CRUMB RUBBER AND WASTE ENGINE OIL MODIFIED BITUMEN

A THESIS SUBMITTED BY

Muhammad Fahad Ali (Group Leader)	18CE62
Abdallah Khaled Awwad Alzyod (AGL)	18CE80
Muhammad Abed Al Ra'of Oweyad Al-Shar'e	18-17CE82

UNDER SUPERVISON OF

PROF. Dr. Rizwan Ali Memon

Thesis report submitted in the partial fulfillment of the requirements for the degree of Bachelor of Civil Engineering

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CERTIFICATE

This is to certify that work presented in this thesis on **"CRUMB RUBBER AND WASTE ENGINE OIL MODIFIED BITUMEN"** is submitted in partial fulfillment of the requirements for the degree of Bachelor of Civil Engineering by the following students:

Muhammad Fahad Ali (Group Leader)	18CE62
Abdallah Khaled Awwad Alzyod (AGL)	18CE80
Muhammad Abed Al Ra'of Oweyad Al-Shar'e	18-17CE82

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PROF. Dr Rizwan Ali Memon

(Supervisor)

__________________________ __________________________

(External Examiner) (Chairman)

Department of Civil Engineering

Dated: ____________________

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DEDICATION

We dedicate this thesis to the Last Prophet Muhammad (PBUH) who's teachings are the nexus of our conduct. Additionally, this research is dedicated to faculty of civil engineering. Further, we extend this research to our supervisor, Prof. Dr. Rizwan Ali Memon, whose constant support, and unique way guidance made this research in the best way possible. Finally, we sympathize with all the flood affected fellow nationalists of Pakistan during rain floods of 2022.

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List of abbreviations:

CR	Crumb Rubber
WEO	Waste Engine Oil
EO	Engine Oil
LDPE	Low Density Polyethylene
HDPE	High Density Polyethylene
AASHTO	American association of State Highway and Transportation Officials
ASTM	American Society for Testing Materials
NHA	National Highway Authority
WEO-CTR-MB	Waste Engine Oil and Crumb Tyre Rubber Modified Bitumen
MB	Modified Bitumen
LLDPE	Linear Low-Density Polyethylene
RLLDPE	Recycled Linear Low-Density Polyethylene
EVA	Ethylene Vinyl Acetate
PVC	Poly Vinyl Chloride
PET	Polyethylene Terephthalate
AC	Asphalt Concrete
PMB	Polymer Modified Bitumen
SBS	Styrene Butadiene Styrene
SP	Softening Point

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ABSTRACT

Bitumen has been widely used in the construction of roads due to its black color and sticky consistency. Furthermore, its versatility and thermoplastic properties contribute to its popularity. The increasing traffic on our roads, global warming, and ever-changing pressures on pavements have made predicting the road life of the roads an arduous and challenging task in recent years. While the pavement industry moves towards a more sustainable future, a number of research areas are seeking to reduce its consumption of natural resources and finite resources, as well as to recycle waste materials. A significant amount of waste engine oil (WEO) from a wide variety of automobiles, as well as tyres from various vehicle types, is disposed of as hazardous wastes. Moreover, heavy metals and a large amount of capital are required to treat these materials in a sustainable manner. This study thus aims to investigate whether enhanced modified bitumen can be produced by using waste engine oil combined with waste rubber, in the form of crumbs (CTR), thereby reducing the amount of bitumen used and transforming bitumen into a sustainable material. As a result of this study, the goal is to determine whether enhanced modified bitumen can be produced by combining waste engine oil with waste rubber, in the form of crumbs (CTR), in order to reduce the amount of bitumen used as well as make bitumen a more sustainable product. In order to compare the properties of modified bitumen with the properties of virgin bitumen, tests were conducted. Upon further investigation, it has been discovered that the modified bitumen demonstrates promising results in terms of the physical properties of the material as a result of the changes made to it.

CHAPTER NO.01

INTRODUCTION

1.1. INTRODUCTION

Economy of a country moves on the wheel; rather the wheel be industry or vehicle. Economic development of a region can be symbolized in the growth of the number of vehicles [17]. The world map is a clear insight of countries having strong economy also have well-developed road infrastructure. Since the 1900s, worldwide roads and highways have been quickly expanding [16], resulting in greater traffic on the road and, as a result, a significant rise in tyre manufacturing. As Pakistan's population has grown, so has the number of automobiles on the road. This growing number of automobiles is wreaking havoc on existing road infrastructures, generating discomfort and breakdowns, as well as pollution emissions and landfills [15]. It can be established that road span and number of tires are function of each other as the track length spans larger the aggregate of vehicles also multiplies. As a result, the production of tire increases [15]. The problem with exacerbating the volume of tires is dumping the augmented number of tires because these require an ample space and remain a perpetual threat to the environment. if left untreated, these are prone to the fire hazard and are the breeding place for mosquitos. if these huge stockpiles are incinerated or caught in the fire, these continue to ignite for many weeks exhausting acrid black plume polluting the environment and planet health. Tires blaze with higher per-pound energy output compared to the coal, and extinguishment becomes very arduous due to the high heat production of rubber tires. To preserve the environment from adverse impacts of waste rubber tires, reprocessing of rubber tire is indispensable. Recycling of these waste tires is a technique in which tires which have completed their service life by wear and tear on roads and can now be exploited again in some other form instead of burning or dumping and leaving the environment in peril. Larger rubber tires are torn apart in the cracker mill, which reduces their size by allowing them to pass between rotating corrugated steel drums. As a result, particles having larger surface area and irregular shape are manufactured and are termed as crumb rubber. Different characteristics of bitumen employed to manufacture crumb modified bitumen (CRMB) are also indispensable lineaments for the ultimate quality of final product [21].

On the other hand, as the number of cars grows, so does the amount of waste engine oil produced. Waste oil is generated in a range of industries, including the manufacturing, automotive, aviation, and marine sectors. The presence of metals and other pollutants in waste oil has major negative consequences for the environment and human health [20].

The most important principle of development now a day is inclined to sustainable advances across the world. To develop material and methods for preservation of natural resources, in a way that not only the demands of the current generation but also the coming generations are fully met without depleting the resources. Sustainable development is thought to be the principle to resource consumption. The road pavement industry, without a doubt, is an industry that has a long-term environmental effect, with bitumen, a petroleum-based binder, as one of the most prevalent components. Commercial modifiers such as fillers, extenders, polymers, fibers, antioxidants, etc. are utilized in bitumen for better performance, however, the cost benefit ratio of such bitumen mixes decreases with their use [19]. Therefore, it is necessary to have substitute modifiers which could improve the properties of bitumen, and which will not exacerbate the price of bitumen mixes. Thus, the utilization of wastes as modifiers for bitumen modification is much hotter topic in the pavement research world.

1.2. AIM

This research study aims to find the ramifications of Crumb Rubber and Waste engine oil in bitumen when both used as an additive.

