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Research Article

Assessment of Adhesion and Moisture Susceptibility of Wood Ashes modified Asphalt

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***Abstract* –** Large quantities of wood ash are produced across the world and are often disposed of in landfills or open dumps, leading to land constraint and environmental problems. Although introducing wood by-products into asphalt helps enhance performance and reduce the aforementioned issues, research has been done to investigate the feasibility of using wood ashes. The purpose of this study is to evaluate how the use of wood ashes affects the performance of asphalt binder and mixes. Asphalt binder and mixes containing 1, 3, and 5 percent by content of mechanically treated wood ashes were prepared. Tests, such as the bitumen bond strength (BBS) and rolling bottle test (RBT), were used to evaluate the rheological and mechanical characteristics of the modified binders and mixes. The findings revealed that a higher concentration wood ashes significantly improved the modified materials adhesion and moisture resistance.

Keywords – Asphalt, Wood ash, Bitumen Bond Strength, Rolling Bottle Test, Chip Board Ash

I. Introduction

The byproduct of burning wood and its compounds is ash, often known as wood ash. When wood is utilized in thermal power plants, it is burnt to produce heat and electricity. When wood is burned for purposes like heating or cooking, it also produces ash. Brick furnaces and other types of furnaces in Pakistan rely on wood for fuel. The Food and Agriculture Organization of the United Nations estimates that in 2017, Pakistan generated over 161 thousand tonnes of burnt biomass from forest products [1].

In addition to its many other use, wood has become the most widely utilized kind of dry biomass fuel in the world. The process of generating power from wood typically results in the production of ash, which is then either disposed of in landfills or thrown away uncontrollably in open agricultural fields. The disposal of wood ash results in a loss of land and has a detrimental influence on the environment due to the presence of heavy metals that are able to poison surface or subsurface water sources, which is especially problematic during the wetter months of the year. [2].

The need for traditional asphalt binder, a key component of roads, continues to rise around the world [3]. Worldwide, traditional binders account for over 87 million tonnes of annual production, with 85 percent going toward making asphalt roads [3], [4]. Similarly, increased population causes more vehicles to travel across pavements each day, which wears them down faster. Given that the materials that are currently used for road pavements are unlikely to perform under current and future traffic load scenarios, there is an obvious need for additives or modifiers that can improve conventional binder to the great extent that can support to fulfil the standards of pavement performance. These standards include riding performance, safety, aesthetics, durability, and serviceability. The mechanical properties of traditional binders can be enhanced by adding various additives and modifiers, such as polymers, crumb rubber, and others [5]. Significant advances in pavement performance have been achieved through the use of modifiers; however, further research is unavoidable given the expectations for even more extensive and intense traffic requests and expansion as well as worse climatic conditions [6].

Xue et al. (2014) examined the rheological properties and chemical composition of two types of biomass ash [7]. The findings were conclusive, and they indicated that employing ashes from biomass led to improvements in the material's resistance to permanent deformation, storage stability, and chemical reactivity with base binders. Date seed ashes have been used in additional biomass research, with promising findings in terms of both permanent deformation and fatigue cracking resistance [8].

The performance-related parameters of asphalt mixtures, such as fatigue, were negatively impacted by the addition of this waste material, whereas the thermal cracking response was improved. Recently, Abbasalizadeh and Hesami (2019) investigated the effects of sawdust wood ash (used to substitute limestone filler) on the Marshall stability, indirect tensile strength, moisture damage, and resilience modulus of asphalt mixtures [9]. According to their findings, the combination of 75% rice husk ash and 25% limestone filler was weaker and more susceptible to moisture than the combination of 25% wood ash and 75% limestone filler. Al-Merzah et al. (2019) did similar research on palm leaf ashes, considered a waste biomass material, for use in the production of cold bituminous emulsion mixtures. Their mechanical characterization and durability tests proved that the palm leaf ash-containing mixtures performed better and lasted longer than the control emulsion mixtures [10]. Based on the results of these analyses, it appears that wood or biomass ashes could be used to increase asphalt's durability in the context of four key types of distress: rutting, low-temperature cracking, fatigue, and moisture. However, the current research is restricted to macro scale work using wood or biomass ashes for asphalt modification.

The vast quantities of wood ash produced annually and often discarded are the key reason for this study since they could be re purposed as a resource for pavement construction. The purpose of this research is to analyze the traditional binder's performance in relation to adhesion and moisture damage after being adding of wood ash.

II. Materials and Method

A. *Material*

Margalla aggregates were sourced from a nearby quarry. Grades of aggregate were chosen in accordance with National Highway Authority (NHA) guidelines. The aggregate gradation was set at the midway values for NHA class B standard [11]. Figure 1 shows the aggregate gradation utilised in mixture production and the primary aggregate attributes [12].

