

Lignin and Bagasse Ash Modified Bitumen for Pothole Repair

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Abstract: Potholes are a major form of distress in flexible pavements, affecting road safety, ride quality, and maintenance costs. Due to weak bonding, traffic loading, and moisture damage, traditional pothole repair techniques frequently fail. The use of bio-based additives to improve the sustainability and performance of asphalt binder has been investigated recently [1]. It has been reported that lignin, a naturally occurring biopolymer derived from biomass, enhances the stiffness and high-temperature stability of asphalt binders [2]. Additionally, sugarcane bagasse ash has been studied as a filler that can improve the durability and strength of asphalt mixtures [3]. By assessing binder characteristics like penetration, softening point, ductility, and viscosity, this study investigates the possible application of bitumen modified with lignin and bagasse ash for pothole repair.

Keywords: Pothole Repair; Modified Bitumen; Lignin; Sugarcane Bagasse Ash; Sustainable Pavement.

I. INTRODUCTION

Road networks are essential for economic activity and transportation efficiency; yet, pavement deterioration continues to be a global concern. Potholes are one of the most troublesome types of pavement distress since they lower ride quality, jeopardise road safety, and dramatically raise vehicle operating and maintenance expenses. Due to moisture damage, traffic loads, and poor bonding of repair materials, conventional pothole repair techniques frequently only offer short-term fixes. As a result, pavement engineering now places a lot of emphasis on enhancing the performance of bituminous binders used in repair operations. The application of bio-based compounds to improve asphalt performance has been highlighted in recent studies. Lignin and sugarcane bagasse ash are examples of materials that have shown promise in enhancing the mechanical and durability characteristics of asphalt mixtures, making them sustainable materials for pothole repair.

A. *Bio-based Modifier*

The use of agricultural waste materials and bio-based modifiers to improve the performance of asphalt binders and mixtures has been investigated in earlier research. Lignin has been extensively studied as a renewable asphalt modifier that can increase bituminous binders' stiffness, durability, and resistance to ageing [1][2]. Similarly, because they can enhance stability and mechanical performance, agricultural by-products like sugarcane bagasse ash have been investigated as filler ingredients in asphalt mixtures [4][5]. Additionally, studies on lignin-based bio-binders have shown benefits for sustainability and better structural performance in pavement applications [3]. Building on these results, the current study investigates the possible application of bitumen modified with lignin and sugarcane bagasse ash for pothole repair in flexible pavements.

II. LITERATURE REVIEW

The use of sustainable and bio-based compounds to enhance asphalt pavement performance while lowering environmental effect has drawn more attention. Because lignin is compatible with asphalt components, it has been extensively researched as a modifier for bituminous binders. Lignin is a natural polymer that is generated as a by-product of biomass processing. According to a number of studies, lignin increases asphalt binders' resilience to oxidative ageing and thermal degradation while also improving their stiffness and rutting resistance [1][2].

Lignin-modified asphalt mixtures exhibit enhanced viscoelastic behaviour, fatigue resistance, and durability under repetitive traffic stress, according to experimental studies [3][4]. Additionally, lignin has been identified by researchers as a partial substitute for petroleum-based bitumen, which can lessen the environmental impact of pavement construction without sacrificing enough mechanical performance [5]. Apart from lignin, agricultural waste materials like bagasse ash and sugarcane bagasse fibres have garnered significant attention in pavement engineering because of their extensive availability in sugar-producing regions and their reinforcing qualities [6]. According to studies, adding bagasse fibres improves the bonding between aggregates and the binder and increases internal friction, which increases the stability of asphalt mixtures [7].

When compared to traditional asphalt mixtures, laboratory tests have further shown that bagasse-modified compositions have better moisture resistance and higher Marshall stability [8]. Bagasse fibres' porous nature has also been shown to improve mixture homogeneity and structural integrity by absorbing excess bitumen and reducing binder drainage [9]. The potential of biomass-derived additives to improve fatigue resistance and extend pavement service life has been highlighted in research [10].

Research on lignin-modified asphalt has shown increases in the binder's rheological performance and resistance to high-temperature deformation [11]. The use of lignin-based bio-binders as environmentally friendly substitutes for materials generated from petroleum in pavement construction has been investigated in other research [12]. It has also been demonstrated that adding agricultural and industrial waste materials to asphalt mixtures increases durability while promoting resource conservation and waste management techniques [13].

