Assessment of Asphalt Binder Characteristics Enhanced by Wheat Straw Ash (WSA) and Waste Engine Oil (WEO)

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Abstracts: Every year, tons of agricultural waste ash from crop residues (such as Wheat straws) are generated through energy production activities. The disposal of this ash in landfills and through open dumping poses serious environmental and health problems, primarily due to groundwater contamination. Additionally, the lack of available land for further dumping exacerbates the issue. The disposal of large amounts of waste products such as Wheat Straw Ash (WSA), and Waste Engine Oil (WEO) presents significant environmental risks, including air and water pollution, along with the challenge of limited space for safe disposal. Utilizing these waste materials in asphalt binder not only enhances asphalt properties but also mitigates environmental issues. In this study, WSA at concentrations of 2%, 4%, and 6% were mixed with 2% WEO to modify virgin bitumen. The modified binder specimens were evaluated using the Bitumen Bond Strength test and Rolling Bottle test, along with conventional testing methods, to assess adhesion and moisture susceptibility. The experimental results indicate that bitumen modified with 2% WEO by weight of virgin binder exhibits better adhesion and moisture susceptibility compared to the control binder.

Keywords: Waste Ash Reutilization, Waste Engine Oil, Wheat Straw Ash, Bitumen Modifier, Environmentally Friendly, Economic Infrastructure

1. INTRODUCTION

Globally, hot-mix asphalt has traditionally been utilized for flexible pavement [1-2]. However, employing hot mix asphalt, the traditional job mix recipe, frequently results in stress-related problems such as fatigue cracking, moisture damage, and rutting. Overloading, weather patterns, and high temperatures make these issues worse [3]. A potential remedy for these stress-related problems is to alter the neat binder [4]. From harvested crops, the agricultural sector generates a significant amount of waste, mostly in the form of straw and husks [5-7]. Due to the volume of agricultural waste produced, there are major environmental issues, particularly landfill-related worries. Ash is a byproduct of burning crop wastes such as wheat straw, rice straw, rice husk, sugar cane bagasse, and sugar cane straw [8–9]. Because they contaminate groundwater, deceptive activities like the open dumping of agricultural waste ash (AWA) hurt the environment and human health. Another significant problem is the restricted amount of land available for further dumping [10–11]. Agricultural waste is frequently burnt in factories and mills as a fuel source or to produce electricity. The idea of recycling these waste materials for use in engineering and industrial building projects, such as pavement for roads, makes sense. This strategy offers a viable option for infrastructure development in addition to addressing the environmental issues related to the disposal of agricultural waste [12–14].

Permanent deformations of flexible pavements have dramatically grown due to the fast expansion of urbanization and the drastic increase in traffic loads, volumes, and speeds [15–16]. High performance and stability, a long service life, and cheap repair costs are desirable for flexible pavements [17]. For a flexible pavement to live up to these expectations, it must be free of major flaws including rutting, poor strength, fatigue fractures, cracks that appear at low temperatures, and permanent deformations. To accomplish these modifications, bituminous binder, one of the flexible pavement ingredients, is often altered. To increase performance, certain additives are added to the asphalt or asphalt binder combination in specific amounts and under specific circumstances. To enhance the performance of hot bituminous mixes, several ingredients have been utilized to create modified bituminous mixtures in recent years. To guarantee asphalt's sustainability in the future, alternative modified binders need to be investigated [18–19]. The majority of renewable resources used in the bitumen modification process are found in biomass products, such as agricultural ashes and leftover cooking oil.

Biomass is a renewable resource used in energy generation that includes organic waste, vegetable oil waste, harvest remnants from agriculture, and byproducts from the processing of forestry and agricultural goods. This kind of energy is regarded as one of the most significant energy sources for the future as it is ecologically benign [20].

The overall objectives of this study are as follows.

• To investigate the effect of wheat straw ash (WSA) and waste engine oil (WEO) on the properties of bitumen.

• To determine the optimum percentage of each waste material individually and to estimate the best combination and dosage when they are mixed.

