SUSTAINABLE MATERIALS TO ENHANCE THE ENGINEERING PROPERTIES OF ASPHALT BINDER

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ABSTRACT

The purpose of this research is to access and simulate the ageing response when a specific neat binder typically used in asphalt pavements, is subjected to extended short-term ageing effect due to long hauling distances and unexpected traffic interruptions. Furthermore, this study is purposed to identify the optimal dosage of an abundantly available waste material (i.e., Waste Engine Oil) for rejuvenation of the extended short-term aged binder. The results of this study reveal that the binder's basic properties of penetration, softening point, ductility, flash point and viscosity are recovered by 81.7%, 100%, 100%, 89.7% and 87.4% long-term virgin binder when 10% Waste Engine Oil (by weight of bitumen) is added in extended short term aged asphalt binder. This research can be further extended to utilize the long-term aged asphalt binder recovered from recycled asphalt pavement (RAP) resulting in sustainable solution.

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INTRODUCTION

1.1 Background:

In the Indus and Euphrates basins, bitumen's history as an engineering material dates back to between 3000 and 3800, when it was used as masonry and waterproofing via surface seepage of natural bitumen. Hot mix asphalt is a composite material made of aggregate, asphalt (bitumen), and air spaces. The asphalt binder, bitumen, is a byproduct of petroleum distillation with distinctive chemical and physical properties. The complex mixture that makes up the asphalt binder is composed of organic compounds. It takes several steps to build a road, starting with determining whether the properties of the components (aggregates and bitumen) meet the necessary specifications, mixing the components under controlled conditions, and then dumping the mixed asphalt and compacting it with a truck at a particular temperature. Each stage of the manufacturing, transportation, and compaction procedures has an effect on the lifetime characteristics of the produced road. The asphalt binders, which are among the most expensive pavement components, have an impact on the performance characteristics of the asphalt mixture, such as low-temperature cracking, fatigue cracking, and permanent deformation. One of the main aspects of the asphalt binder that affects the overall standard of the constructed road is aging. A physical, rheological, or chemical property change known as ageing—which affects asphalt when it is exposed to high temperatures over an extended length of time—occurs. As a result, the asphalt starts to oxidize, lose volatile components, and evaporate. As a result, harder asphalt will be produced. Age-related increases in the viscosity and stiffness of the asphalt binder enhance the risk of cracking and ravelling. [1]

Short-term and long-term ageing of bitumen are the two types. During production, shipping, and compaction at the building site, which all take place over a short period of time, hot mix asphalt ages briefly. Strong oxidation rates and rather high temperatures (>130°C) set it apart. Due to exposure to traffic and environmental variables during their service life, asphalt pavements in the field age over time. In contrast to short-term ageing, long-term ageing is a continuous oxidation process that mostly impacts the upper millimeters of the surface course. There is continuous debate in science regarding the effects of UV radiation on the aging process and whether or not oxidizing agents other than atmospheric oxygen contribute to long-term aging.[2]

Researching the aging characteristics of the asphalt binder can simulate the short-term aging of the entire hot mix asphalt mixture because, according to several studies, the behavior of the asphalt binder, as opposed to the manufacturing and construction processes, is more closely related to short-term aging. Thanks to technology and researchers, the antiquated behavior of asphalt binder may be controlled and restrained. Numerous rejuvenators bring back the asphalt binder's original state an aged one. Rejuvenators are primarily used to transform aged bitumen's rheological properties back into those of young bitumen. Rejuvenators are high-maltiness additives produced chemically or biologically that can replenish aged bitumen's lost maltiness during asphalt oxidation. Some of these rejuvenating materials include lubricant stock, slurry oil, soft asphalt binder, asphalt flux binder, and industrial process oil. Waste engine oil binder is one of the rejuvenators for asphalt binders because of its similar chemical composition.[3]