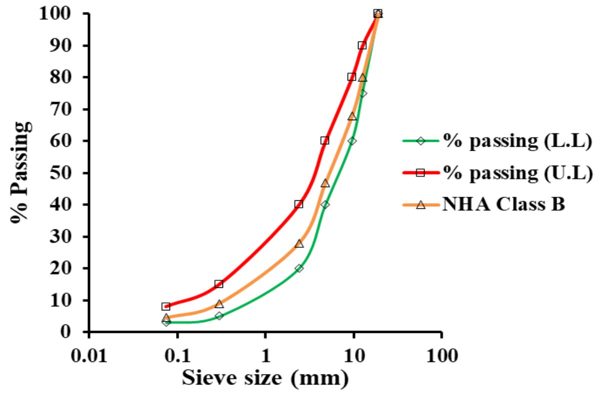

Fig. 1 Gradation curve of aggregates.

Table 1. Properties of Wood Ash

Chemical Composition%	
CaO	29.53
Al_2O_3	5.14
SiO_2	28.11
K_2O	9.64
SO_3	0.97
MgO	5.14
Na_20	0.32
Fe_2O_3	2.91
P_2O_5	2.48

Specific Gravity (g/cm^3)	2.52
Median Particle Size, d_{50} (μm)	22.486

The bitumen used in this study was a Pen 60/70 binder grade from Attock Refinery Limited. Bitumen has a specific gravity of 1.03.

The ash from recycled chipboard, known as Chip Board Ash (CBA), was procured from a chipboard manufacturer in Multan. Wood ash was dried at 110 degrees Celsius, processed, and sieved through a 75μm. Table 1 shows the characteristics of wood ash.

B. *Testing Program and Sample Preparation*

The effect of the CBA binder was evaluated by conducting penetration and softening point tests in accordance with ASTM D5 [13] and ASTM D36 [14] , respectively. Using a PATTI (Pneumatic Adhesion Tensile Testing Instrument) in both dry and wet conditions, the binding strength of bitumen and aggregate was evaluated in accordance with ASTM D 4541 [15]. In both dry and wet environments, all samples were evaluated (after 24, 48, and 72 hours). The binding strength of the bitumen aggregate system was measured using a CBA base binder at concentrations of 1%, 3%, and 5% by weight of binder. By plugging the PATTI value into equation 1, we can determine the bursting pressure at which the stud separates from the aggregate sample, and hence the Pull Off Tensile Strength (POTS).

$$POTS = \frac{(BP \times A_g) - C}{A_{ps}} \qquad (1)$$

POTS = Pull-off tensile strength,
BP = Burst pressure,
Ag = Contact area having a value of 2620 mm^2,
C = Piston constant 0.286,
Aps = Area of pull-stub having a value of 127 mm^2, for this research F-4 stub was used.

In accordance with BS EN 12697-11 [16], the influence of water on a CBA-modified, 60/70 penetration-grade binder was studied using RBT. To make the sample, 170 grammes of aggregates and 8 grammes of bitumen were mixed together. Bitumen coating samples were taken at 6, 24, 48, and 72 hours throughout the rolling time.

III. RESULTS AND DISCUSSION

A. *Conventional Testing*

Conventional testing procedures were used to examine the effect of these compounds on bitumen. Modified bitumen's adhesion strength and resistance to moisture damage are directly related to its penetration and softening point hence these properties are frequently tested [17]. The results of typical experiments and evaluations are shown in figure 2.

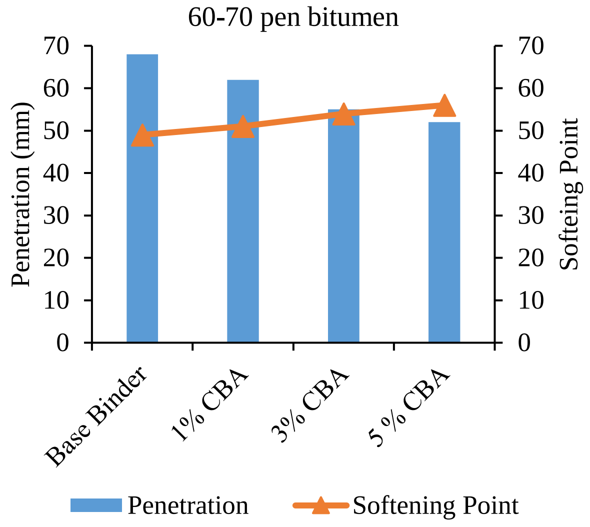

Fig. 2 Penetration and softening point values for modified and unmodified bitumen of pen grade 60-70

As a binder, 60-70 pen bitumen has a penetration value that decreases by 8%, 19%, and 23% when CBA is added at 1%, 3%, and 5%, respectively. On the other hand, the softening point increases by 4%, 10%, and 14% when CBA is applied at these concentrations.

As more CBA is added to 60-70 pen bitumen, the binder gets stiffer because the penetration values fall and the softening point increases.

B. *Analysis of adhesion by BBS test*

Effects of CBA on adhesion were studied experimentally using the Pneumatic Adhesion Tensile Testing Instrument (PATTI). The main advantage of this kind of test is that it is simple to determine whether or not there is adhesion between the bitumen and the aggregate by applying force. The 60-70 pen bitumen's dry-condition POTS values increased by 55% when 5% CBA was added, as comparison to the base binder. Figure 3 shows that the mean results, as shown by the error bar, are significantly different from the 60-70 pen bitumen.