2. MATERIALS AND METHODS

Materials were obtained for the trial study from Rahim Yar Khan, the Highway Department. The majority of the road projects in the Rahim Yar Khan area get their materials from this well-known asphalt company. The supplies used in this experiment were given to us at no cost. The methodology section's flowchart will clearly illustrate the entire narrative of the carried-out research project.

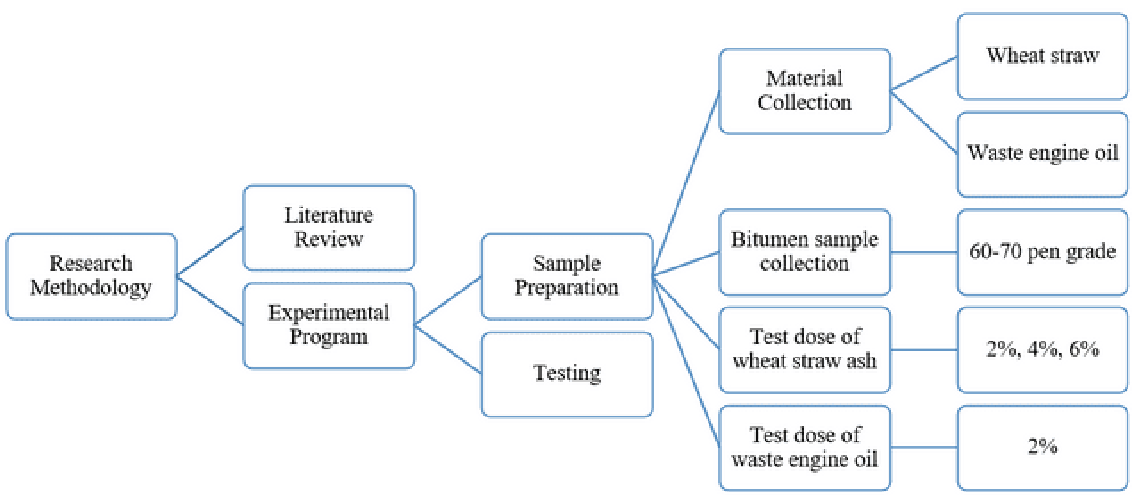

Figure 1: Flowchart of the research methodology followed for the study

Because of the current hot weather in the region, bitumen with penetration grades of 60 to 70 is advised for use in this experimental activity. A range of percentages (2%, 4%, and 6%) of waste motor oil and agricultural waste ash were used in the experiments. Following the completion of these studies, the results demonstrate that the bitumen material's qualities have changed, with some exhibiting increases and others showing declines. A sample was generated by the criteria for the experimental task, and the experiments were carried out to determine the research study's conclusions. The entire narrative of the laboratory inquiry will be clearly explained by the experimental work's flowchart.