1.2 Problem Statement:

Asphalt pavement construction requires the creation of asphalt mixtures at temperatures recommended by the producers of asphalt binders. For the asphalt to soften and become viscous enough to coat the particles, the temperature is necessary. An asphalt mixture is made, then transported to the construction site where it is spread out and compacted to make an asphalt pavement. Minimum temperatures are needed for the placement and compaction of asphalt pavements in order to create a high-quality, high-performing pavement. After being generated, trucks are utilized to transport the asphalt mix to the construction site. During the time it takes to load a truck at the manufacturing facility and transport it to the building site, the asphalt mixtures will continue to lose some heat. Due to this heat loss from the combination, the mixes may occasionally arrive at the construction site with temperatures that are lower than those needed for lay down and compaction. Such circumstances lead to the rejection of loads of asphalt mixtures, squandering material, delaying the schedule of construction projects, and raising the likelihood of conflicts as a result of the delays in project completion. The problem with elevated temperatures is that they may worsen the deterioration of the asphalt binder than what would be brought on by normal manufacturing temperatures, which would raise the rate of short-term ageing and may have a negative effect on how well the asphalt pavement works. According to numerous studies, oxidation and volatilization play a major role in how quickly asphaltic binders harden (age).Due to the mechanisms' enhanced strength at high temperatures, the binders in the mixture have worse ageing properties. In certain circumstances, a longer transportation distance means the hot mix asphalt will be heated up for a longer period of time, which could result in further hardening. The interaction of elevated temperature and extended exposure time may have a negative effect on the performance of the pavement.[4]

The building blocks of developing economies are their roadways, which are built and maintained on a yearly basis in the thousands of kilometers. The economy, energy use, social structure, and ecology are all significantly impacted locally by the maintenance of asphalt pavements[5]. The heating of asphalt during manufacture and construction causes the binders used in mixes to oxidize and volatilize. Volatilization and oxidation cause asphalt pavements to degrade by making the binders more stiff, making them more prone to cracking, and negatively impacting the functional and structural performance of the pavements. In the early stages of a pavement's life, high manufacturing temperatures lead to the oxidation and volatilization of asphalt binders, which is known as short-term ageing (STA). Elevated temperatures and prolonged exposure to elevated temperatures can increase the STA of asphalt.[4]

The features of aged asphalt mixtures play a key role in determining these materials' long-term performance (such as durability). Given the increasing usage of lowered temperature combinations, such as warm-mix asphalt and WMA, there is ongoing concern about how a drop in short-term ageing affects the properties of bituminous materials during long-term ageing. This study aims to improve our understanding of how the temperature of the asphalt manufacturing process affects ageing and the subsequent mechanical properties of bituminous binder by examining the effects of short- and long-term ageing of various bitumen samples as a function of short-term ageing temperatures.[2]

Due of its low cost and eco-friendly nature, used engine oil has gained interest as a rejuvenator in asphalt binder. Asphalt pavements experience a decline in quality and durability over time due to various physical, chemical, and environmental changes. With the addition of waste engine oil to the asphalt binder, it is possible to repair the asphalt's physical and chemical properties, enhancing its functionality and age resistance. The aim of this study is to investigate the viability and effectiveness of waste engine oil as a rejuvenator in asphalt binder as well as the impacts of waste engine oil on the ageing parameters of the asphalt mixture. The study's conclusions will help the construction sector use this strategy and reduce the cost and environmental impact of maintaining and repairing asphalt pavement.

1.3 Objectives:

The primary research aims are covered in the sections that follow.

- To evaluate the asphalt binder's short-term ageing effects.
- To use the optimized dosage of WEO rejuvenator in an aged asphalt binder

1.4 Research Questions:

The following research questions will serve as a guide for this study:

- How does WEO affect the engineering properties of the asphalt binder?
- What is the recommended WEO addition for rejuvenation of the asphalt binder?

1.5 The study's significance

The significance of this study is discussed below.