1.3. OBJECTIVES

This thesis study aims to study the physical properties of bitumen when modified with waste engine oil and crumb rubber.

I. To determine and compare the physical properties of bitumen when modified with waste engine oil and crumb rubber.
II. To find the optimum content of waste engine oil and crumb rubber for effective use.

1.4. SCOPE

Scope of this study is limited to only five conventional tests on modified and conventional bitumen. No material other than bitumen, crumb rubber, and waste engine oil is used in this study.

1.5. PROBLEM STATEMENT

Pakistan is progressing rapidly, as a result, it puts an effort to keep up with the expansion of its road network. Poorly constructed roads have resulted from ineffective construction due to irregularity and malfeasance. Additionally, the effects of global warming have made predicting the life of a road considerably challenging. Furthermore, another concern that would have a negative impact on the road is ever increasing level of serviceability. Constant pressure on the road generates fatigue, which leads to the collapse of the pavement surface. Bitumen, which is utilized as a binder in asphalt pavement, softens in hot weather and hardens in cold weather. Greater stiffness at rising temperatures, higher cracking resistance at lower temperatures, improved moisture resistance, and fatigue service life are all benefits of bitumen modification.

In Pakistan, maintenance can be problematic due to limited resources, on other the hand, the country also has trouble of disposing garbage, particularly waste tires resulting in massive garbage sites around densely populated areas, which spreading diseases like malaria. Rubber tires could be recycled and used to change the properties of bitumen. Furthermore, in Pakistan, a large amount of waste engine oil from various automobiles is disposed of as a hazardous waste into the atmosphere contaminating water as a result posing threat to the marine life. In a nutshell, bitumen modification with this waste material such as crumb rubber (CR) and waste engine oil (WEO) can be cost-effective. However, to tackle both concerns, a new strategy based on utility of waste material should be devised.

CHAPTER NO.02

LITERATURE REVIEW

2.1. BITUMEN

As light fractions like liquid petroleum gas are separated from heavy crude oils, bitumen is formed [18]. This is a viscous, sticky material made up of a mixture of organic fluids with a black color. Over 110 million metric tonnes of asphalt are required around the world [1]. For the building and maintenance of road infrastructures, the Pavement sector requires a significant amount of finite and natural resources, such as bitumen and aggregates [7]. Bitumen, in simple terms, is a liquid binder that keeps asphalt together.

2.2. VARIOUS FORMS OF BITUMEN

A variety of bitumen types are available which have distinct physical, chemical, and mechanical properties with different specifications and their consumption mainly depend upon needs of consuming industry. Distinct bitumen specifications also inhibit subsequent variance with the safety, physical properties, solubility, and the service life. Following are few varieties of bitumen briefly explained.

2.2.1. Penetration Grade Bitumen

This sort of bitumen is made at refineries and comes in a variety of viscosities. The penetration test is used to characterize the bitumen and is performed based on its hardness. As a result, it's known as penetration bitumen. For road paving, penetration bitumen comes in grades ranging from 15 to 450. However, the most common range is 25 to 200. As a control factor, the distillation process is critical. Furthermore, by partially regulating the fluxing of leftover bitumen with the oils, the desired hardness may be produced.

2.2.2 Bitumen Emulsion

This type of bitumen is considered to be ideal for hilly roads. More preferably on locations where heating is difficult. It is a combination of fine driplets of bitumen and aqua. Since the bitumen is a petroleum product, therefore, it does not mix with water. It doesn't easily get disintegrated into fine driplets because it’s sticky in nature. For this reason, an emulsifier is utilized. Emulsifiers are surface-active agent which induce negative charges on bitumen droplets to produce the repulsive action in mix. Emulsifier maintain the bitumen in its fine driplets state by no allowing it to mix with other driplets. As the driplets are very fine they remain suspended in water. Emulsion bitumen contain 60% of bitumen and remaining portion is water. When emulsion bitumen is applied on road these start to break down in form of water and start to mix. The setting time shall depend upon the grade of bitumen.

2.2.3. Cutback Bitumen

This kind of bitumen has a pro tem low viscosity due to addition of an oil of volatile nature. This volatile material gets evaporated after the application and original viscosity of bitumen is restored. Its viscous behavior is different for different temperatures. During pavement construction, this is substantial for the material to be in liquid state at the time of placing. More importantly, it must regain its original characteristics after complete setting is achieved. Moreover, the fluidity of bitumen is adjusted by changing the temperature to higher scale. It utilized in colder regions. Naphtha, kerosene, Furnace, and diesel oil refineries are commonly used for preparation of cutback bitumen. This again is divided into three other types:

- **a.** Rapid Curing: commonly used for dressing the surface and working on the patches.
- **b.** Medium Curing: used when mixing with lower of amount of fine aggregate is needed.
- **c.** Slow Curing: used when mixing with higher of amount of fine aggregate is needed.

2.2.4. Bituminous Primer

This type of bitumen is mainly used for stabilizing the surface. Road surface absorbs the distillate. Absorbance capacity is influenced by the porosity of road. This can easily be prepared on construction site by mixing penetration bitumen and distillate.

2.2.5. Modified Bitumen

When compared to regular bitumen, this kind of bitumen has better performance. To increase its qualities, several chemicals are added. Bitumen has been modified using waste materials such as plastic bags and crumb rubber to improve its properties [8,9]. Waste engine oil (WEO) and 10-15% crumb rubber (CR) will be used as bitumen modifiers in this study to improve bitumen characteristics. The fundamental features (penetration values and softening point temperatures) of bitumen treated with 20% CR and 7.5 percent EO were demonstrated to be the most promising [4].

2.3. REQUIREMENTS OF BITUMEN

Following are properties of bitumen which should be expected form a high-quality bitumen.

- **Adhesion:** Bitumen must be able to bind different materials together in a proper manner without disrupting the characteristics of added materials.
- **Waterproof:** Insufficient water-resistive property lowers service life, reduces bitumen strength, and decreases adhesion. therefore, bitumen should be high resistant to the aqua.
- **Strength:** Strength also depends upon filler materials. However, the binding material, bitumen, must also have adequate strength to withstand various loading conditions.
- **Durability:** The binder should hold filler material together for longer span. Durability is a function of various variable such type and grade of bitumen, environmental and climate conditions, and surface conditions.

- **Versatile:** Bitumen should be effective (workable) throughout the construction stage, and it must remain rigid during the operation stage.
- **Hardness:** Hardness of bitumen is defined in penetration value and grade. Various grades of bitumen having different penetration value are incorporated depending upon the climatic conditions and functional requirements.
- **Softening Point:** Softening point value of bitumen vary with different grades.
- **Ductility:** Ductility refers to the ability of bitumen to permit it to go through deformation up to a certain extent. This also depends upon grade of bitumen, the temperature, etc.
- **Viscosity and Flow:** Bitumen viscosity should be optimum. This mean that it should neither be less viscous nor very high viscous because high viscosity brings many complexities during application and lower viscosity causes inadequate binding of materials as these flows at quicker rate.
- **Loss on heating:** During heating of bitumen, the volatiles are left out as a result, loss in mass occurs. It is recommended that the loss of bitumen due to heating must be bare minimum.