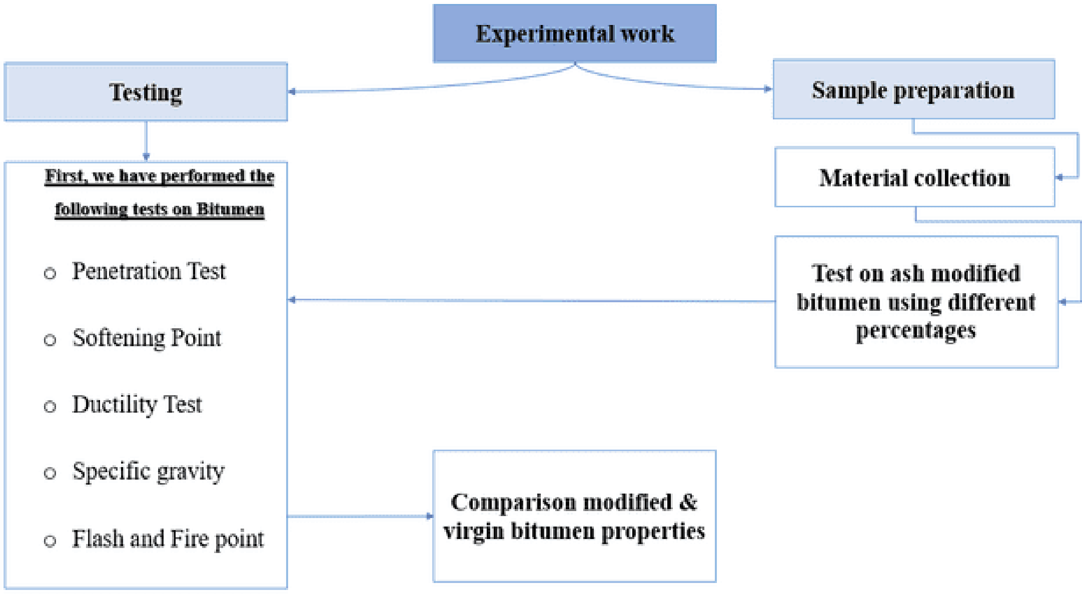

Figure 2: Flowchart of the experimental work performed in the study

Experiments Performed on Bitumen

The tests that were performed on the bitumen test samples are given in detail below.

Penetration Test

If the sample is started at room temperature, it is melted and then chilled in a controlled environment. A penetrometer, which administers a standard needle to the sample under particular circumstances, is used to quantify the penetration. By measuring the distance, in tenths of a millimeter that a standard needle penetrates vertically into the bitumen specimen under specified loading, duration, and temperature circumstances this test evaluates the consistency of a bitumen sample. The most used technique for determining bituminous material consistency at a specific temperature is this one. Rather than being a gauge of quality, it is a method of categorization.

Figure 3: Penetration test apparatus in the laboratory

Softening Point Test

The temperature at which bitumen reaches a particular level of softness under particular test circumstances is known as the softening point. The Ring and Ball device is used for this test. This method involves suspending a brass ring carrying a bitumen sample in a liquid at a preset temperature, such as glycerin or water. The bitumen sample is covered with a steel ball, and a rate of 5.0°C per minute is applied to the liquid medium. When the bitumen softens and comes into contact with a metal plate placed a certain distance below the ring, the temperature is measured. In general, a greater softening point is favored in hotter areas since it indicates reduced vulnerability to temperature changes.

Figure 4: Softening test apparatus in the laboratory

Ductility Test

The term "ductility" describes bitumen's capacity to stretch under the weight of traffic without breaking, which is essential for building new roads. The bitumen's ductility test determines how far it can stretch in millimeters before cracking. This test helps establish the bitumen's grade (ductility grade) and gives information about its tensile strength.

Figure 5: Ductility test apparatus in the laboratory

Specific Gravity

Using a pycnometer, this test technique describes how to measure the relative density and density of semisolid bituminous materials, asphalt cement, and soft tar pitches. The numbers in parentheses are only meant to be used as guidance; the values expressed in SI units are to be considered the standard.

