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Partial Replacement of bitumen by Plant Polymer Lignin in Bituminous Pavement

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***Abstract*—Lignin is the second-largest plant polymer on Earth after cellulose. About 98% of lignin produced in the papermaking and pulping industry is used for combustion or power generation. Less than 2% of lignin is used in more valuable fields, mainly in the formulation of dispersants, adhesives, and surfactants. Asphalt is one of the most important materials in pavement engineering. It is a dark brown complex mixture composed of hydrocarbons with different molecular weights and their non-metallic derivatives which is extracted from crude oil. Because the chemical structure of lignin is similar to that of asphalt, it is a carbon-based hydrocarbon material. The high cost and the environmental impact associated with using petroleum bitumen in pavement construction is a problem facing the asphalt industry. In this study partial replacement of bitumen by lignin is done, and various physical properties like penetration, ductility and softening point are done to find its optimum replacement value. Later to measure the maximum load and flow rate of lignin modified asphalt specimen Marshall Test is done and to study about its rheological properties of the asphalt binder Dynamic Shear Rheometer Test (DSR) is performed. These tests are performed to confirm the properties and to provide a sustainable solution in the coming future.**

Keywords— lignin, alternative for bitumen, partial replacement, sustainable

I. INTRODUCTION

The most prominent application of lignin in pavement engineering was to add lignin as an asphalt modifier, which can significantly improve the aging resistance of asphalt and had different effects on the high-temperature rheological property, low-temperature crack resistance, and fatigue resistance of asphalt. Lignin can also be used as an asphalt filler. It can reduce the consumption of asphalt and achieve the effect of energy conservation, emission reduction, and cost reduction. In our project we are partially replacing bitumen by lignin in 0,5,10,15, 20,25 percentages to find the optimum value of replacement. This is estimated by comparing values of penetration, ductility and softening point. Later Marshall test is done to find the load and flow rate, and to roll to study about its rheological properties of the asphalt binder Dynamic Shear Rheometer Test (DSR) is performed. These tests are performed to confirm the properties and to provide a sustainable solution in the coming future. Lignin is nature's most abundant aromatic polymer. It is a type of wood waste, that is unwanted during the production of paper or ethanol and is frequently used as a source of fuel for power industrial plants through combustion. The efficient use of waste lignin in the production of bitumen pavements will not only reduce the environmental impact, but also reduce reliance on petroleum bitumen and also improve efficiency in the wood industry by utilising an unwanted waste by-product. The overall demand for the bitumen accounts for about 100 million tons per year i.e., about more than 700 million barrels are consumed annually. The majority of asphalt used commercially is obtained from petroleum. Nonetheless, large amounts of asphalt occurring are concentrated form in nature. Naturally occurring deposits of bitumen are formed from the remains of ancient, microscopic algae (diatoms) and other once-

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living organisms.

II. MATERIALS USED

A. Bitumen

Bitumen is a black viscous mixture of hydrocarbons obtained naturally or as residue from petroleum distillation. Bitumen is commonly used to build highways and motorways. Bitumen is known for its waterproofing and adhesive properties and is commonly used in the construction industry, notably for roads and highways. Production occurs through distillation, which removes lighter crude oil components like gasoline and diesel, leaving the heavier bitumen behind. In this project viscosity grade 30(VG30) is used. This bitumen is primarily used for the construction of extra-heavy bitumen pavements that have to bear significant traffic loads. Bitumen VG30 is the most widely used type of bitumen in road construction, insulation, building construction industries, and also in the production of cutback bitumen. It's better to know that this VG30 bitumen can be used instead of 60/70 penetration bitumen grade.

B. Lignin

Lignin is a plant polymer which provides structural support to plants. They are a by-product obtained from the manufacturing of paper industry. They are mainly used in the manufacturing of paint. In asphalt, lignin can be used as a modifier, extender, emulsifier, antioxidant, and coupling agent. In asphalt mixtures, lignin can be used as an additive. In road base soils, lignin can be used as a soil stabilizer. Furthermore, the article analyzed the application effects of lignin from the life cycle assessment.

III. SAMPLE PREPERATION

The bitumen binder was uniformly mixed with different amounts of lignin which was preheated 1 hour before at 110 degree Celsius. The bitumen is heated at 180 degree Celsius and are together mixed with a high-speed dynamic shear mixer until uniformly combined, without lumps.