2.4. CRUMB RUBBER

Crumb rubber is recycled rubber which is produced from automotive and truck scrap tires. First, tires are shredded and then these are processed into small particles by a fine grind and with the help of magnets steel is separated out [22]. The fabrics are separated by air separators. Finally, oversize granules are separated by Screening process to produce the same group and grade of crumbs [23].

Vehicle tires are often disposed in landfills, which can have negative environmental consequences [22]. Tires on vehicles cannot be bridged. Despite this, more than a billion tyres are discarded each year [22]. Organic and inorganic chemical components, each with a specific concentration and amount, are found in waste tyres. As a result, proper waste tyre disposal is essential. Burning tyres releases hazardous chemicals that are harmful to human health [24]. There are numerous options for dealing with old tyres, including recycling, reusing, and recovering raw rubber resources [22]. Crumbling rubber and using it in pavement and building materials might be a good way to reduce waste rubber in landfills while also providing value to the construction industry [22]. Crumb rubber raises the softening point temperature, increases bitumen viscosity, and lowers the penetration value [11]. When different grades of CTR are employed, the properties fluctuate substantially. The results revealed that the CTR gradation has a substantial influence on the performance of the CRMB final blend. In comparison to the coarser gradation, which gives a greater elastic response due to its particles' stability in the swelled state, finer particles dissolved (or partially dissolved) in the bitumen during the blending process, lessening the final CR blend's elasticity (elastic recovery). As a result, we may estimate that we'll need to use a coarser CR – #30 gradation in our investigation.

2.5. WASTE ENGINE OIL

WEO undergoes a number of chemical and physical changes over time, causing it to vary chemically and physically from new oil. Waste engine oil recovered engine oil bottoms, and re-refined engine oil bottoms (REOB) have all been studied as bitumen extenders or modifiers [12]. When compared to fresh EO, WEO includes more gasoline, additives [25], and heavy metals such as Fe, Cd, Cr, Pb, and other heavy metals [26], as well as Mg and Zn. When these metals are dumped into ground or water sources, they pollute groundwater and soil [27]. WEO also oxidises (combines chemically with oxygen) to form a number of other chemicals. WEO is made up of a variety of chemical compounds with molecular weights less than 200 g/mol, implying that low molecular weight molecules are the main constituents of waste engine oil. The major chemical components of WEO are assumed to include aromatic solvents, paraffin oil, and polyolefin oil, all of which are similar to asphalt aromatics [28].

2.6. VARIOUS STUDIES CONDUCTED ON CRUMB RUBBER AND WASTE ENGINE OIL BITUMEN MODIFICATION

While EO inclusion in bitumen has certain advantages, Sara, et al. [4] reported that the matching binder may lack the necessary qualities to be utilized directly in asphalt mixtures, especially at high service temperatures, resulting in significant permanent deformations. Polymers should thus be used in conjunction with these binders. Polymers are compounds that help bitumen withstand long-term deformation and heat vulnerability.

Kamoto, et al. (20200 [2] investigated bitumen production utilising used engine oil, suitably sized tires and coal tar. Impurities were eliminated from the three basic ingredients by shredding and reducing the size of rubber tires. For example, the most likely combination might be 20% lubricating oil, 50% crumb rubber, and 30% coal tar. At room temperature, the final sample was a pure black semi-solid in phase. The technique involved heating and mixing the ingredients using a high-speed shear mixer. The oil heats and melts the crumb rubber, causing it to depolymerize and disintegrate, yielding standard-quality bitumen [2]. While bitumen and rubber are fundamentally different, both may be used as basic materials.

To conclude the use of crumb rubber as an addition in asphalt concrete mixture, use of Crumb Rubber as an Additive in Asphalt Concrete Mixture was conducted by **Wulandari et al. (2016) [3]**. In the study, crumb rubber improved the strength and quality of an asphalt mixture. It has been found that crumb rubber modified asphalt requires less asphalt. Low asphalt concentration, on the other hand, increases the quantity of air space in the mixture, increasing permeability while lowering durability.

Distinct grades of CR have significantly different properties, according to **Jamal et al. (2021) [29].** The findings demonstrated that CR gradation has a substantial influence on the CRMB final blend's performance. During the blending process, the finer particles, in the bitumen, there are substances dissolved (or partially dissolved) that are less thermodynamically stable. Due to the particles' stability in the swelling state, the finer grade has a lower elastic response, so this further reduces the elasticity (elastic recovery) of the final CR mix. Therefore, we may deduce that a coarser gradation (CR – #30 mesh) is necessary for this inquiry.

By mixing waste motor oil products with polymers, **Sara et al. (2017) [4]** generated better modified bitumen. According to the researchers, bitumen changed using waste motor oil products and polymers had the same penetration values and softening point temperatures as commercially modified binders. The research focuses on developing innovative modified binders with a high waste content, such as EO or RB (as partial bitumen substitutes) and polymers (waste HDPE, waste CR and SBS). As a result of this study, we discovered new alternative binders that perform equally well or better than bitumen. Some of the findings are as follows: It is feasible to partially replace basic bitumen with EO or RB mixed with polymers. The most promising fundamental qualities (penetration values and softening point) were exhibited by a handful of investigated binders, such as those modified with 6% HDPE and 10% EO or 15% RB, 5% SBS and 10% EO or 12.5% RB, and 20 percent CR and 7.5 percent EO or 15% RB.

Aaron, et al. (2008) [5] studied asphalt modification using lubricating oil and observed that increasing the oil level resulted in softening of asphalt materials as well as low-temperature-grade enhancements such as enhanced penetration and decreased softening point.

According to **M. R. Ibrahim et al. (2013) [6]** the crumb rubber modification improves bituminous binder characteristics such as viscosity, softening point, loss modulus, and storage modulus. As a result, the rutting resistance, toughness, and fatigue cracking resistance of asphaltic mixes improve. In order to achieve a superior and balanced CRMB in terms of high and low temperature properties, key aspects such as mixing time, temperature, crumb rubber and bitumen type source, and mixing time, temperature, and crumb rubber and bitumen type unique properties must be factored in, as these are the variables that govern the resulting efficiency of asphaltic mixes. It's also critical that the completed CRMB has the appropriate viscosity.

According to **A.I. Al-Hadidy et al. (2019) [10]**, adding plastic wastes to bitumen lowers penetration values and elevates the softening point temperature. Because of an increase in permanent deformation and fatigue resistance, the stability and longevity of the essential asphalt mixes are increased. .