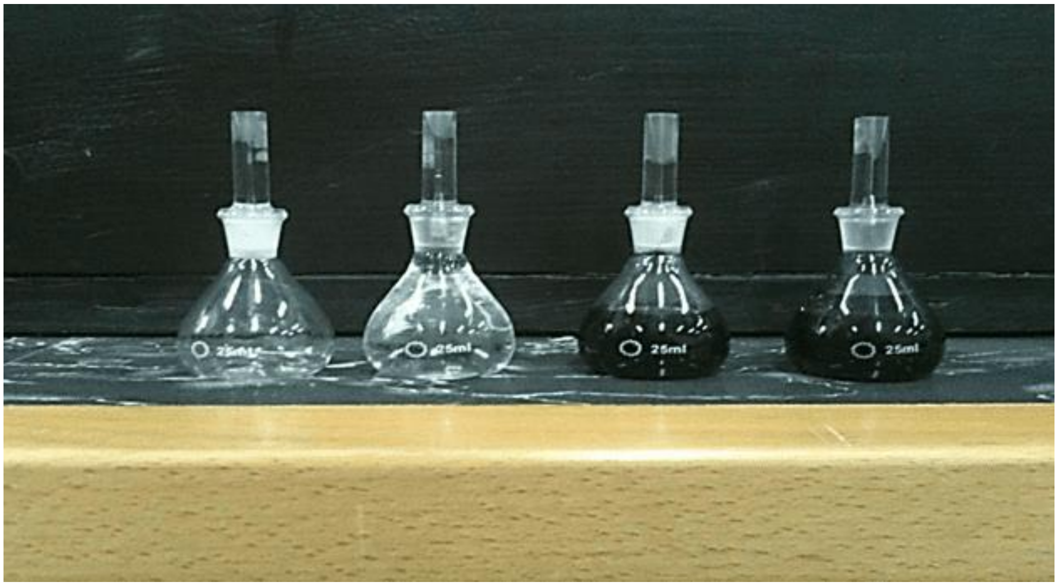

Figure 6: Specific gravity test apparatus in the laboratory

Flash and Fire Point

This test technique may be used to check if an asphalt cutback was made using solvents that fall within the intended range of flammability and to make sure that lower flash point solvents haven't contaminated the final product.

Bituminous materials release fumes of hydrocarbons that can catch fire at high temperatures. Thus, to prevent dangerous situations, the heating temperature of bituminous materials should be limited. The safe heating temperature of bituminous materials is ascertained by the application of flash point and fire point tests.

RESULTS AND DISCUSSION

This part contains all of the findings upon completion of the inquiry and an explanation of each detail in the preceding sections. Use the methodical technique outlined in the section headings below.

Table 1: Comparison of Virgin and Modified Bitumen Properties

Test Name	Base Binder	WSA			WSA + WEO		
Percentages used	0%	2%	4%	6%	2%+2%	4%+2%	6%+2%
Penetration test	68	65	63	60	66	62	59
Softening point	49	50	51	52	55	51	52
Specific gravity	1.03	1.045	1.05	1.05	1.01	1.03	1.04
Ductility	101	95	92	85	94	89	75
Flash point	240	235	236	237	233	234	235
Fire point	248	243	247	245	243	245	246

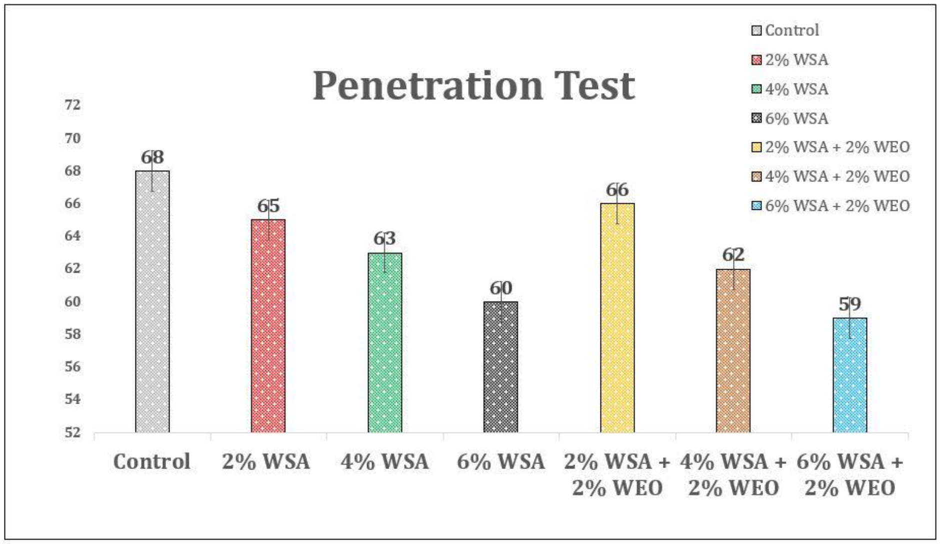

Figure 7: Graph between Percentages used and Penetration

DISCUSSION

The findings indicate that when wheat straw ash concentration rises, penetration value falls. The Penetration values exhibit a considerable decrease when mixing modifier-modified bitumen with 60/70 bitumen. As a result, the modified blends' penetration values have significantly decreased, indicating an improvement in their resistance to temperature susceptibility.

