AN EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF BITUMEN USING WASTE ENGINE OIL & CRUMB RUBBER

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Abstract- Bitumen is a strong hydrocarbon that is often used as a binding material in flexible pavement and is produced as a by-product of petroleum refineries. Bitumen is non-toxic at room temperature, although when heated between 165–200 C to cover all the aggregates, it generates a poisonous smoke which is extremely damaging to someone's health also environmental destruction, depletion of petroleum resources, and rising prices were among the consequences. Other binder sources for pavement structure will be investigated by researchers. This experiment will examine the impact of using wasted crumb rubber and engine oil to reduce emissions. The amount of bitumen used was a combination of crumbs rubber and wasted engine oil. Both Modifiers are manufactured from waste products, are easily accessible, and are low-cost. This technique of recycling these waste items reduces clutter and helps to keep the environment clean. AASHTO and ASTM standards were used to examine the rheological and physical properties of modified binders in the laboratory. To determine if the unique mixture might be utilized on an industrial level, the results will be compared to a sample group of neat bitumen. To determine the relationship between factors such as shear modulus and phase angle at different frequencies, master curves were produced. According to the study findings, bitumen could be replaced up to 12.5 percent as a sample of W5CR7.5, resulting in comparable or better performance based on rutting resistance, stability, and flow. This work directly makes a unique contribution to highway and transportation developments in the establishment of alternate materials for pavement structure by providing improved binder composition from waste resources.

Keywords- Bitumen, Waste materials, Modified binder, Pavement material.

1 Introduction

At the end of its life, the asphaltic pavement has a significant amount of value [1]. Overlays of fresh concrete mixture layers can be used to repair degraded parts in which situation the underneath old asphalt can still provide significant structural strength. In places at which modifications in ending pavement level can impair storms water draining and bridge clearance, all or a section of the affected pavement is shaved away from the sections such that the overlay's elevation conforms to the pavement surface [2]. Pavement grinding is now so common that massive amounts of Recycled Asphalt Pavements (RAP) are produced each year. RAP would either be landfilled or preserved for use in future construction projects. To conserve natural resources and to save finances, the use of RAP in asphalt binders is becoming more popular as a rehabilitation alternative. RAP substance also has been commonly used as a granular base course content in Portland and asphalt cement concrete construction, while also integrated back into asphalt mixtures for innovative pavement construction [3].

With the advancement of the Superpave efficiency grading scale, a necessity for the formation of Superpave recommendations for using RAP in asphalt pavement has recently arisen [4]. Superpave is a key product of the Strategic Highway Research Program (SHRP), which is a framework of specified requirements, testing procedures, and engineering practices that allow for the adequate selection of material as well as mixture layout of hot mix asphalt to fulfill the atmospheric and traffic patterns of road surface pavement projects. Highway engineers and builders can utilize this methodology to produce pavement that lasts longer, needs less maintenance, and has a shorter life expense than pavement planned to use earlier engineering techniques [5]. Realizing the importance of flexibility of asphalt pavement recycling as well as its potential application in Pakistan, there is an urgent need to design and establish Superpave guidance to use RAP in asphalt pavement recycling and rehabilitative operations under severe climate and loading conditions. These standards must be founded on rigorous testing of materials to assess the predicted performance of various ingredients and their quantities in asphalt binder [6].

This study examines the performance qualities of several mixes for existing grades 60-70 virgin and recovered asphalt binders from two tasks on N-5 (i.e., Mandra & Nowshera). To characterize the binder mixes according to the Superpave function graded system, extensive laboratory testing is performed (PG grades). This study only considers the low and high-temperature characteristics of Rolling Thin Film Oven (RTFO) residues as evaluated by Dynamic Shear Rheometer (DSR) and Bending Beam Rheometer (BBR). Furthermore, the mixing charts and master curves are produced as guidelines for PG grade determination and prospective asphalt pavement recycling and rehabilitation operations in Pakistan.

2 Experimental Procedures

Bitumen Pen 60/70 was chosen to determine the physical properties of both the modified asphalt binder and make a comparison to the properties of the pure bitumen binder. Different types of physical tests such as the ductility test (ASTM D113), softening point test (ASTM D36-06), penetration test (IS:1203-1978), and viscosity test was carried out (IS 1206-PART-2). The procedure of Preparation of some experimental samples is shown in **Figure 1**. The purpose of this study was to compare the effects of crumb rubber and waste motor oil on the rheological performance of asphalt binders. The AASHTO T315 Dynamic Shear Dynamometer test was carried out. The phase angle, viscous and elastic components termed loss modulus and storage modulus were all determined using a dynamic shear rheometer. The rheometer test is carried out to study the effect of bitumen aging at different temperatures on its performance at different frequencies in terms of Phase Angle versus Complex Modulus.