Using WEO enhances penetration and decreases bitumen softening point temperatures and viscosity, decreasing manufacturing and compaction temperatures of asphalt mixtures, according to **X. Jia et al. (2014) [13]**. However, the elastic recovery and permanent deformation resistance of these materials may be impaired because of their incorporation [13], demanding careful mix design.

S. Rubab et al. (2011) [14] investigated the impacts of motor oil remnants on asphalt cement quality and discovered that the modified binder including recovered engine oil bottoms had abnormal ageing, which might contribute to early pavement cracking. At ambient temperatures (10–40°C), heavy-weight fractions, such as asphaltenes, offer bitumen visco-elastic qualities, whilst light-weight fractions, such as oils, serve as a carrier for the asphaltenes and resins. [35]

Shen and Amirkhanian (2005) [30] observed that for 15 percent of rubber crumb, a 15-minute mixing operation at 177°C is enough to fully react with the binder. rubber crumb size between 30 and 40 mesh rubber crumb size between 30 and 40 mesh rubber crumb size between 30 and 40 mesh rubber crumb size between 30 and 40 mesh rubber crumb size between 30 and 40 mesh rubber crumb size between 30 and 40 mesh rubber crumb size between 30 and 40 mesh rubber crumb size between 30 and 40 mesh rubber crumb size between 30 and 40 mesh rubber crumb size between 30 and 40 mesh rubber crumb size between 30 and 40 mesh rubber crumb size between 30 and 40 mesh rubber crumb size between Jeong et al. [31] found that a longer blending duration of up to 60 minutes and a mixing temperature of roughly 177°C can result in a higher failure temperature and binder viscosity at 135°C for a 10 percent crumb ruber combination.

Fine rubber crumb was recommended by **Attia and Abdelrahman (2009) [32]** for producing CRM terminal mixes. This method saves energy since only 8% of the contact time necessitates a high temperature of 200°C, while the storage phase may be done at a lower temperature. According to Billiter et al. [33], increased mixing temperature can reduce mixing time and shear rate, resulting in a more uniform and totally elastic final blend with improved performance.

The viscosity of CRMB increased as the temperature increased. When **Jeong et al. (2010) [34]** compared the viscosity of a binder mixed at 177°C to one mixed at 200°C, they found that the viscosity increased by 5% at 200°C and 41% at 223°C. Researchers discovered that blending the binder for 5 minutes increased viscosity by 11 percent, while mixing it for 480 minutes increased viscosity by 46 percent. Furthermore, the temperature difference between binder mixed at 177°C and binder mixed at 200°C was found to be minor. As the mixing time extended to 60 minutes, the failure temperature rose. The failure temperature was shown to be unaffected by mixing time after 60 minutes.

The viscoelastic characteristics and amount of crumb rubber swelling in CRMB were studied by **Ould Henia and Dumont (2021) [35],** who combined pure bitumen with different saturates, aromatics, resins, and asphaltenes. Because aromatic oils operate as lubricants for asphaltenes, bitumen with a greater aromatic content has a higher viscosity and is more temperature sensitive than bitumen with a lower aromatic content.

CHAPTER NO.03

METHODOLOGY

3.1. OVERVIEW

Rigid pavement and flexible pavement are the two most common forms of road pavement. Flexible pavement is extensively utilized across the world, including in Pakistan, since it is less expensive and more flexible than rigid pavement. Flexural moment is not produced by flexible pavements. Aggregates and filler are utilized as components in flexible pavement bitumen. Bitumen is only utilized in small amounts (4% to 6% by weight of asphalt), but it acts as a binder that improves engineered pavement performance more than aggregates. The properties of bitumen are largely responsible for the engineering performance of flexible pavement. Because of this, flexible pavement loses its elasticity and cohesion over time, resulting in rutting and pavement cracking.

This phenomenon happens when bitumen is exposed to extremes in temperature. It's also vital to improve bitumen performance to prevent rutting, peeling, and cracking of pavement. We blend waste motor oil and crumb rubber with bitumen (grade 80/100) as a result. Bitumen is a semi-solid hydrocarbon product that is made by refining crude oil and removing the lighter components. This is a sticky, black-colored substance made up of a viscosity-high combination of organic liquids. Bitumen is a tar-like kind of petroleum that, in its natural condition, is too thick and heavy to use without being heated or blended with other elements to create a new substance for the required use.

3.2. CRUMB RUBBER

Crumb rubber was acquired from (name site here), Pakistan, in the ground form of scrap rubber tyres. This investigation employed CR #30 mesh since it is more thermally vulnerable. When EO is used alone in bitumen, it may not have the qualities needed to be employed in asphalt mixtures, particularly at higher temperatures, which could lead to large permanent deformations. As a result, these binders should be used in conjunction with polymers. Crumb rubber is utilized in our research.

3.3 WASTE ENGINE OIL

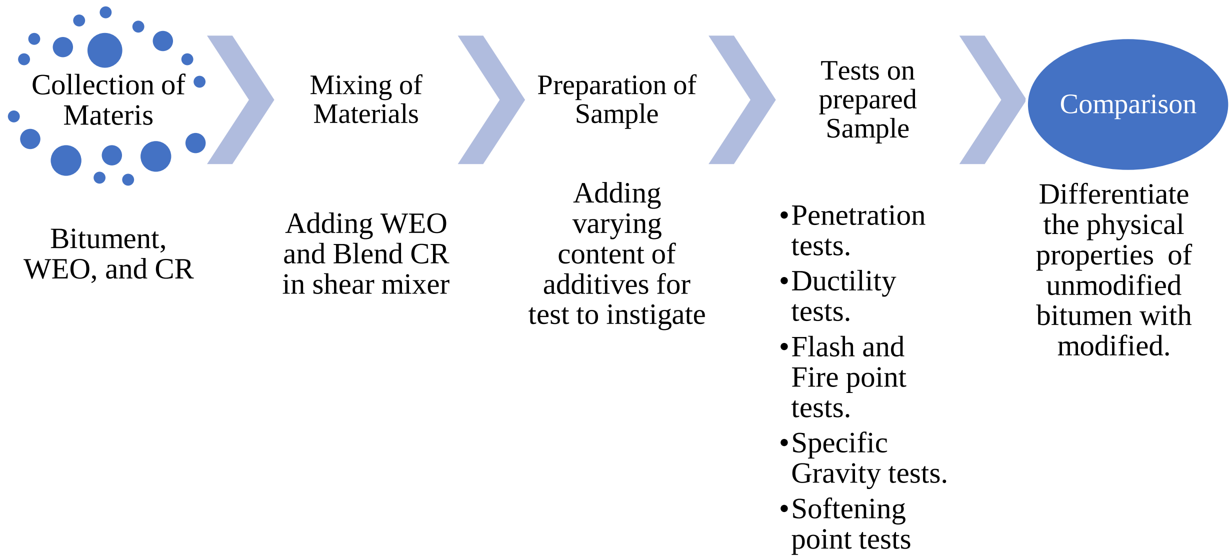
In comparison to new engine oil, waste engine oil contains significantly more fuel, additives, and heavy metals. When these metals are dumped into ground or water sources, they pollute the groundwater and soil. WEO may also interact chemically with oxygen to generate a range of chemicals. Furthermore, waste engine oil contains aromatic solvents, paraffin oil, and polyolefin oil, which are like asphalt aromatics. Various amounts of waste motor oil will be used in this investigation, ranging between 3% to 9%.