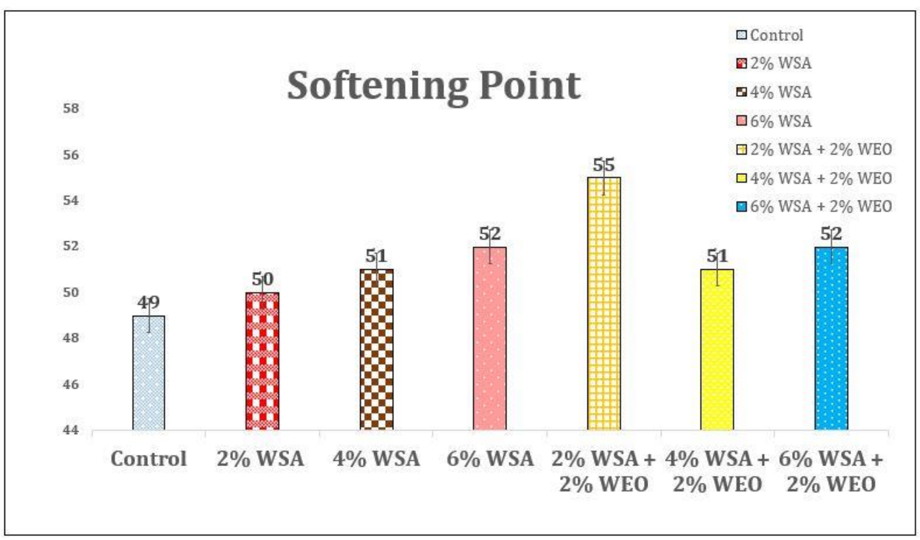

Figure 8: Graph between Percentages used and Softening

DISCUSSION

The findings indicate that when wheat straw ash levels rise, so does the softening point value. The bitumen gets more viscous, which causes the softening point to increase in the percentage of modifiers. Adding 0, 0.8, and 0.9 percent ash raises the softening point of 60/70 bitumen to more than 55. Thus, the maximum percentage for 60/70 bitumen should be between 0.6 and 0.7 percent. The findings indicate that bitumen changed to 80/100 and 60/70 ratios with a lower percentage of WSA may be used to construct roads satisfactorily; however, bitumen modified to a higher percentage, i.e. 0.8 percent to 0.12 percent, should not be utilized to construct roads but can be used as a roofing material.

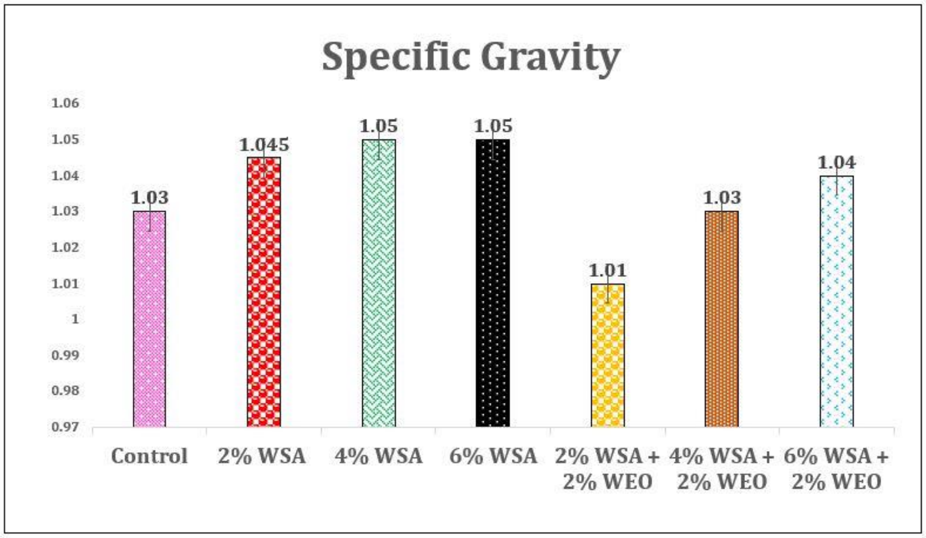

Figure 9: Graph between Percentages used and Specific Gravity

Discussion

The findings indicate that while specific gravity increases when WSA increases, specific gravity also increases when WEO increases. The specific gravity of the bitumen will be greater if there are mineral impurities present. It can be shown that altering the bitumen considerably raises the specific gravity values. After a 0.12% adjustment, the results for virgin 60/70 bitumen are 1.020 and 1.067 respectively.

