with suitable temperatures and moulds of bio modified asphalt mixture are prepared.
- The mechanical test such as Marshall stability test is carried on the respective bio modified asphalt mixture moulds to determine the stability of the material.
- The results of all the tests mentioned above are further evaluated.

Preparation of Specimen

- The coarse aggregates, fine aggregates and the filler material should be proportioned and mixed as per the dry mix design
- The required quantity of the dry mix is taken so as to produce a compacted bituminous mix specimen of thickness 63.5 mm approximately
- Considering the specific gravities of aggregates in this region, approximately 1200gm of aggregates and filler would be required to get a standard specimen
- The dry mix of aggregates and filler is heated to a temperature of 150 to 170℃
- The compacted mould assembly and rammer are cleaned and kept preheated to a temperature of 100 to 145℃
- The bitumen is heated to a temperature of 150 to 165℃ and the required quantity of bitumen is added to the heated aggregates and thoroughly mixed.
- The mixing temperature should be 165℃
- The mix is placed in the mould and compacted by a rammer with about 75 blows on each side.
- The compacted specimen should have a thickness of 63.5 ± 3.0mm.

Marshall Stability Test

Marshall Stability test is conducted on compacted cylindrical specimens of bituminous mix of diameter 101.6 mm, thickness 63.5 mm. The load is applied perpendicular to the axis of the cylindrical specimen through a testing head consisting of a pair of cylindrical segments, at a constant rate of deformation of 51 mm per minute the standard test temperature of 60°C. The "Marshall Stability of the bituminous mix specimen is defined as a maximum load carried in kg at the standard test temperature of 60°C when load is applied under specified test conditions. The Flow Value' is the total deformation of Marshall test specimen at the maximum load, expressed in mm units. The Marshall Stability Value of a compacted specimen of bituminous mix indicates its resistance to deformation under applied incremental load and the flow value indicates the extent of deformation it undergoes due to loading or its flexibility.

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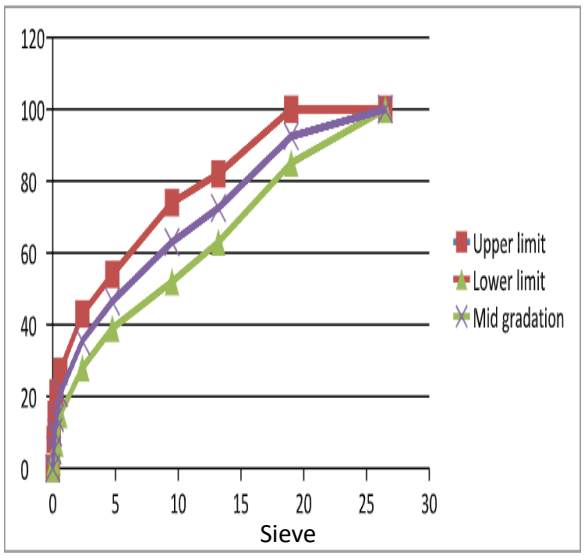
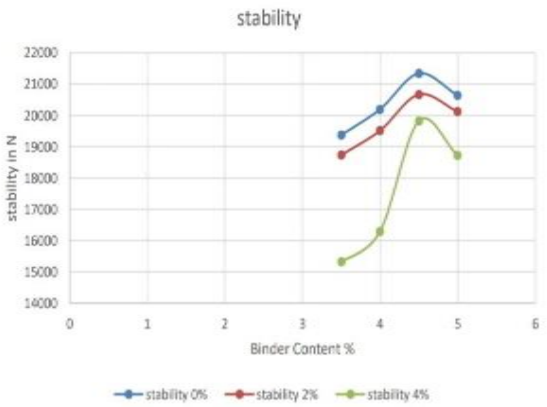
Mid Gradation Graph



Marshall Stability Test Results

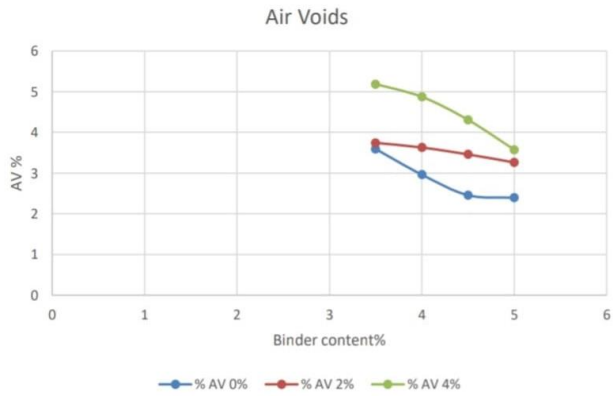
Stability



The stability graph shows that there is increase in 0% bio-oil when compared to that of 2% and 4%.

Therefore we can conclude that stability increase with binder content.