Figure 1: Preparation of Sample

As shown in **Table 1,** test samples of various bitumen ratios were prepared with the replacement of waste engine oil and crumb rubber.

Table 1 Mix Design Ratio of samples

Sample ID	Bitumen Type	Binder %	Waste Engine Oil %	Crumb Rubber%
Virgin (W0CR0)	Pen 60/70	100	0	0
W5CR5	Pen 60/70	90	5	5
W5CR7.5	Pen 60/70	87.5	5	7.5
W5CR10	Pen 60/70	85	5	10
W7.5CR5	Pen 60/70	87.5	7.5	5
W7.5CR7.5	Pen 60/70	85	7.5	7.5
W7.5CR10	Pen 60/70	82.5	7.5	10

3 Research Methodology

Before the start of experimental work detail, literature studies were performed. Experimental work involved sample preparation with two different materials including waste engine oil and crumb rubber. The raw material including waste engine oil and crumb rubber was collected from local workshops, Bitumen material of Pen 60/70 was also procured. After that test doses of 0,5%,7.5%, and 10% of waste engine oil and crumb rubber were given in replacement of neat bitumen as shown in **Table 1**.

3.1 Selection of materials

The most important aspect of developing a customized alternatives binder is material selection. Materials were chosen based on their availability and cost-effectiveness. The following materials were used to make samples.

i. Bitumen 60/70 (Penetration grade)
ii. Waste Engine oil.
iii. Crumb Rubber.

3.2 Laboratory evaluation

Laboratory tests were separated into two categories to assess the qualities of modified binder samples and compared them to the behavior and properties of neat sample bitumen 60/70.

i. Physical test

The viscosity test, penetration, and softness point elasticity were used to determine physical attributes. Physical testing results supported the research by determining allowable combining ratios of crumb rubber and waste engine oil. Results of the physical test are shown in **Figures 2,3,4** and **5**.

ii. Rheological test

In this study, a dynamic shear rheometer test was used to analyze the rheological properties of the sample to identify rutting requirements and fatigue. The viscoelastic properties of bitumen were determined using a Dynamic Shear Rheometer (DSR). DSR can measure the sample's phase angle (δ) and complex shear modulus (G*).

4 Results

4.1 Physical test

Physical test reviled that by replacing the Waste Oil and Crumb Rubber Content in greater content samples softening points were found decreasing and Penetration depth found in an increasing trend as shown in **Figure 4** and **Figure 2** respectively. Also, by increasing cooking oil waste the sample becomes less viscous and increasing the content of crumb rubber results in more viscose as shown in **Figure 3** but overall, these additives enhance the working abilities of the binder. **Figure 5** shows that the sample's ductility may vary with a change in the composition of both additives as by increasing the percentage of crumb rubber due to its elastic nature, the sample shows more ductile behavior but by increasing the percentage of waste engine oil the sample's elastic limit may decrease up to certain limit.