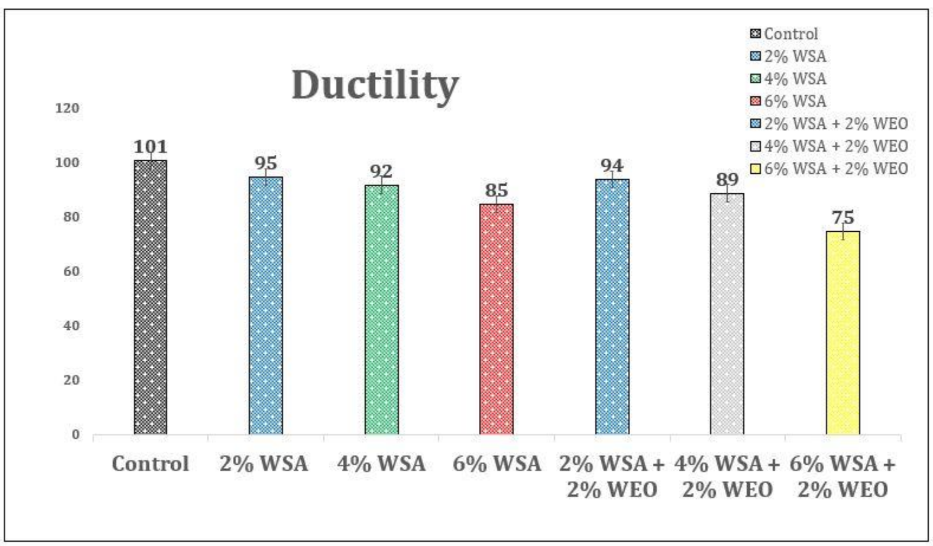

Figure 10: Graph between percentages used and Ductility test

Discussion

High ductility binders attach well to aggregates and have strong cementing properties on the road surface. The value of ductility reduces as plastic waste polymers (LDPE, PET, and HDPE) are added, although the rate of loss is slower when the amount is increased over 0.6 percent, according to the data. Road construction should not employ ductility values less than 50 cm, nevertheless, they can be used as filler materials for joints and cracks.

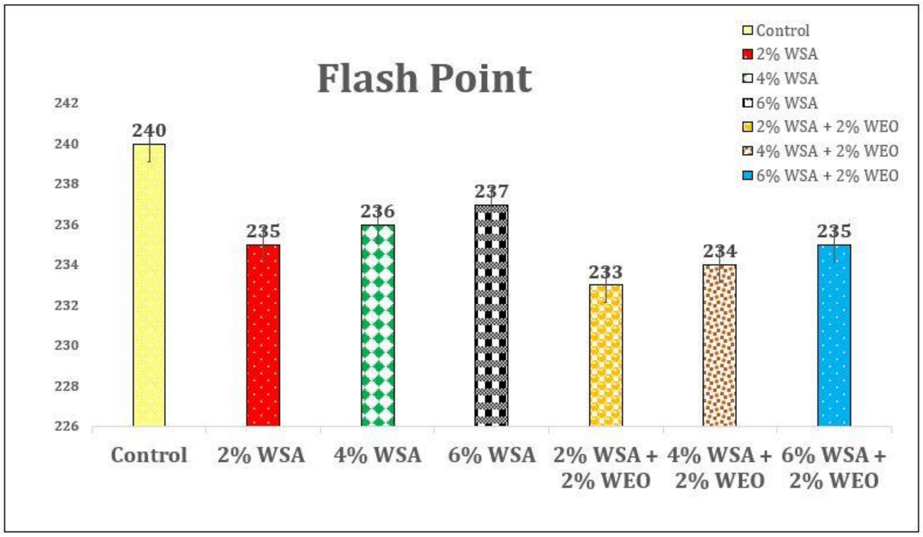

Figure 11: Graph between percentages used and Flashpoint

Discussion

The findings indicate that when WSA increases, the value of the flash point drops. A liquid's overall combustibility or flammability may be determined by looking at its flash point. The values for virgin 60/70 bitumen are 310, and after a 0.6% alteration, they drop to 235.