3.4. RESEARCH METHODOLOGY

This research will be in five different phases. First phase will include the collection of materials. The materials incorporated in this study are bitumen, crumb rubber and waste engine oil. Second phase will cover mixing of materials. Third phase will work on the preparation of distinct samples. Fourth phase will focus on the tests to be conducted on proportioned sample mixes in phase three. And finally, in phase five, the test results of modified samples shall be compared with that of unmodified sample. These phases are further illustrated below.

1. Collection of materials
2. Mixing of materials
3. Preparation of samples
4. Tests on prepared samples
5. Comparison of physical properties of unmodified bitumen with modified bitumen.

This is further shown in the following flow chart.



3.4.1. Collection of Materials

The very first objective of this investigation is to collect materials. The materials are procured during this step. The following materials will be collected, based on the scope of this study.

1. Bitumen: In Pakistan, softer bitumen is utilized in pavement building, especially in cooler regions, and NHA recommends bitumen grade 80/100. As a result, we used bitumen grade 80/100.

2. Used Engine Oil: Used Engine Oil will be gathered from a local auto repair shop or an oil changer. Before being included into the modified bitumen, it was filtered with filter paper.

3. Crumb Rubber: Crumb rubber was obtained from local tyre shops in Hyderabad vicinity. The crumb rubber was #30 mesh in size.

3.4.2. Mixing of Materials

In this phase of the experiment, the partial replacement was mixed with the base bitumen (grade 80/100) using a low shear mixer for 20 minutes at the base bitumen's production temperature (150°C). The composition of the Waste Engine Oil utilized in this phase ranged from 1% to 10%. The WEO binder was subsequently replaced with crumb rubber in a high shear mixer at 160°C-180°C for 20 minutes (45 minutes was advised by sir). The crumb rubber dispersion in the binder was improved using this unique mixer. The polymer concentrations varied from 5% to 15% of the total.

3.4.3. Preparation of Samples

Following sample shall be prepared for laboratorial tests on modified bitumen.

Table 3.4.3.1. WEO-CTR-MB Blends

Sample No.	% WEO	% CTR	S.P °C	$P_{25°C}$ 0.1 mm	PI
VB	0	0	46.5	82	-0.92
MB-1	3	5	49.5	98.5	0.5
MB-2	3	7	50.5	94	0.62
MB-3	3	9	51	91.5	0.67
MB-4	3	11	53	89	1.09
MB-5	3	13	55.5	87	1.63
MB-6	3	15	56.5	83.5	1.73
MB-7	5	5	48.5	116	0.77
MB-8	5	7	49.5	112	0.93
MB-9	5	9	51	109	1.25
MB-10	5	11	52.5	106.5	1.57
MB-11	5	13	54	102.5	1.82
MB-12	5	15	55.5	101	2.13
MB-13	7	5	46	132	0.47
MB-14	7	7	48.5	127	1.1
MB-15	7	9	49	119	1.01

MB-16	7	11	51.5	117.5	1.66
MB-17	7	13	52	116.5	1.76
MB-18	7	15	54	115	2.23
MB-19	9	5	36	146	-3.14
MB-20	9	7	37	141	-2.77
MB-21	9	9	37.5	135	-2.68
MB-22	9	11	38	132	-2.53
MB-23	9	13	39	131.5	-2.12
MB-24	9	15	39.5	126	-2.05

3.4.4. Tests on Prepared Sample

These tests will help researchers build a comparison between modified and ordinary bitumen. Bitumen comes in a variety of forms and grades. To examine the applicability of all these binders, groups including as ASTM, Asphalt Institute, British Standard Institution, and ISI have created a variety of physical tests. The following tests will be performed as part of this research:

I. Penetration tests.
II. Ductility tests.
III. Flash and Fire point tests.
IV. Specific Gravity tests.
V. Softening point tests.

3.4.4.1. Penetration Test

This test is used to assess the hardness of a material by determining the vertical penetration depth of a standard needle in tenths of a millimeter under the required load, duration, and temperature conditions. Standard penetration implies that materials with higher penetration values have increasing penetration values unless further conditions are mentioned.

AASTO Designation: 49-74 ASTM DESIGNATION: D 5-97

3.4.4.2. Ductility Test:

When strain is applied to a material, it might stretch before breaking. When installed in pavements to restore loads, all bitumen modification must fulfil particular ductility standards such that they deform instead of crack. Furthermore, the binders from the ductile thin film around the aggregate are crucial when bituminous binders are used in flexible pavement construction. The ductility of a standard bitumen briquette is measured in centimetres and is defined as the farthest a thread can be extended before breaking. At a temperature of 25 + 0.5'C and a rate of 1 cm per minute, the test is conducted. Certain agencies do a low temperature test at O'C at a pace of I cm per minute. (AASHTO Designation: T 5—74)

3.4.4.3. Flash and Fire Point Test:

At high temperatures, bituminous materials leak volatiles depending on the grade. These combustible materials set fire to themselves. This is a very dangerous scenario, thus paving experts need to understand what temperature each bitumen grade is at and that they can maintain mixing and application temperatures well below the limits. The test determines the threshold temperature below which fire dangers must be avoided during application. Under specific test circumstances, a substance's flash point is the lowest temperature at which it ignites.

(AASHTO Designation: T 73—74), (AASHTO Designation: D 93—72) by Pensky-Martens Closed Tester.

3.4.4.4. Specific Gravity Test**:** The certain gravity of a substance is calculated by dividing the weight of a specific volume of the material by the weight of an equal amount of water at room temp. An important criterion for identifying bituminous binders for use in paving projects is their unit weight. This test can be carried out using the techniques listed below.