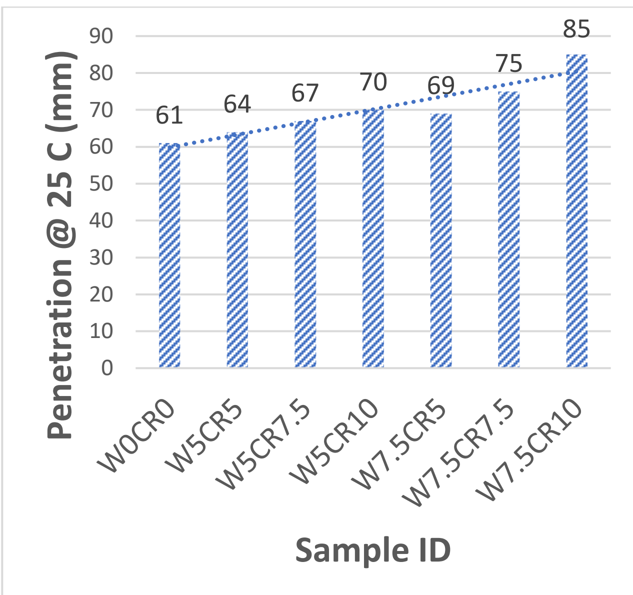

Figure 2: Penetration Test results

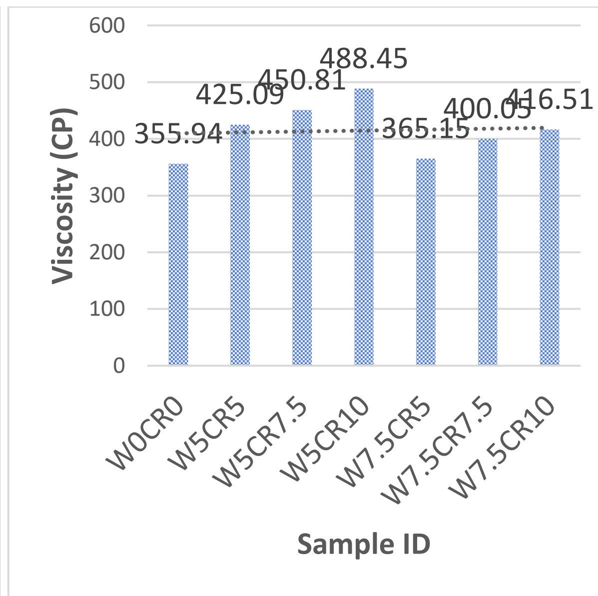

Figure 3: Viscosity Test results

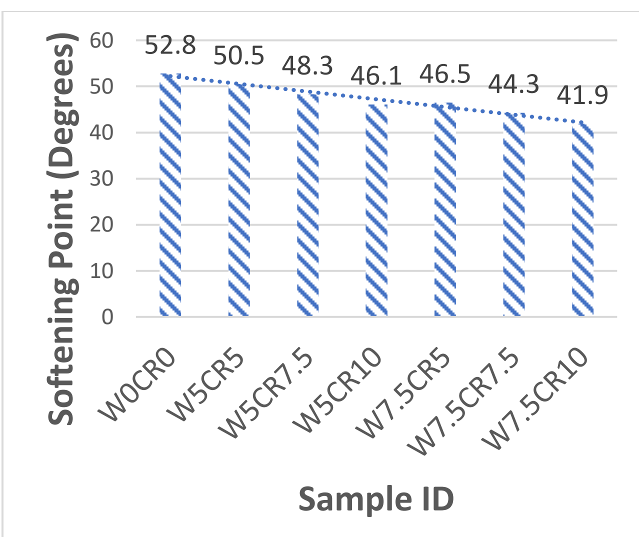

Figure 4: Softening Point Test results

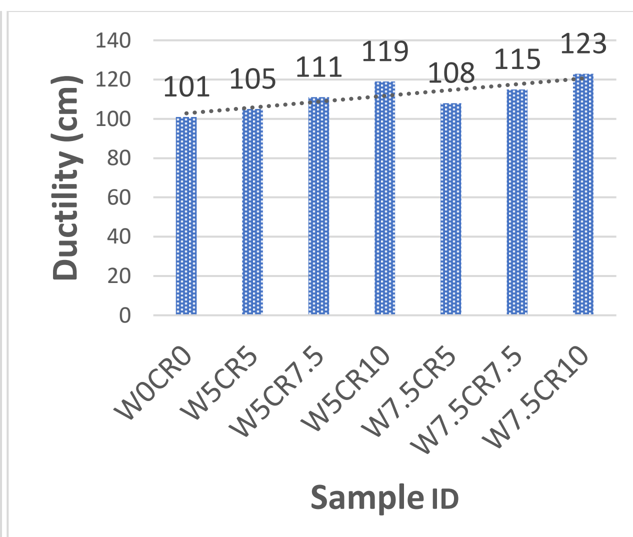

Figure 5: Ductility Test results

4.2 Rheological test

Results shown in **Figure 6** indicated that under a specific loading frequency, the complex modulus decreases with an increase in temperature. In contrast, at a given temperature, it increases with an increase in frequency. This demonstrates that the viscoelastic properties of the elastic component decrease over the temperature range from 22°C to 74°C. The phase angle values of the binders were primarily in the 39° to 87° range. These values of phase angles for both asphalt binders and mixtures confirm the results of previous research and are in accordance with their limits.

