International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 07 | July - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

USE OF MODIFIED BITUMEN BY LIGNIN AND WASTE PLASTIC IN BITUMINOUS CONCRETE

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Abstract -The advancement of the country's transport infrastructure is a key factor in the growth of a country. Since India uses flexible pavement often, measures must be done to prolong the life of bituminous pavements. Due to repetitive traffic loads, flexible pavement is frequently vulnerable to issues including rutting, cracking, and other failures and emits significant amounts of CO2, CH4, and N2O. In this project, we have substituted lignin and plastic waste for bitumen in the amounts of 2 & 2%, 4 & 4%, 6 & 6%, 8 & 8%, 10 & 10%, and 12 & 12%, respectively. A number of tests, including those for penetration, ductility, softening point, flash & fire point, and Marshall Stability test, have shown that waste materials like lignin and plastic can act as a binding material for asphalt, improving its properties and helping to reduce CO2, CH4, and 2 omissions. When compared to other proportions employed, it is discovered that the mix percentage of 8 & 8% produces effective outcomes.

Key Words - Bitumen, Lignin, aggregate, Plastic

1. INTRODUCTION

The building of highway and airport pavements, which combined account for around 85% of the world's bitumen use, is a common application for bitumen. Typically, hot mix asphalt produces significant amounts of CO2, CH4, and N2O emissions. This substance contributes to the high carbon emissions catastrophe region of the transport sector, which is detrimental to the growth of a low-carbon economy. The use of sustainable alternative binders (Lignin and plastic), which can substitute bitumen, helps to lower emissions of CO2, CH4, and N2O.

Another difficulty for the bitumen business is that lower chain hydrocarbons with higher added value than bitumen are being produced by the petrochemical sector with increasing efficiency. The quality and availability of bitumen are impacted by this. The availability is increased by the use of substitute sustainable binders. Lignin is a natural alternative polymer that will be used in place of bitumen in some circumstances.

One of the most prevalent naturally occurring polymers found in plant material is lignin. Lignin has a significant quantity of hydroxyl groups compared to bitumen. As a result, lignin becomes more hydrophobic and lignin-compatible. Lignin's chemical makeup differs across species. Aspen samples typically include 63.4% carbon, 5.9% hydrogen, 0.7% ash (a mineral component), and 30% oxygen. Formula roughly is (C31H34O11)n. It is possible to employ lignin as a substitute to bitumen since its chemical structure closely resembles that of bitumen. The VG-10 grade of asphalt was employed in this investigation. The research outlines a proof-of-concept for replacing some bitumen with waste lignin and plastic without sacrificing functionality. It has been discovered that lignin and plastic function as binding agents for asphalt, enhancing bitumen properties and lowering CO2, N2O, and CH4 emissions. This discovery also addresses the issue of how to dispose of waste plastic. Additionally, it improved the road's durability and effectiveness.

1.1 PROJECT ACTIVITIES

The waste materials lignin and plastic might be utilized in road building, and field testing showed that when properly processed as an addition, they would increase the durability and tensile strength of pavement while also lowering the cost of bitumen. The advancement of employing plastic and lignin waste to create bituminous pavements is highlighted in this paper. The production of lignin and waste plastic has expanded as a result of the speedy urbanization and growth. Since plastic is not biodegradable, it persists in the environment for a long time, and landfill disposal of waste plastic is dangerous because harmful compounds seep into the ground, contaminate underground water, and contaminate water bodies. The disposal of waste plastic and lignin is a significant issue for the civic sector because to habitual littering, an inadequate waste management plan, and other factors.As previously noted, disposing of lignin and plastic waste presents one of the major challenges for a developing nation like India. At the same time, India requires a vast network of roadways to ensure the efficient growth of its economy and society. Bitumen scarcity necessitates careful planning to enable quick pavement construction.

Currently, one of the biggest issues with waste management in the globe is how to dispose of waste products like plastic and lignin. Therefore, attempts have been undertaken in this inquiry to determine the prospective use of waste materials like plastic and lignin in civil engineering projects. The purpose of the current study is to examine the best way to include plastic and lignin waste into bitumen for the building of road paving.

1.2 OBJECTIVE OF THESTUDY

1.2.1 GENERAL OBJECTVE

The primary goal of the experimental inquiry is to develop methods for evaluating and improving the characteristics of pavement utilising waste materials like plastic and lignin so that it may be used more confidently in driveways and streets.

1.2.2 SPECIFIC OBJECTIVE

- The study's exact goal has been determined while keeping in mind the aforementioned premise.
- To investigate the BC mix's strength and stability properties with regard to VG-10 bitumen.
- In order to assess engineering qualities utilising Marshall stability, research is being done on lignin and plastic modified asphalt mixes.
- To research the fundamental characteristics of aggregates and uncomplex bitumen.