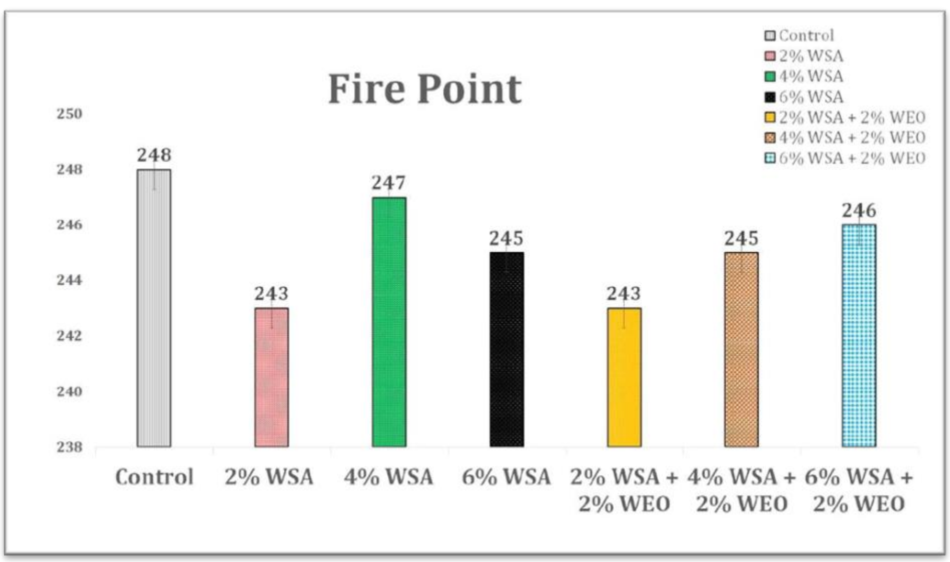

Figure 12: Graph between percentages used and Fire point

Discussion

The findings indicate that, under the test conditions given, the value of the fire point lowers as plastic WSA and WEO grow. After a 0.6% adjustment, the results for virgin 60/70 bitumen dropped to 285 from 340. The lowest temperature at which a substance ignites and burns is known as the fire point.

CONCLUSION

The research's conclusion part is provided below.

The purpose of this project is to find efficient ways to recycle waste ash and use it as a bitumen modifier for flexible pavements. Recycled waste ash has a useful use when it is put to use in asphalt pavements. The softening point, specific gravity, and other desired qualities of bitumen are greatly improved by adding around 6% processed waste ash by weight of bitumen. This enhances pavement performance and results in a little reduction in bitumen consumption. Waste motor oil and wheat straw ash are added to bitumen to enhance its qualities including penetration and softening point. For the changed blends, penetration values show a significant decline, suggesting improved resistance to temperature susceptibility. A larger amount of waste ash raises the softening point because the bitumen gets tougher and needs more heat to soften. The findings indicate that bitumen changed with less waste ash can be utilized successfully in road construction, whereas bitumen modified with more ash (more than 0.7%) would be a better fit for roofing materials. When the proportion of the modifier is increased, the ductility value lowers; however, the rate of loss is slowed down when waste engine oil is added. Road construction should not employ ductility values less than 50 cm, yet they could be appropriate for joint and crack-filling materials. Because the use of waste ash in road building helps consume vast quantities of waste ash, this procedure is affordable and advantageous for the development of infrastructure, making it ecologically benign.

Research Implications

Hot mix asphalt that contains agricultural waste ashes as a modifier has a big influence on the environment and society. The bitumen's qualities are improved by the inclusion of these ashes. This study shows that by lowering the amount of garbage dumped in landfills, employing agricultural waste ashes will be good for the environment. This method not only makes agricultural waste more valuable, but it also creates environmentally beneficial technologies.

Road building that uses agricultural waste ashes enhances ride quality and hence reduces maintenance expenses. Furthermore, incorporating these ashes into asphalt lowers air pollution, which in turn lowers illnesses linked to pollution. Since bitumen is a byproduct of petroleum residue, using less natural resources is required to meet the growing need for road building. Using varying quantities of agricultural waste ashes to modify the binder is the best way to save expenses and preserve natural resources.

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