The Extended Rolling Thin Film Oven (RTFO) test imitates how quickly asphalt deteriorates when exposed to high temperatures for an extended period of time while being transported. This method can be used to evaluate bitumen taken from reclaimed asphalt pavement (RAP) materials to determine how well rejuvenation treatments and recycling techniques function. This can reduce both the expense of using fresh bitumen and the impact of making asphalt on the environment.

Waste engine oil (WEO), a readily available waste material, can be used to revitalize and restore the chemical and physical properties of asphalt binder. By combining waste engine oil with used asphalt binder, the softening point, a measurement of the temperature at which the asphalt binder starts to lose its ability to keep its shape, can be lowered. The lowering of the softening point may improve the asphalt binder's ability to maintain its shape and make it less vulnerable to damage and cracking.By lowering the softening point of the asphalt and the overall stiffness of the asphalt binder, WEO can increase the flexibility and damage resistance of the asphalt. Together, a lower softening point and reduced stiffness can improve the asphalt binder's overall performance, extending its useful life and reducing the need for maintenance and repairs.By reducing the quantity of waste engine oil wasted in landfills, WEO's use as an asphalt binder rejuvenator age can also benefit the environment. Reusing waste engine oil reduces the need to create petroleum-based rejuvenators, which can be resource-intensive and environmentally hazardous. This helps conserve resources.

1.6 Scope of the Study:

This study's objectives are to determine the efficacy of waste engine oil (WEO) as an asphalt binder rejuvenator and to determine the appropriate WEO adding rate. The study's main focus will be on how WEO affects the engineering properties of asphalt binder, including their softening point, stiffness, and resistance to damage. In a laboratory setting, samples of asphalt binder will be prepared with various WEO concentrations, analyzed, and it will be determined how WEO affects the properties of the binder. By offering a complete analysis of WEO's potential as a rejuvenator for asphalt binder, the study will aid in the development of more efficient and long-lasting recycling techniques for asphalt materials. The findings of this study will contribute to the development of long-term plans for the replacement of asphalt binder and will directly impact the construction and maintenance of roads.

2 CHAPTER-2

LITERATURE REVIEW

2.1 Bitumen:

The term "asphalt binder" is also used to refer to binder, a petroleum distillation byproduct with unique chemical and physical characteristics. Bitumen is a complicated blend of organic substances. The performance standards for different types of asphalt mixtures depend on the asphalt binders, which are one of the priciest pavement materials. Deformation, fatigue cracking, and low-temperature cracking are a few performance criteria. Ageing is the primary asphalt binder property that has an impact on the overall performance of the built road. [2]

At room temperature, asphalt binder is a thick, smelly, sticky fluid that is semi-solid . It is exceptionally water resistant. While its primary application is the creation of asphalt pavements, it is chemically resistant to acids and salts [4].

The world's oldest engineering substance is asphalt cement. Natural asphalts were employed by many ancient civilizations for a variety of purposes, including mummification in Egypt and water proofing brickwork [4]. The fact that the features heavily depend on the characteristics of crude oil and an appropriate distillation procedure is widely acknowledged . Bitumen is a reasonably priced thermoplastic substance [1]. From a functional standpoint, it must be elastic and supple enough to resist thermal cracking in addition to being fluid enough at high temperatures[6].

Despite being a non-renewable substance, more than 100 million tonnes of asphalt binder are used each year on the world's highways . The flexible paving is typically designed to last 10 to 15 years [7]. Nearly 34% of all trash produced globally is produced by the construction industry, which is followed by the transportation and infrastructure sectors . Bituminous material used in roadways ages and loses its characteristics after several years of use [8].