3.4.4.5. Softening Point Test:

The softening point of bitumen is the temperature at which it softens to a given degree under specified test circumstances. Because it determines the temperature at which bituminous material acquires a specified consistency, this test is categorized as a consistency test. It's used in asphalt standards for crack filling, roofing point sealing, and other applications where materials are put in thick films to keep them from flowing during service. T 53—74 (AASHTO Designation) (ASTM D 36-09)

CHAPTER 04

RESULTS AND DISCUSSIONS

4.1 Penetration Test (AASHTO Designation: 49-74)

Figure 1 illustrates the penetration values for both virgin and modified bitumen. The penetration value for virgin bitumen is 82 (0.1 mm), while for 3% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding penetration values are 98.5, 94, 91.5, 89, 87, and 83.5, respectively. It is clear from the results that the grade value of bitumen decreases with increasing CTR content, as the addition of CTR makes bitumen harder to penetrate compared to virgin bitumen. Similarly, the penetration values for modified bitumen with 5% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR are 116, 112, 109, 106.5, 102.5, and 101, respectively. For 7% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding penetration values are 132, 127, 119, 117.5, 116.5, and 115, respectively. Similarly, the values of 9% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR is 146, 141, 135, 132, 131.5, and 126, respectively. Interestingly, at each concentration of CTR, the penetration values for modified bitumen increase with the increase of WEO content. This is because bitumen becomes softer as the WEO concentration in the mix increases, resulting in improved deformation resistance and fatigue resistance of the asphalt mixture, enhancing its stability and durability, consistent with the literature survey [38]. Moreover, it is well established that the bitumen with a higher aromatic content tends to have higher viscosity and increased sensitivity to temperature than bitumen with a lower aromatic content. Therefore, aromatic oils such as WEO serve as lubricants for asphaltenes [31], resulting in bitumen with increased viscosity and temperature sensitivity. Overall, the results demonstrate that the addition of CTR and WEO significantly impacts the penetration values of modified bitumen.

4.2 Softening Point Test (AASHTO Designation: T 53-4)

Figure 2 illustrates the trend of the softening point for WEO-CTR-MB, showing the temperatures at which the mixture will soften under various conditions. The laboratory results show that the softening temperature for virgin bitumen is 46.5°C, whereas for modified bitumen with 3% WEO and 5%, 7%, 9%, 11%, 13%, and 15% CTR, the corresponding temperatures for softening point are 49.5°C, 50.5°C, 51°C, 53°C, 55.5°C, and 56.5°C, respectively. Similarly, for modified bitumen with 5% WEO and 5%, 7%, 9%, 11%, 13%, and 15% CTR, the corresponding temperatures for softening point are 48.5°C, 49.5°C, 51°C, 52.5°C, 54°C, and 55.5°C, respectively. When the WEO content was increased to 7%, and 5%, 7%, 9%, 11%, 13%, and 15% CTR, the corresponding temperatures for softening point for modified bitumen were observed as 46°C, 48.5°C, 49°C, 51.5°C, 52°C, and 54°C, respectively. Finally, for 9% WEO and 5%, 7%, 9%, 11%, 13%, and 15% CTR, the corresponding temperatures for softening point are 36°C, 37°C, 37.5°C, 38°C, 39°C, and 39.5°C, respectively. The laboratory results reveal that an increase in the proportion of waste engine oil in modified bitumen decreases the temperature at which the bitumen softens. Conversely, as the amount of crumb rubber tyre in bitumen increases, the softening point temperatures also increase. It can be inferred that the bitumen is relatively stiff for a lower concentration of WEO and a higher concentration of CTR, thereby having a higher softening point. The upshot suggests that modifying bitumen with WEO and CTR may improve the performance of asphalt mixtures by enhancing their resistance to deformation and fatigue, thereby enhancing their stability and durability.

4.3 Flash and Fire Point Test (AASHTO Designation: T 73-74 & D 93-72)

Figures 3 and 4 demonstrate a significant improvement in the flash and fire point values of WEO-CTR-MB. The laboratory results indicate that virgin bitumen's flash and fire points are 282°C and 294°C, respectively. However, for modified bitumen with 3% WEO and 5%, 7%, 9%, 11%, 13%, and 15% CTR, the corresponding temperatures for flash and fire points are 310°C and 326°C, 312°C and 331°C, 315°C and 337°C, 316°C and 344°C, 318°C and 350°C, and 324°C and 353°C, respectively. Moreover, for modified bitumen with 5% WEO and 5%, 7%, 9%, 11%, 13%, and 15% CTR, the corresponding flash and fire point temperatures are 293°C and 316°C, 296°C and 323°C, 301°C and 331°C, 303°C and 336°C, 307°C and 344°C, and 314°C and 355°C, respectively. Furthermore, an increase in WEO content to 7% and 5%, 7%, 9%, 11%, 13%, and 15% CTR resulted in the corresponding flash and fire point values of modified bitumen as 281°C and 303°C, 285°C and 311°C, 287°C and 316°C, 288°C and 320°C, 291°C and 326°C, and 301°C and 340°C, respectively. Finally, for modified bitumen with 9% WEO and 5%, 7%, 9%, 11%, 13%, and 15% CTR, the corresponding flash and fire point values are 272°C and 286°C, 277°C and 294°C, 279°C and 299°C, 282°C and 307°C, 285°C and 314°C, and 302°C and 329°C, respectively. Since the results of the flash and fire tests are within the safe limits, it can be concluded that the WEO-CTR-MB is a risk-free product for operation. It is essential to note that the increased flash and fire point values of the modified bitumen result in enhanced safety during transportation, storage, and application. Hence, using WEO-CTR-MB in pavement construction is a promising approach for with minimal risks associated with asphalt handling.

4.4 Ductility Test (AASHTO Designation: T 5-74)

The laboratory results indicate that the ductility value of modified bitumen has been adversely affected by the inclusion of crumb tyre rubber (CTR) and waste engine oil (WEO) in virgin bitumen. Figure 5 provides a graphical representation of the ductility values for both virgin and modified bitumen. It is evident that the ductility value of virgin bitumen (measured in centimeters) is 102.7, while for modified bitumen with 3% WEO and 5%, 7%, 9%, 11%, 13%, and 15% CTR replacement, the corresponding ductility values are 41.5, 40.8, 39.2, 39, 37.6, and 36, respectively. Similarly, for modified bitumen with 5% WEO and 5%, 7%, 9%, 11%, 13%, and 15% CTR replacement, the corresponding values for ductility are 35.4, 34.7, 33.2, 30.1, 31, and 30, respectively.

Moreover, when the proportion of WEO was increased to 7% and CTR replacement was 5%, 7%, 9%, 11%, 13%, and 15%, the corresponding ductility values for modified bitumen were observed to be 28.9, 27.8, 26.9, 25.7, 24.6, and 24, respectively. Finally, for modified bitumen with 9% WEO and 5%, 7%, 9%, 11%, 13%, and 15% CTR replacement, the corresponding ductility values were 23.5, 21.4, 20.7, 19.3, 19, and 20.1, respectively. It is noteworthy that the ductility of WEO-CTR-MB decreases with an increase in the proportion of WEO and CTR replacement. For example, for modified bitumen with 3% WEO and 5% CTR, the ductility value drops to 41.5 cm, and for modified bitumen with 9% WEO and 15% CTR, it further reduces to 20.1 cm. These results suggest that the addition of CTR and WEO may have a negative impact on the performance of bitumen in certain applications.