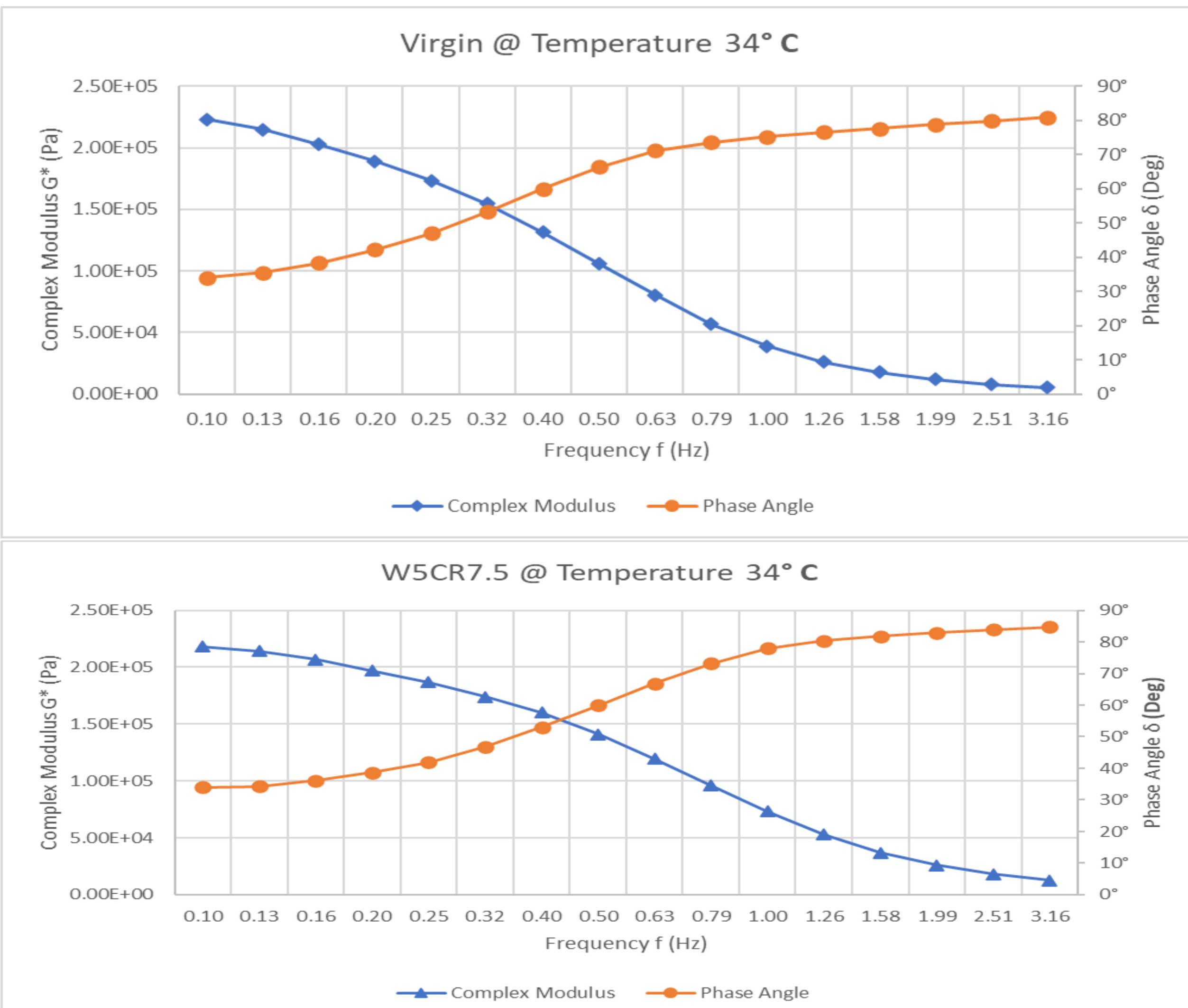

Figure 6a & 6b: comparison of virgin sample @ 34^{Oo} and W5CR7.5 @ 34^{O}C

The black diagram in **Figure 7** of the Virgin sample vs W5CR7.5 indicates linear trends in results. We can see from this comparison shown in **Figure 7** that by adding W5CR7.5 with bitumen, the value of complex modulus rises from a high value that indicates the improved performance of the binder sample.