Furthermore, research on natural fibres in asphalt mixtures has shown increases in overall pavement performance and fracture resistance [14]. In order to achieve balanced mechanical and rheological properties in asphalt binders, recent studies have concentrated on optimising the dosage of lignin modifiers [15].

Additionally, studies have shown that bagasse ash can improve the stiffness and stability of asphalt mixtures by acting as a mineral filler [16]. Additionally, research on sustainable pavement highlight how mixing many bio-based modifiers can produce synergistic effects that improve mixture durability and binder performance [17]. The combined use of lignin and sugarcane bagasse ash for pothole repair applications has not received much attention, despite these encouraging results [18].

III. MATERIAL AND METHODS

The experimental program was conducted to examine the performance of a modified bituminous mix for pothole repair applications. For this purpose, both conventional and modified binder samples were prepared to enable a comparative evaluation. The modification involved blending selected bio-based additives with the base binder under controlled heating and mixing conditions to achieve uniform dispersion. After preparation, the samples were subjected to standard laboratory tests to observe the influence of the modification on binder behavior. The results obtained from the modified binder were compared with those of the conventional binder to understand the potential improvement in properties relevant to pavement repair performance.

Table 1: Material to be used.

Sr. No.	Material	Type
1	Bitumen	VG-30
2	Sand	River sand
3	Coarse Aggregate	Locally Available
4	Lignin	Agriculture Waste

Table 2. Proposed Binder Modifications.

Sr. No.	Composition
1.	Conventional Bitumen
2.	Modified Bitumen [Conventional + Lignocellulosic bio polymer + Bagasse ash]

Lignin was incorporated as a binder modifier at **5% by weight of asphalt binder**, based on findings reported by Xu et al. (2021), who observed improved rheological performance of lignin-modified asphalt binders. Sugarcane bagasse ash was used as **5% of the asphalt mixture weight** as mineral filler replacement following the experimental results reported by Sarir and Wu (2020).

Table 3. Compositions.

Sr. No.	Material	Proportion	Source
1.	Bitumen	95% (by weight of binder)	-
2.	Lignin	5% (by weight of binder)	Xu et al., 2021
3.	Sugarcane Bagasse Ash	5% (by weight of asphalt mix)	Sarir & Wu, 2020

To assess the practical performance of the developed mix, a small field demonstration was conducted. Pothole repair

was carried out on the same pavement surface using two different mixes: conventional bitumen mix and lignin–bagasse ash modified bitumen mix. Photographs were taken during the repair work, immediately after filling the potholes, and again after six months to observe the comparative condition and durability of both repairs under actual field conditions.



Figure 1: Pothole filling operation.



Figure 2: Pothole repaired using conventional bitumen mix (immediately after repair and after 6 months)



Figure 3: Pothole repaired using modified bitumen mix (immediately after repair and after 6 months)

IV.RESULT AND DISCUSSION

Table 4. Test on Bitumen.

Sr. No.	Test	Conventional Bitumen	Modified Bitumen (Bagasse Ash +Lignin)
1.	Softening Point	48	58
2.	Penetration (25°C)	62	54

3.	Ductility (25°C)	78	84
4.	Absolute Viscosity (60°C)	2500	3800

The addition of lignin and sugarcane bagasse ash improved the binder's performance. Higher softening point and viscosity suggest better thermal stability and structural strength. Reduced penetration indicates increased stiffness, while maintained ductility shows the binder can still resist cracking. Overall, the modified binder exhibits enhanced durability and suitability for pothole repair applications.

V.CONCLUSION

- The study investigated the performance of bitumen modified with 5% lignin and 5% sugarcane bagasse ash for pothole repair applications.
- Laboratory test results showed improvement in binder properties, with higher softening point and viscosity, indicating better thermal stability and structural strength.
- The reduction in penetration value confirmed increased stiffness, while adequate ductility ensured resistance to cracking.
- A comparative field demonstration was carried out by repairing two potholes using conventional and modified bitumen.
- Visual observations from the field trial indicated that the modified binder provided better bonding and surface stability compared to conventional repair.
- The use of lignin and bagasse ash also promotes sustainable utilization of agricultural waste in pavement maintenance.
- Therefore, lignin and bagasse ash modified bitumen can be considered a promising and sustainable material for pothole repair, though further long-term field performance evaluation is recommended.

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