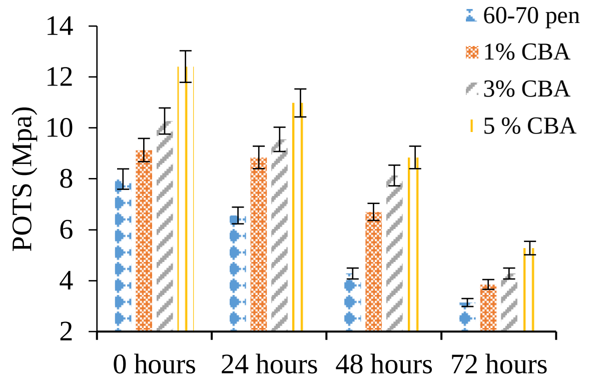

Figure 3. Modified and unmodified 60-70 pen grade bitumen at dry and wet conditioning POTS values.

The CBA's POTS values decrease after 24 and 48 hours of wet conditioning, but they are still higher than those of the base binder after 72 hours [18]. This is because the bond between the bitumen and the aggregate is weakened when water penetrates the bitumen-bitumen contact or the bitumen-aggregate interface.

In dry conditions, the modified bitumen with a CBA content of 60-70 pen had higher POTS values than the base binder. However, when conditioned in water, CBA-made modified bitumen lost some of its original value. In dry and wet conditions, the POTS values of the new binder are lower than those of CBA, but it still outperforms the base binder.

C. *Analysis of failure surface*

When a stub breaks away from an aggregate surface, it may do so in two ways: adhesively or cohesively. Bitumen residues on the aggregate sample are used to visually determine the failure mode. Adhesive failure happens when all of the bitumen is gone, whereas cohesive failure occurs when more than half of the bitumen's initial surface area is still on the aggregate. When there is still 50% of the bitumen on the aggregate, it fails in a cohesive-adhesive way.

Table 2 shows the bitumen covering percentage and failure type after both dry and wet conditioning. After 24 hours of water conditioning, the failure mode of CBA-modified 60-70 pen bitumen changed from cohesive to adhesive, resulting in higher binding strength.

Table 2: Coverage percentage of 60-70 pen Bitumen

CT	60/70 pen	1% CBA	3% CBA	5% CBA
0 hours	71C	78C	71C	69C
24 hours	60C	70C	62C	64C
48 hours	50C/A	59.5C	48.9A	48A
72 hours	31A	44A	39A	37A

CT = Curing time; A = Adhesive failure; C = Cohesive failure; C/A = 50% adhesive 50% cohesive failure

D. *Assessment of moisture damage by RBT*

The compatibility of bitumen and aggregate was evaluated using a rolling bottle test. Figure 4 shows that as rolling time decreases, bitumen coverage increases. The CBA-modified mixture had much better adhesion than the control mixture. Coverage is improved by 30% after 72 hours of rolling with the CBA modified combination compared to the control mixture. CBA-modified 60-70 pen-grade bitumen had a stronger adhesive effect than control mixture.

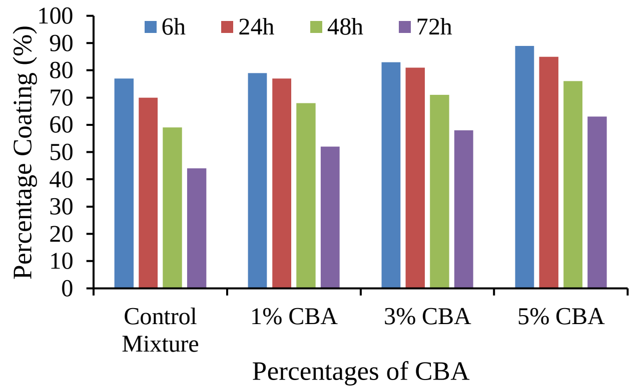

Fig. 4 Coverage percentages of modified and untreated bitumen over time of varying durations

IV. CONCLUSIONS

Based on the findings of the research, we conclude the following:

- When applied to 60-70 pen-grade bitumen, 5% CBA reduces the penetration value by 23% and raises the softening point by 14%. When CBA are added to bitumen, the penetration values decreases and the softening point increases.
- The POTS values of binders prepared with CBA at 5% increase by 55% as compared to

binders made with 60-70 pen bitumen in the dry condition. After being conditioned in water for 72 hours, the POTS values of 60-70 pen bitumen and CBA modified binders dropped in comparison to their values in the dry state. Consequently, the CBA modified binder outperforms the 60-70 pen bitumen binders in terms of POTS.

- Bitumen coverage is improved by 30% when 5% CBA is added to a base binder. Bitumen coverage is greater in the CBA binder after 72 hours of rolling compared to 60-70 pen bitumen binders.

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