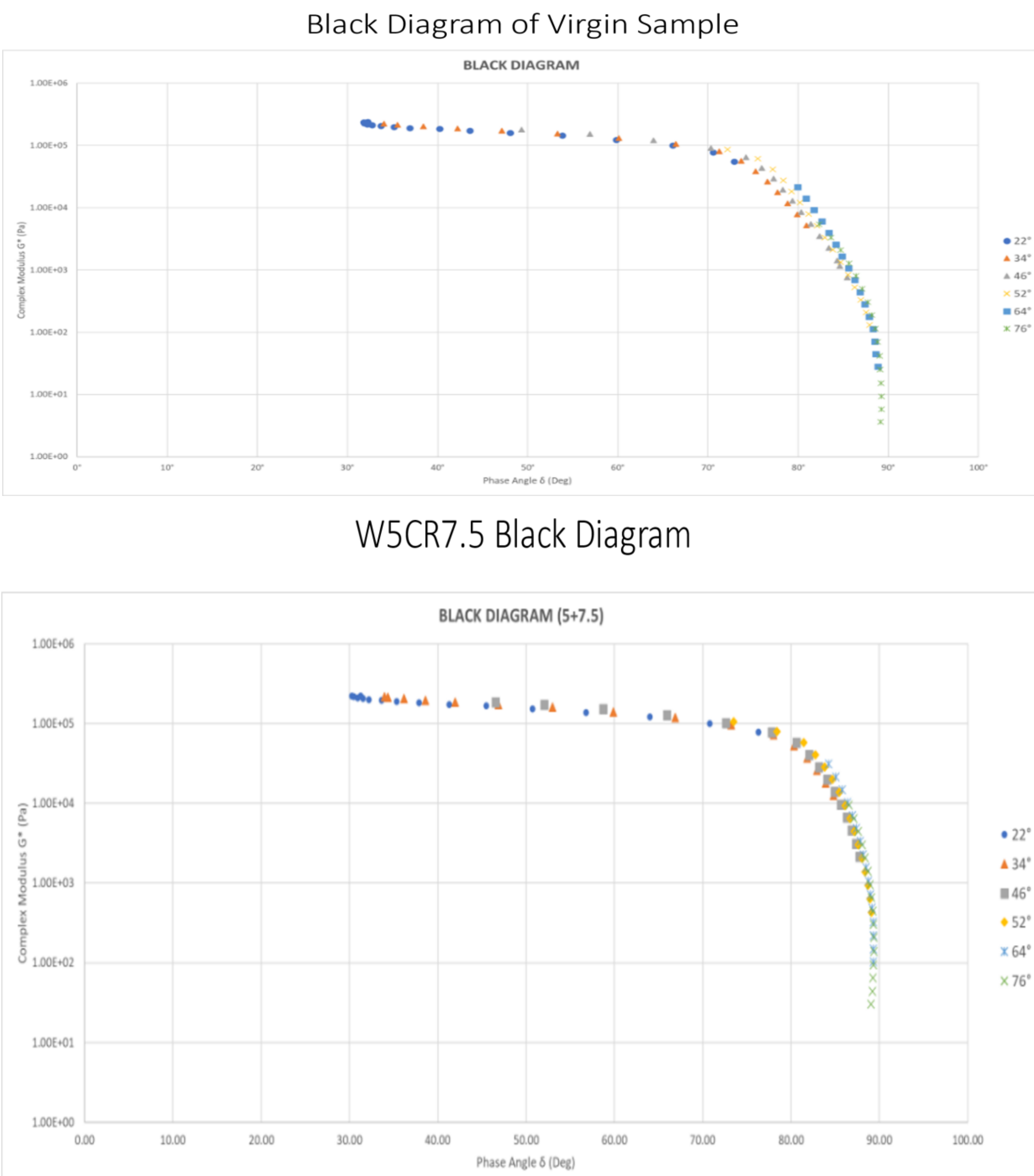

Figure 7a & 7b: comparison of black diagram of virgin sample and W5CR7.5 @ temperature ranges from 22º-76º

Master curves were created for the examination of the relationship between complex modulus and phase angle at different frequency levels using neat bitumen with engine oil and crumb rubber under various time and temperature circumstances as shown in **Figure 8**. Results indicated that temperature and loading frequency had a significant impact on asphalt's physical behavior.