IV. LABORTARY TESTS ON BINDERS

A. Penetration Test

Penetration is measurement of hardness and consistency of bituminous material. The penetration of a bituminous material is the distance in tenths of a mm, that a standard needle would penetrate vertically, into a sample of the material under standard conditions of temperature, load and time. The objectives of the penetration test are to determine the consistency of bituminous material and to assess the suitability of bitumen for its use under different climatic condition and type of construction. It is not regarded as suitable for use in connection with the testing of road tar because of the high surface tension exhibited by these materials and the fact that they contain relatively large amount of free carbon.

It is determined by measuring the depth in tenths of a millimetre to which a standard needle (100gms) will be penetrated vertically for 5 sec. For bituminous macadam, penetration macadam, IRC suggest bitumen grade 30/40, 60/80 and 80/100. In warmer region lower penetration grade like 30/40 is preferred, whereas higher penetration grade is used in colder region. Penetration value of bitumen is found out as per IS: 1203-1978.

B. Softening Point Test

The softening point of bitumen or tar is the temperature at which the substance attains a particular degree of softening. It is the temperature (in ºC) at which a standard ball passes through a sample of bitumen in a mould and falls through a height of 2.5 cm, when heated under water or glycerine at specified conditions of test. The binder should have sufficient fluidity before its application in road uses. The determination of the softening point helps to know the temperature up to which a bituminous binder should be heated for various road use applications. Softening point is determined by the ring and ball apparatus.

Higher softening point indicates lower temperature susceptibility and preferred in warm climates. Higher grade bitumen possesses higher softening point than soft grade bitumen. Softening point of various bitumen grades varies between 35°C-70°C. Softening Point of bitumen is found out as per IS: 1205-1978.

C. Ductility Test

The 'Ductility Test' gives a measure of the adhesive property of bitumen and its ability to stretch. In a flexible pavement design, it is necessary that the binder should form a thin ductile film around the aggregates so that the physical interlocking of the aggregates is improved. Binder material having insufficient ductility gets cracked when subjected to repeated traffic loads and it provides pervious pavement surface. Ductility of a bituminous material is measured by the distance in centimetres to which it will elongate before breaking when two ends of a standard briquette specimen of the material are pulled apart at a specified speed and at a specified temperature.

Bitumen with low ductility value may get cracked in cold weather. The ductility value varies from 5 to over 100 for different bitumen grades and a minimum value of 75cm is preferred by ISI for bitumen of grades 45 & above. Figure 3.6 and 3.7 shows the briquette mould and ductility testing machine respectively which are used to find out the ductility value of bitumen. Ductility of bitumen was found out per IS: 1208-1978 (Reaffirmed 2004).

D. Marshall Test

In this method, the resistance to plastic deformation of cylindrical specimen of bituminous mixture is measured when the same loaded at the periphery at a rate of 5cm/min. The test procedure is used in the design and evaluation of bituminous passing mixes. The test is extensively used in in routine test program for the paring jobs. There are two major features in the Marshall method of designing mixes mainly,

(i) Density void analysis

(ii) Stability flow test

The stability of the mix is defined as the maximum load carried by a compacted specimen at a standard test temperature of 600 C. The flow is measured at the deformation in unit of 0.25m between no load and maximum load carried by the specimen during stability test. In these to an attempt is made to obtain optimum binder content to the aggregate mix type and traffic intensity

E. Dynamic Shear Rheometer

The dynamic shear rheometer (DSR) is used to characterize the viscous and elastic behavior of asphalt binders at medium to high temperatures. This instrument is used to study the rheological properties of asphalt binders. Asphalt binders are viscoelastic. This means they behave partly like an elastic solid (deformation due to loading is recoverable – it is able to return to its original shape after a load is removed) and partly like a viscous liquid (deformation due to loading is non-recoverable – it cannot return to its original shape after a load is removed). The DSR measures a specimen's complex shear modulus (G*) and phase angle (δ). The complex shear modulus (G*) can be considered the sample's total resistance to deformation when repeatedly sheared, while the phase angle (δ), is the lag between the applied shear stress and the resulting shear strain. The larger the phase angle (δ), the more viscous the material. Phase angle (δ) limiting values are:

- Purely elastic material: δ = 0 degrees
- Purely viscous material: δ = 90 degrees

V. RESULTS

A. Penetration Test

% of replacement	Penetration values
0	65
5	61
10	57
15	53
20	50
21	48
22	40
25	38