The subbase, base, and asphalt layer are the three layers that make up a standard asphalt pavement; they all rest on top of the subgrade. A schematic of a typical asphalt pavement structure can be found in Figure 2.1. The dirt already present beneath the pavement structure is known as the subgrade. On top of the subgrade, a layer of coarse-grained rock is positioned beneath the base and subbase layers. The two base layers' principal function is to give the asphalt pavement structure and range in thickness from 4 to 12 inches. Base course, binder course, and surface course are the three sublayers that make up the asphalt pavement layer, which can range in thickness from four inches to more than two feet in the case of permanent pavements. The surface or wearing course of asphalt concrete is the top layer that is visible to traffic. The primary cause of pavement friction and smoothness is the surface course, which is rarely thicker than two inches. [4]

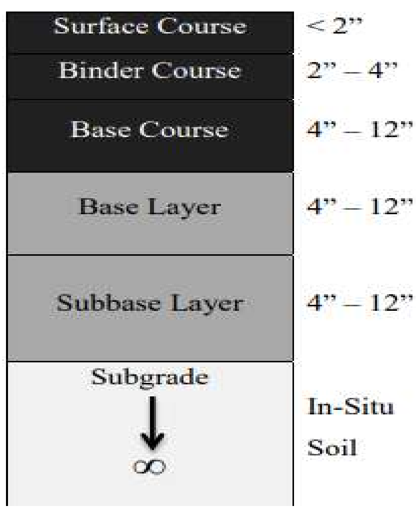


Fig 2.1 asphalt pavement structure

2.2 Bitumen Structure:

Chemically speaking, bitumen is described as a viscous, viscoelastic liquid that is completely soluble in toluene, essentially non-volatile, and softens gradually when heated. It is composed primarily of hydrocarbons and their derivatives at room temperature. It consists of a huge variety of polarity and molecular weight-variant molecular entities. Elemental study demonstrates that bitumen composition is largely influenced by the source of the crude oil, making it challenging to make a precise geographical generalisation (many suppliers also blend bitumen from many sources). Wide-ranging research by SHRP (Strategic Highway Research: Special Report) has demonstrated this. According to this research, bitumen is mostly composed of carbon, which ranges from 80 to 88 weight percent, and hydrogen, which ranges from 8 to 11 weight percent. [1]

Sulphides, thiols, and sulfoxides, ketones, phenols, and carboxylic acids, pyrrolic and pyridinic compounds, and most metals form complexes like metalloporphyrins are the primary compounds of the polar heteroatoms mentioned above from a molecular perspective. A thorough chemical characterisation of bitumen is highly challenging since it is a complex mixture of 300 to 2000 chemical components (median value 500–700), according to a Molecular Weight Distribution Analysis. Because of this, bitumen is typically fractionated using less complex techniques, making it possible to distinguish between two main constituents:

- Asphaltenes
- Maltenes, also known as Petrolanes

After that, maltenes are divided into three groups: saturate, aromatic, and resin. These three groups—along with asphaltene—are collectively referred to as the bituminous SARA fraction. The bitumen's chemical composition can be linked to both its internal structure and parts of its macroscopic features thanks to the relative abundance of the SARA components.

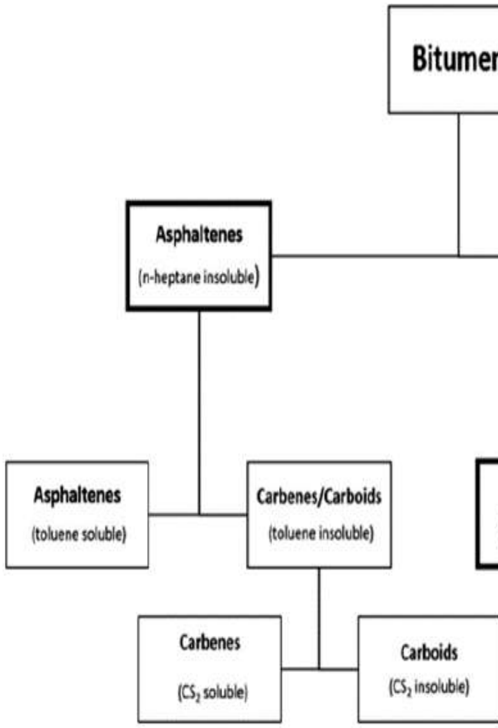


Fig 2.2 1 depicts the basic hierarchical structure of bitumen.