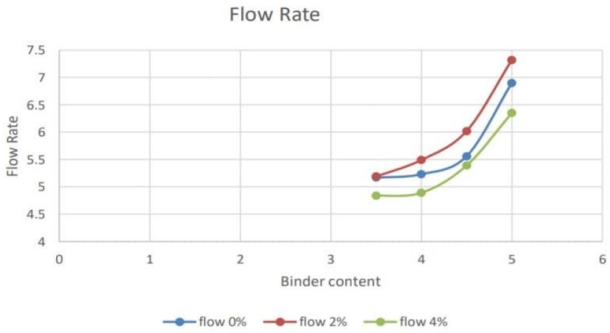
Air Voids



The air voids graph shows that there is increase in 4% bio-oil when compared to that of 0% and 2%.

Therefore we can conclude that air voids decrease with increase in binder content.

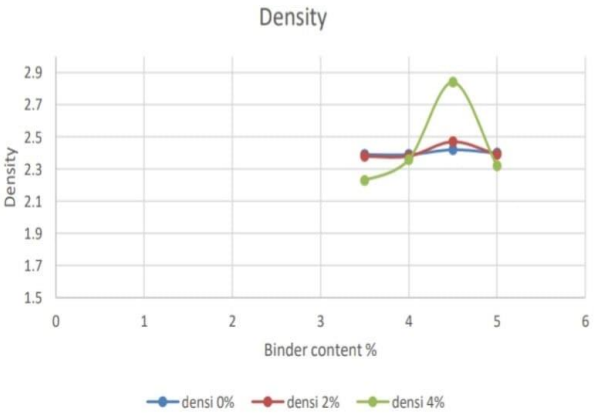
Flow rate



The flow rate graph shows that there is increase in 2% bio-oil when compared to that of 0% and 4%.

Therefore we can conclude that flow rate increase with increase in binder content.

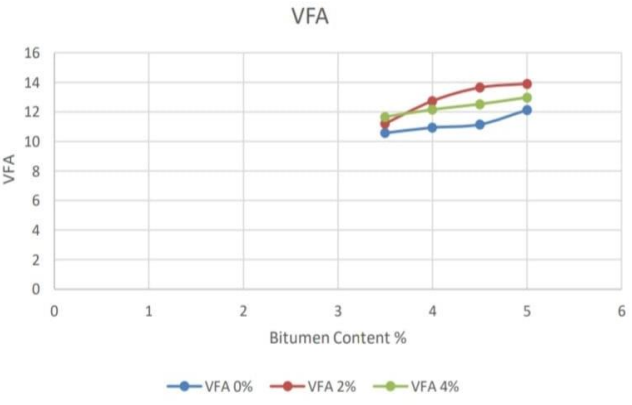
Density



The density graph shows that there is increase in 0% bio-oil when compared to that of 2% and 4%.

Therefore we can conclude that density at 2% boi-oil shows marginal difference in volumetric properties.

Voids in mineral aggregate (VFA)



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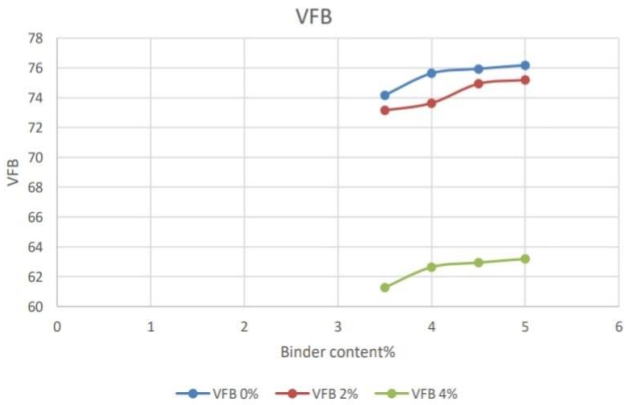
The VFA graph shows that there is increase in 2% bio-oil when compared to the of 0% and 4%.

Therefore we can conclude that VFA increase with increase with binder content.

Voids Filled with Bitumen (VFB)



The VFB graph shows that there is increase in 0% bio-oil when compared to the of 2% and 4%.

Therefore we can conclude that VFB increase with increase with binder content.

The Asphalt Institute Procedure

$$\text{Asphalt Content} = \frac{\text{(Maximum density + Maximum stability + 4\% air voids)}}{3}$$

As per The Asphalt Institute Procedure-
For 0%, Asphalt Content = 4.08%
For 2%, Asphalt Content = 4016%
For 4%, Asphalt Content = 4.58%

CONCLUSION

- Marshall Stability Test was conducted on the base binder and the following conclusions are drawn: Using the Asphalt Institute Procedure, optimum binder content for virgin bitumen mixture was obtained at 4.08%. Similarly when 2% and 4% of bio oil was blended respectively, optimum binder contents were obtained at 4.16% and 4.58% respectively.
- The density found to be decreased for virgin and 2% Bio-oil mix as compared to 4% Bio-oil OBC.
- The 2% Bio-oil modified mix has marginal difference in volumetric properties.
- The dosage of Bio-oil at 2% Bio-oil modified mix was observed to be 1.08%.
- Future scop is that performance test can be carried out.

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