However, it is essential to note that the lack of ductility is not necessarily an indication of poor bitumen quality [39], as the suitability of the modified bitumen will depend on the specific application and the conditions in which it will be used. Other properties such as stiffness, viscosity, and temperature susceptibility will also be significant factors to consider when evaluating the suitability of the modified bitumen for a given application.

4.5 Specific Gravity Test

Figure 6 illustrates the specific gravity values for virgin and modified bitumen. For virgin bitumen, the specific gravity value is 1.016. However, for 3% WEO and 5%, 7%, 9%, 11%, 13%, and 15% CTR, the corresponding specific gravity values are 0.996, 0.987, 0.984, 0.982, 0.977, and 0.973, respectively. The specific gravity of bitumen has been observed to decrease when mixed with WEO and CTR. Similarly, for 5% WEO and 5%, 7%, 9%, 11%, 13%, and 15% CTR, the specific gravity values are 0.997, 0.989, 0.986, 0.981, 0.974, and 0.971, respectively. Furthermore, when the WEO content was increased to 7% and 5%, 7%, 9%, 11%, 13%, and 15% CTR, the corresponding specific gravity values for modified bitumen were observed to be 0.994, 0.983, 0.98, 0.978, 0.973, and 0.972, respectively. Finally, for 9% WEO and 5%, 7%, 9%, 11%, 13%, and 15% CTR, the corresponding specific gravity values are 0.992, 0.984, 0.981, 0.978, 0.973, and 0.967, respectively. The decrease in specific gravity is attributed to the lower density of the mixing materials (WEO and CTR) compared to virgin bitumen. These observations indicate that adding waste materials to bitumen can affect its physical properties, which can impact the performance of asphalt mixtures. Therefore, it is important to carefully select and evaluate the waste materials used in bitumen modification to ensure the desired properties are achieved.