- To investigate how waste lignin and plastic affect the BC mix's strength and stability properties.
- Save the bituminous concrete road by studying how waste lignin and plastic may be used as binding agents.
- lignin and plastic trash should be included with the aggregate.
- In order to test the qualities of a bituminous mix specimen made by combining plastic and lignin waste,
- To identify a viable replacement for current materials that is less expensive and has improved strength and other parameters for flexible pavements.

To research the stability properties of BC mix as well as the strength qualities of waste lignin and plastic.

1.3 SCOPE OF THE STUDY

The goal of the project is to modify asphalt mixes using lignin and waste plastic to increase their performance and lessen pavement damage from rutting, thermal cracking, and water damage.

2. METHODOLOGY AND DATA CALCULATION

2.1 BASIC RAW MATERIALS

The materials used are as follows:

- Aggregates
- Bituminous binder
- Lignin
- Waste Plastic

2.1.1 LIGNIN

The cells, fibres, and vessels that make up wood and the lignified components of plants, such as straw, are bound together by lignin, an organic binding substance. Lignin has a significant quantity of hydroxyl groups compared to bitumen. As a result, lignin becomes more hydrophobic and lignin-compatible. The paper sector is one of the most significant suppliers of lignin. During the paper-making process, great efforts were taken to remove as much lignin as possible. Lignosulfonates, Soda lignin, Kraft lignin, and hydrolyzed lignin are among the most significant types of lignin. Lignosulfonates are utilised as a binder in this investigation. The most widely used and reasonably priced source of lignin is lignosulfonate. There are several different lignosulfonate products on the market, including calcium lignosulfonates, sodium lignosulfonates, and magnesium lignosulfonates.

Fig.1: Sodium Lignosulfonates

2.2 MATERIALS USED

- **AGGREGATES**

For the creation of bituminous mixes, aggregate should be graded in accordance with MORHT standards, as shown in Table 1. The substance's specific gravity is shown in Table 1.

Sieve size (mm)	Percentage passing	Spec. Limit of % passing
40.00	100.00	100
25.00	96.80	85-100
20.00	73.72	71-95
12.50	60.80	58-82
10.00	54.00	52-72
4.75	38.00	35-50
2.36	35.00	28-43
0.60	22.00	15-27
0.30	18.00	7-21
0.15	11.00	5-15
0.075	5.00	2-8

Table.1: Aggregates gradation for bituminous concrete

Types of aggregates	Specific gravity
Coarse	2.71
Fine	2.61
Filler	2.62

Table.2 : Specific gravity of aggregates

- **BITUMEN**

In this experiment, samples were prepared using VG-10 bitumen, a standard, widely-used bituminous binder. To ascertain the physical characteristics of bitumen, many tests must be performed. Table 3 provides a summary of the obtained physical attributes.

TESTS	TESTS RESULTS
Penetration value test at 25^0C	88.00
Softening point test, ^{0}C	45.00
Ductility test at, 27^0C	75.00
Flash point test, ^{0}C	225.00
Fire point test, ^{0}C	237.00

Table.2 : Physical properties of binder

- **LIGNIN**

Sodium lignosulfonates are employed as an addition in the

current investigation. Organic liquids were added to the mixture to increase the sodium lignosulfonates' compatibility with asphalt. Kerosene and creosote both worked well to spread sodium lignosulfonates more evenly throughout the asphalt.

Fig.2: Sodium lignosulfonate mixed with kerosene

- **WASTEPLASTIC**

In the current investigation, stabilising additives include polypropylene, low density polyethylene, high density polyethylene, and polypropylene. The used plastics were gathered, then washed and cleaned by soaking them in hot water for two to three hours. Then they were dried.

Fig.2- Shredded Waste Plastic

2.2 PREPARATION OF LIGNIN AND PLASTIC MIXED AGGREGATE-

Collection of waste polyethene enramadas, garbage trucks, dumpsites and compost plants, rag pickers, waste-buyers. Clean and dried waste polythene is shredded into small pieces (2 mm to 4 mm). The initial mixing method involved heating the lignin and Bitumen to about 110 to 180 degrees Celsius on a hot plate with a different percentage and mixing them with a spatula for several minute. After the samples of lignin and Bitumen are prepared by the desired process the various tested need to be performed on the samples (Lignin & bitumen). The tests done are penetration test, ductility, softening point, Flash & Fire and find out the optimum bitumen content of Lignin and Bitumen mixed. lignin purchased from market will be in powdered form and need to be heated to approximate temperature of 125°C to make it viscous. Lignin bought from the market will be in powder form, and it must be heated to around 125°C to make it viscous.