Asphaltenes are amorphous dark or black solids with particle sizes ranging from 5 to 30 m at ambient temperature. They are insoluble in n-heptane but soluble in toluene. Their percentage in bitumen ranges from 5 to 25%. Oxygen, nitrogen, sulphur, and heavy metals (V, Ni, etc.) are all present in asphaltene in the form of complexes like pyrrolic and pyridinic rings, as well as metallo-porphyrins with lengthy aliphatic chains (up to 30 carbon atoms). Asphaltene molecules are shown in Figure to consist of fused aromatic rings, most likely between 4 and 10 units, along with some aliphatic chains as ring substituents. This is shown by UV-fluorescence spectroscopy, Fourier transform infrared spectroscopy (FTIR), X-ray Raman spectroscopy, and NMR spectroscopy.[1]

2.3 Ageing of Asphalt Binder

The performance and durability of the pavement are significantly influenced by the asphalt binder, a vital component of asphalt concrete. However, because to exposure to environmental elements including sunlight, water, and air, asphalt binder is prone to ageing. The elasticity, cracking, and rutting of asphalt binder can all be caused by ageing, which can also cause the binder to harden. [9]

Asphalt binder ageing is a complicated phenomenon that involves rheological, chemical, and physical changes. Volatiles evaporate during the physical ageing of asphalt binder, which causes the binder to harden. Oxidation, which happens when the asphalt binder is exposed to air and sunshine, is what causes the chemical ageing of asphalt binder. Chemical bonds are formed during the oxidation process, increasing the binder's molecular weight and decreasing its flexibility. Asphalt binder undergoes rheological ageing, which results in changes to its mechanical characteristics like stiffness, viscosity, and elasticity. [10]

The premature breakdown of the pavement can be caused by the asphalt binder ageing, which is a significant challenge for the road construction sector. Numerous rejuvenators have been created that can restore the mechanical qualities of the old asphalt binder in order to offset the effects of ageing. [10]

Throughout its lifetime, bitumen experiences changes in its mechanical properties, chemical content, and microstructure because it is an organic material. The two main causes of these changes are oxidation and the loss of volatile components at high temperatures. Over time, bitumen has a tendency to change mechanical properties, becoming stiffer, more elastic, more brittle. A change in the SARA (saturates, aromatics, resins, and asphaltenes) fractions of the chemical composition can be seen, with an increase in asphaltenes and a decrease in aromatics. The term "ageing" often refers to these alterations