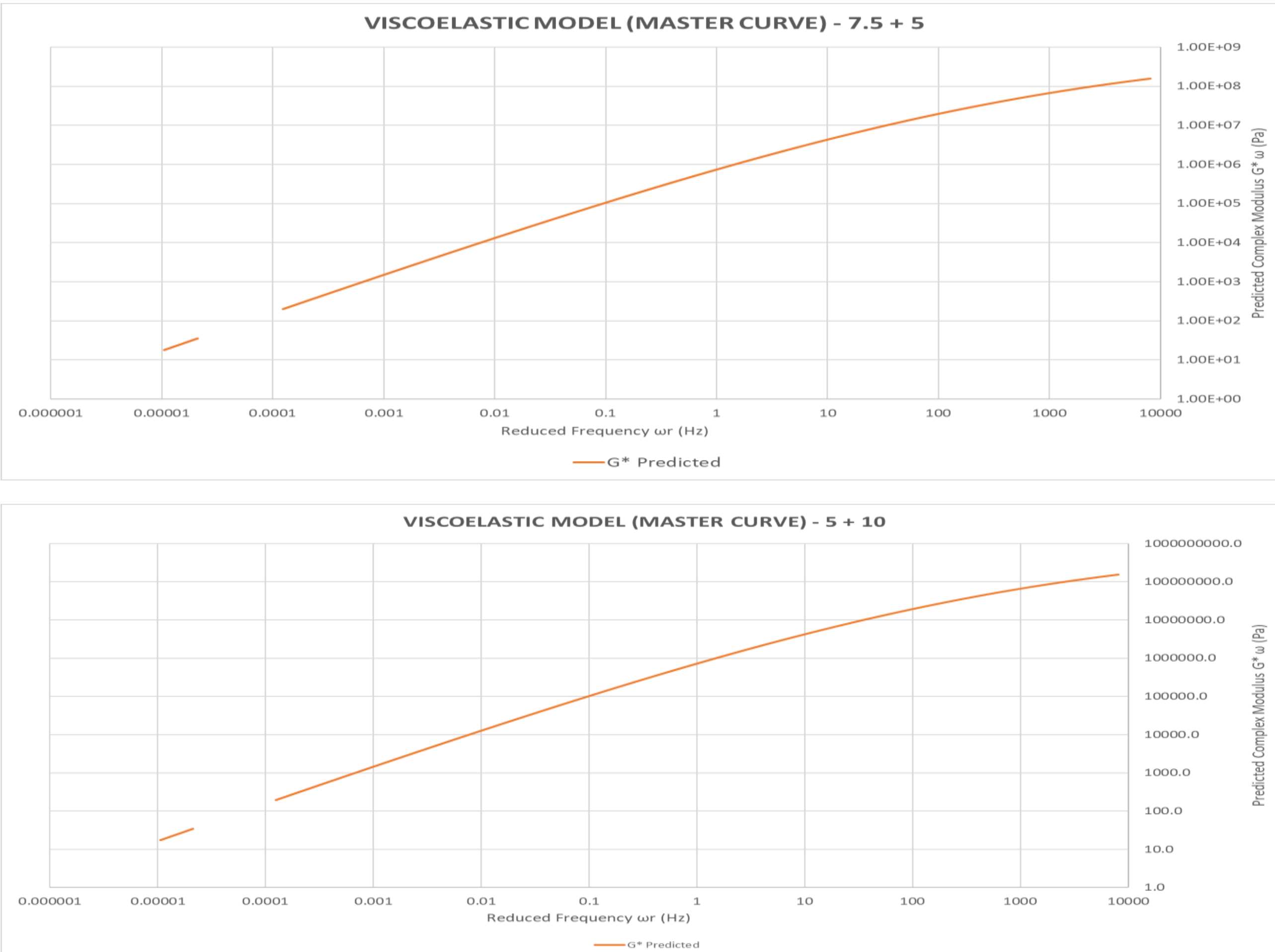

*Figure 8a & 8b: comparison of Master Curve of virgin sample and W5CR7.5 to find Predicted Complex Modulus G**

5 Conclusion

The research has led to the following conclusions:

1. From a detailed study of the physical properties of the modified sample of engine oil and crumb rubber with neat bitumen, it is revealed that by increasing cooking oil waste the sample becomes less viscous and increasing the content of crumb rubber results in more viscose but overall, they enhance the abilities of the sample if added up to some limit.
2. It is also concluded that by replacing the Waste oil and Crumb Rubber Content in greater content samples Softening points were found decreasing and Penetration depth was found in increasing trend.
3. From the rheological properties study, it is also observed that the Complex Modulus which is resistant to deformation for a mix of Waste Engine oil and crumb rubber has shown greater value up to 34° resulting in better performance as compared to the virgin sample.

4. It is concluded from the black diagrams that by increasing additive as in the case of W5CR7.5 up to certain limits black diagram has shown a linear trend indicating consistent behavior of binder which results in a good performance.

Finally, it is concluded that the replacement of engine oil and recycled crumb rubber with bitumen is a very useful technique to meet the industry requirement and utilizing this waste material will help a more significant cause to protect the environment.

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