Organic liquids were added to the mixture to increase the compatibility of the lignin with the asphalt. Kerosene and creosote were successful in enhancing lignin dispersion in the asphalt. For effective mixing, the bitumen VG-10 was additionally heated to its melting point.

The plastic is also heated to between 1100 and 1800 degrees Celsius and is ready to be mixed with bitumen. Various samples of plastic and bitumen are made at different percentages by volume once the optimal mixing time has been determined. The tests include one for penetration, ductility, softening point, flash and fire, and determining the ideal bitumen concentration of a mixture of plastic and bitumen.

Fig.3- Preparation of Lignin and Waste Plastic mixed aggregate

2.3 TEST ON PREPAREDBITUMEN

- **PENETRATION TEST**

When a standard needle is inserted into bitumen while being subjected to a load of 100 grammes for five seconds at 250C, the penetration is measured in tenths of a millimeter. The test that is most frequently used to grade bitumen for hardness is the penetration test. Bitumen comes in a variety of penetration grades, with warmer locations using bitumen with lower penetration and colder regions using bitumen with greater penetration values.

Bitumen is softened at a pouring consistency between 800C and 1100C for the penetration test.To make the sample material uniform and free of air bubbles, it is thoroughly mixed. The containers are then filled with the sample material and let to cool in the environment for one hour. It is then submerged for 60 minutes at a temperature of 250C in a temperature-controlled water bath. Under the proper loading, a conventional needle is permitted to pierce the surface for 5 seconds. This is accomplished with a penetrometer, a device. IS: 1203-1978 has standardised this test.

Fig.4- penetration test

S. No	SAMPLE	PENETRATION
1	1	92.00
2	2	88.00
3	3	84.00

Table.3:- penetration test

$$\text{Average Penetration value (VG-10)} = \frac{\text{penetration Value}}{No.of\ samples}$$

$$\text{Average Penetration Value (VG-10)} = \frac{(92+88+84)}{3}$$

$$= \mathbf{88}$$

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2.4 SAMPLE PREPARATION

- **MARSHALL SAMPLING MOULD**

Table 3.4 provides the specifications for the Marshall sample mould and hammer

APPARATUS	VALUE	WORKING TOLERANCE
	MOULD	
Average internal diameter, mm	101.20	0.50
	HAMMER	
Mass, kg	4.535	0.02
Drop height, mm	457	1.0
Foot diameter, mm	98.5	0.5

Table.4:-Dimensions of Marshall Sampling Mold & Hammer

Fig.5:- Marshall Sampling mold

Fig.6:- Marshall hammer

2.5 MIXING PROCEDURE

1. The following method (STP 204-8) was used for the ingredient mixing.
2. We collected the necessary amounts of coarse aggregate, fine aggregate, and mineral fillers in an iron pan. 1650 to 1900 C was used to heat the aggregate.
3. To ensure proper mixing, the bitumen VG-10 was also heated to the melting point.
4. For a few minutes, the required quantity of lignin and shred waste plastic was heated on a hot plate between 110 and 180 degrees Celsius. The mixture was then put into a storage container after that.
5. Organic liquids were added to the mixture to enhance the lignin's compatibility with asphalt. The lignin in the asphalt was effectively improved by creosote and kerosene.
6. Bitumen was added after the created combination of lignin and plastic, and they were stirred for 15 to 20 minutes.When added to the aggregate, the resulting mixture was well mixed.
7. The mixture was then moved to a casting mould.
8. A Marshall hammer was used to condense this mixture. Table -3.4 provides information on this hammer's specifications, including its height of release.
9. The samples received 75 blows on each side, after which the mold-containing samples were stored separately and tagged.
10. Using the Marshall technique of mix design, the 4, 4.5, and 5% bitumen by weight of the produced mix aggregates were added to create the Marshall test specimens.

Fig.6- Marshall Sample

2.6 SAMPLE CALCULATION

Below is a discussion of the numerous tests done on the bitumen sample using various mixing ratios.

Sample 1: Bitumen without replacement

Sample 2 has 2% lignin and 2% plastic in place of some of the bitumen.