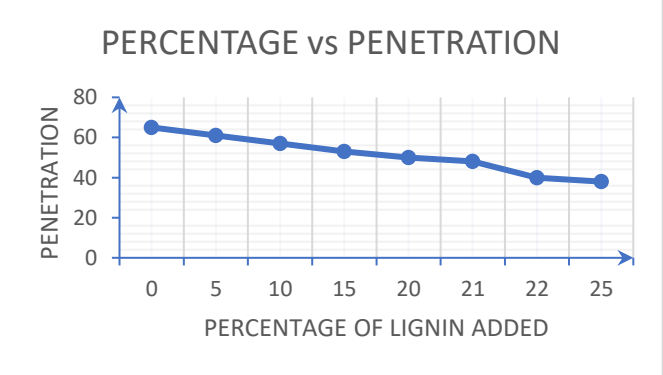

Figure 1: Graphical representation of percentage of lignin replaced Vs Penetration Value

B. Softening Point Test

% of replacement	Softening values
0	50
5	48
10	50
15	52
20	54
21	52
22	50
25	47

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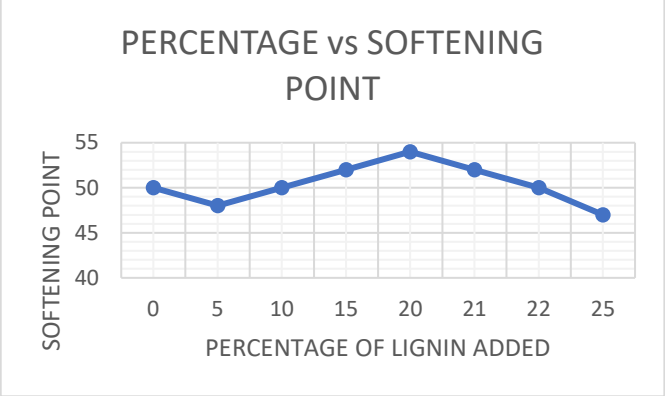

Figure 2: Graphical representation of percentage of lignin added Vs softening point values

C. Ductility Test

% of replacement	Ductility values
0	59.3
5	24
10	29
15	33
20	45.5
21	22
22	19
25	13.5

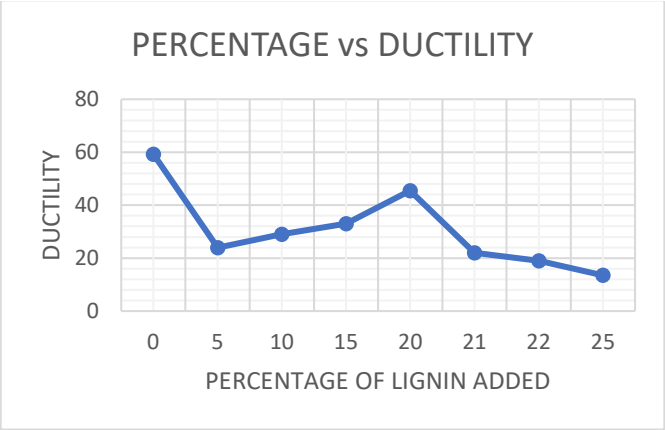

Figure 3: Graphical representation of percentage of lignin added Vs ductility values obtained.

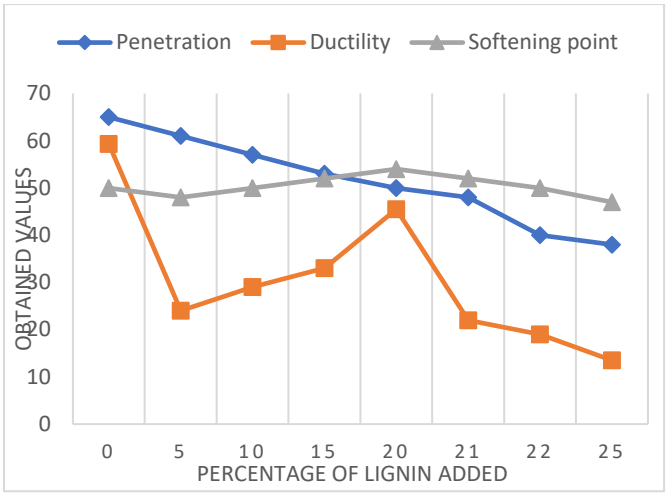

*Figure 4:*Combined graphical representation of different values of penetration, softening point and ductility with different percentages of lignin added.

VI. CONCLUSION

Till now optimum value of lignin that can be replaced is found out by comparing the values of penetration, ductility and softening point. Its is founded out to be 20%.

VII. WORKS TO BE COMPLETED

The works to be completed are:

a) Marshall test to find the maximum load and flow rate of lignin modified asphalt specimen.

b) Dynamic shear rheometer test is yet to be performed to find the rheological properties like rutting resistance of the asphalt binder.

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