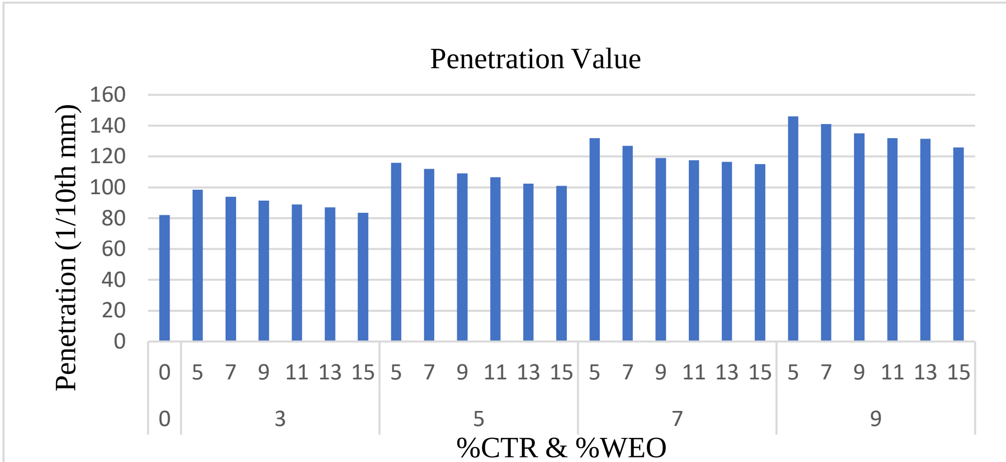


Fig. 1. Penetration

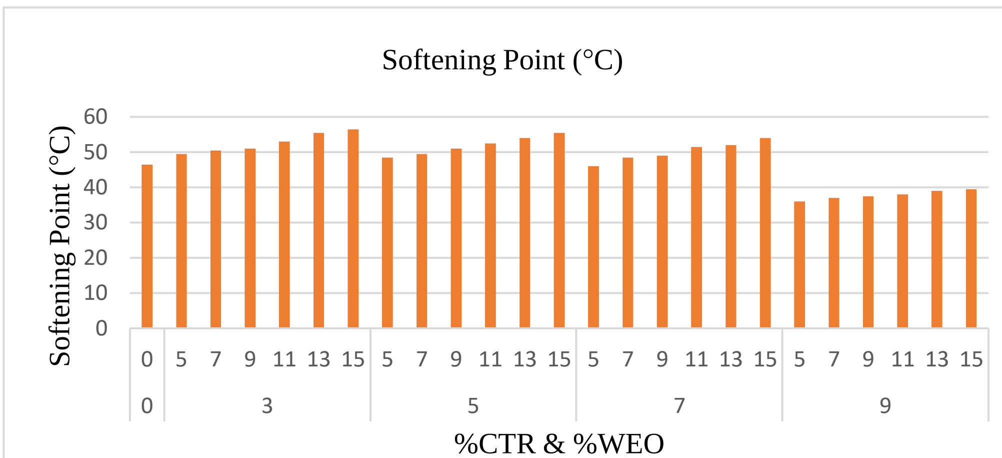


Fig. 2. Softening Point

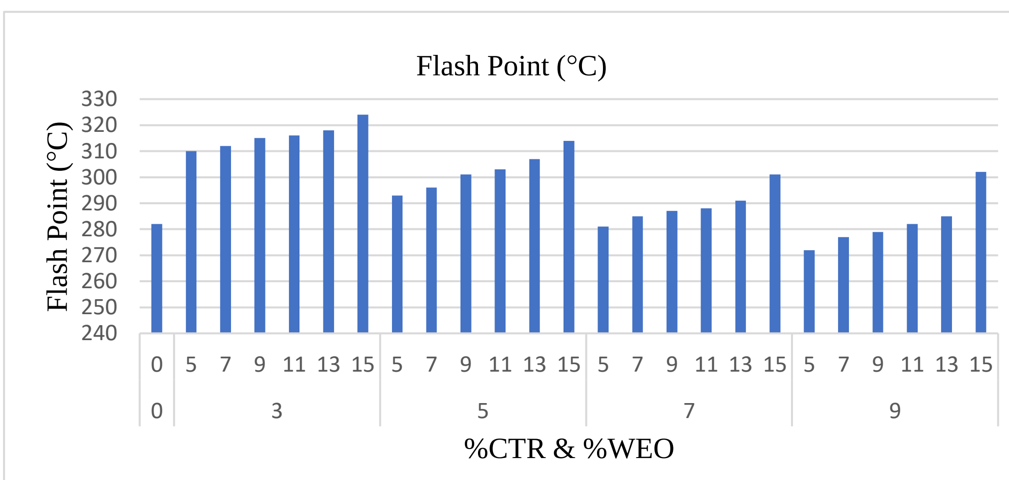


Fig. 3. Flash Point

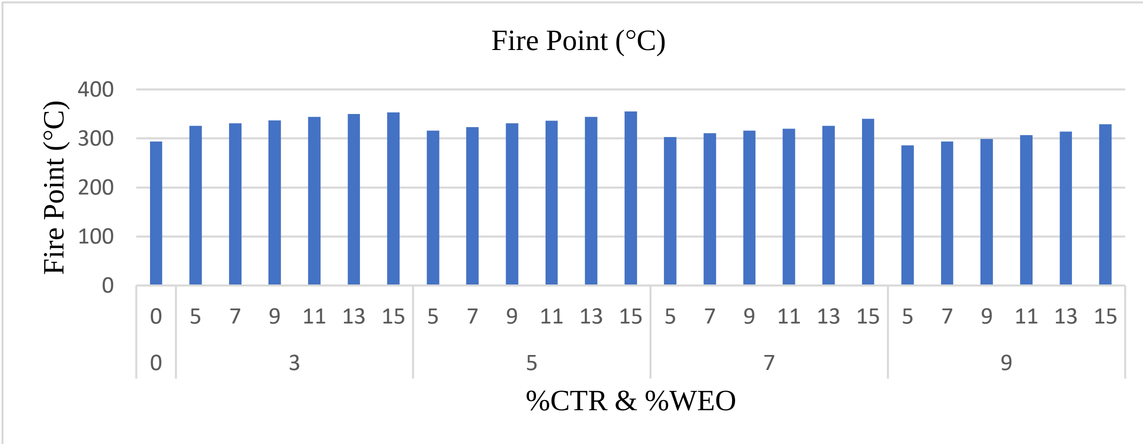


Fig. 4. Fire Point (°C)

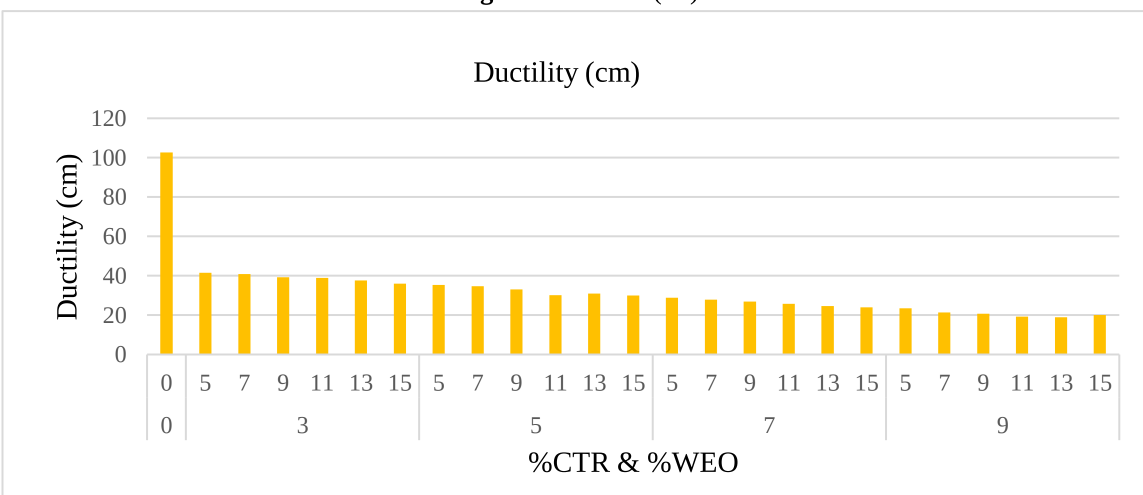


Fig. 5. Ductility

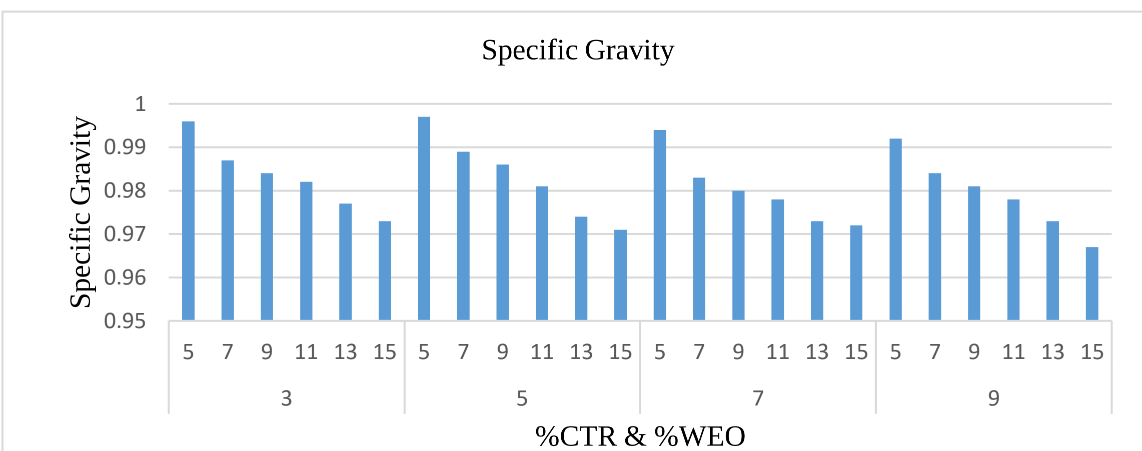


Fig. 6. Specific gravity

CHAPTER 05

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Different concentrations of WEO and CTR have been mixed with virgin bitumen and tested for physical characteristics such as penetration, softening point, flash and fire point, ductility, and specific gravity. The samples have been prepared and tested in the laboratory. The results indicate that with an increase in CTR concentration in the bitumen, the modified bitumen becomes harder, which results in a decrease in penetration value. The blend consisting of 5% CTR and 9% WEO has the highest penetration value among all the samples tested, making it suitable for reducing excessive brittleness in bitumen. This blend may be used to reduce rutting and suggests the economic benefits of modified bitumen leading to sustainable pavements.

Additionally, adding CTR in the bitumen has increased the softening point value. The blend prepared with 5% CTR and 9% WEO has the least softening temperature, while the highest softening temperature has been observed in the 3% WEO and 15% CTR blend. The ductility value has decreased significantly with increased WEO and CTR concentrations. The blend with the highest ductility value (41.5 cm) is 3% WEO and 5% CTR. Furthermore, the flash and fire point value for all the mixes have improved, and all are within safe limits of operating with HMA, ensuring the safe operation of WEO-CTR-CR modified bitumen. Lastly, the specific gravity value for all the samples has decreased. A similar trend of penetration, softening point, ductility, specific gravity and flash and fire point results has been seen when CR has been used with Bio-oil [39]. On the final note, this bitumen modification successfully addresses concerns about the costly recycling of hazardous wastes (WEO and CTR), using these for sustainable development of the pavement industry.

5.2. Recommendations

WEO-CTR-MB can be further tested in detail by investigating the rheological characteristics of the modified bitumen, such as phase angle, shear modulus, and FTIR spectral analysis. Moreover, examining the hot asphalt mixes and the long-term performance of the WEO-CTR-MB asphalt pavements is recommended.

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