Sample 3: Bitumen with 4% lignin and 4% plastic in place of some of the asphalt

Sample 4: Bitumen with 6% lignin and 6% plastic in place of some of the asphalt

Sample 5: Bitumen with 8% lignin and 8% plastic in place of some of the asphalt

Sample 6: Bitumen that has 10% lignin and 10% plastic partially replacing it

Sample 7: Bitumen that has 12% lignin and 12% plastic partially replacing it

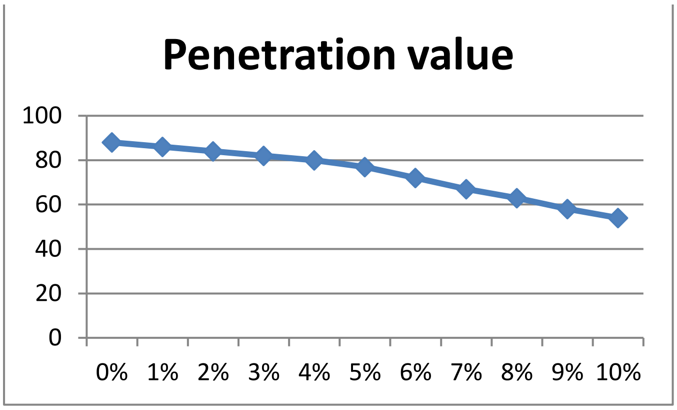
3. ANALYSIS OF RESULT

- **PLOTTING CURVES FOR WASTE PLASTIC**

Penetration value v/s Waste Plastic content-

Waste Plastic (%)	Optimum Bitumen Content (%)	Penetration value ($1/10^{th}$ of mm)
0%	4%	88.00
1%	4%	86.00
2%	4%	84.00
3%	4%	82.00
4%	4%	80.00
5%	4%	77.00
6%	4%	72.00
7%	4%	67.00
8%	4%	63.00
9%	4%	58.00
10%	4%	54.00

Table.5- Data for plotting curve

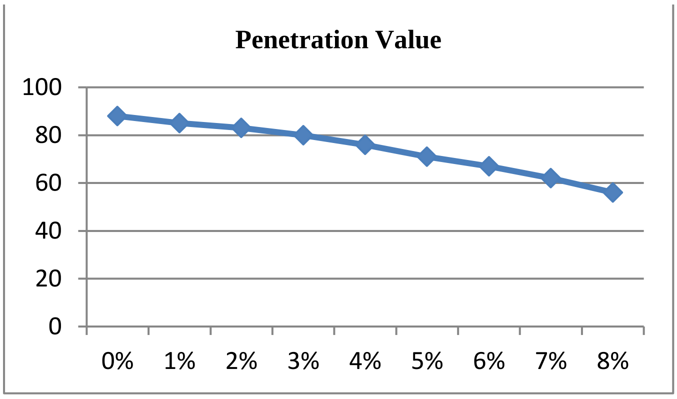


Penetration value v/s Waste Plastic content

- **PLOTTING CURVES FOR LIGNIN**

Lignin (%)	Optimum Bitumen Content (%)	Penetration value (mm)
0%	4%	88
1%	4%	85
2%	4%	83
3%	4%	80
4%	4%	76
5%	4%	71
6%	4%	67
7%	4%	62
8%	4%	56

Table.6:-Data for Plotting Curves (Lignin)



Penetration value v/s Lignin content

4. CONCLUSIONS-

Based on research on how waste plastic and lignin behave The changed mix procedure was found to enhance the bitumen's penetration, ductility, softening, flash, and fire qualities in all areas, extending the lifespan of pavements. By partially substituting bitumen with lignin and waste plastic up to 8% and 8%, respectively, all these qualities of bitumen have gradually increased.

Up to an 8% Lignin and 8% Waste Plastic content, the Marshall Stability value rose; beyond that, it starts to decline. We found that the Marshall Flow value decreased when lignin and plastic were added, increasing the resistance to deformations caused by large wheel loads and ensuring that the values of the parameters VMA, VA, and VFB were within the required ranges.

Taking into account these elements, we can guarantee that a Lignin and Waste Plastic pavement mix will be more stable and lasting. The tiny study not only makes good use of the leftover non-biodegradable plastic and lignin but also gives us a better pavement with more strength and longevity.

Plastic waste and Lignin Modified pavements would be beneficial in India's hot and oppressively humid environment, where temperatures often exceed 500C and torrential downpours severely damage much of the country's roads. The pavements' lifespan is negatively impacted by this. Lignin and waste plastic demonstrate enhanced pavement building capabilities. This may also lessen the quantity of lignin and waste plastic that would otherwise be a danger to the environment's hygienic conditions.

FUTURE SCOPE-

Solid waste rose proportionately with the population growth. The finest option for using garbage as building material while ensuring proper disposal. Due to the practicality of this technology, it would effectively help future generations manage their solid waste. The primary goals are: -

- **Economic in terms of bitumen: -** The polymer made of lignin and shredded plastic covers the aggregates and takes up more space on the road, lowering the amount of bitumen required.

- **Effective non-biodegradable waste management: -** Lignin is a byproduct of the pulp and paper industry, and plastic is a toxic, non-biodegradable waste that is mostly to blame for land contamination. Its effective management will arise from its use in road building.

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