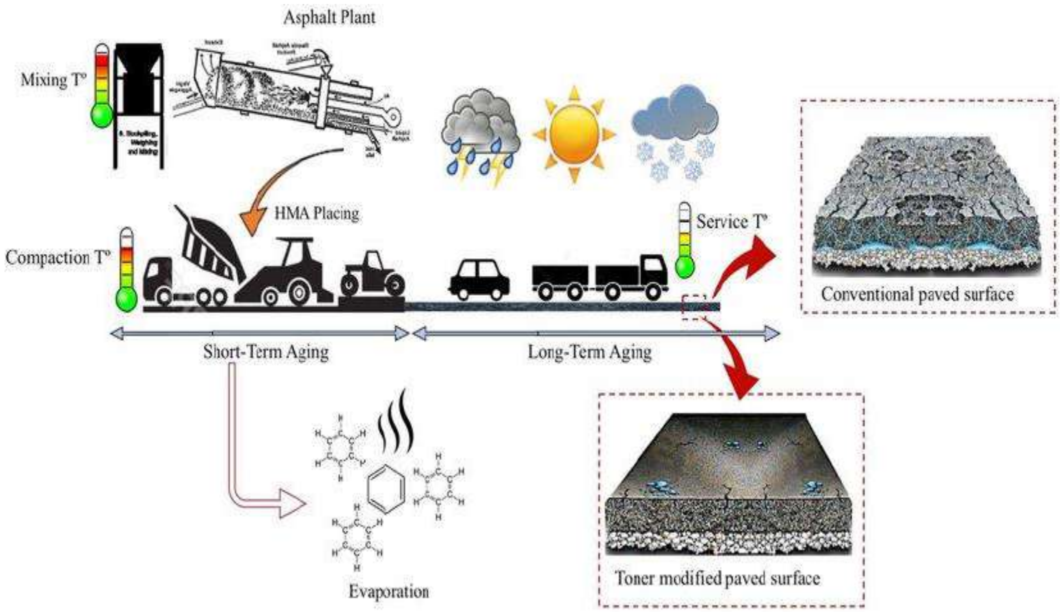


Fig 2.3 depicts the ageing phenomena

One of the main causes contributing to the degradation of asphalt pavements is bitumen ageing. Traffic and thermally induced cracking, as well as ravelling, are significant ageing-related mechanisms of failure. Two different sorts of mechanisms are involved in bitumen ageing. The primary ageing mechanism is an irreversible one that is characterised by alterations in the binder's chemical composition, which in turn affects the rheological properties. The oxidation, loss of volatile components, and exudation (migration of oily components from the bitumen into the aggregate) are the mechanisms that cause this form of ageing. Physical hardening is the second method, which is reversible. Molecular structuring, or the reorganisation of bitumen molecules or bitumen microstructures to almost an ideal state, may be responsible for physical hardening. state of thermodynamics under a particular set of circumstances. (24)

There are two types of bitumen ageing: short-term and long-term. Hot mix asphalt undergoes brief ageing during production, transportation, and compaction at the construction site, all of which take place in a matter of hours. It is characterised by strong oxidation rates and relatively high temperatures (>130°C). Asphalt pavements in the field experience long-term ageing as a result of exposure to traffic and environmental factors throughout their service life. Long-term ageing, in contrast to short-term ageing, is a steady oxidation process that mostly affects the top several millimetres of the surface layer [11]

When asphalt is subjected to high temperatures, ageing occurs, which is a change in physical or chemical properties. As a result, the asphalt will become less volatile, evaporate more quickly, physically harden, and oxidise . Age causes the asphalt binder to become more viscous, which can lead to cracking and ravelling . Long-term ageing and short-term ageing are two categories of ageing . It is thought that bitumen with a lower viscosity is less likely to age than soft asphalt binder . Asphalt binder's ability to age is time-dependent [2]

The chemical makeup of the bitumen, which in turn depends on the type of crude oil it is (paraffinic or naphthenic), greatly influences the ageing process that affects bituminous mixtures. Bitumen is made up of a wide range of diverse components, the nature of which varies according on the binder, making it challenging to isolate and pinpoint shared properties. The ageing process is also significantly influenced by other inherent characteristics of the mixture, such as void content, layer thickness, aggregate type, etc., as well as environmental factors, such as temperature and solar radiation. [12]

Reclaimed asphalt pavements will raise performance grade and make asphalt pavements firmer in nature [4]. In the building industry, reclaimed asphalt pavement has been regarded as one of the finest ways to protect natural resources [13].

In order to determine a material's consistency and resistance to deformation, thermal stability at higher temperatures, and capacity to withstand plastic deformation without breaking or rupturing, tests such as penetration, softening point, and ductility of the asphalt are used . These alterations are linked to the ageing process [13]. While long-term ageing happens over the course of the service life of the asphalt, short-term ageing happens during the building period [11].

Additionally, oxidation has a major impact on short term . Reclaimed asphalt pavement (RAP) particles clump together to form clusters, a phenomenon known as clustering. Old clusters and fresh clusters are the two sorts of clusters. The first one is created before to the new mixing phase, but the second one is created during the mixing phase [14].

After prolonged ageing, there appears to be a considerable reduction in the phase angle [15]. The laboratory studies used to replicate the various ageing processes, such as UV ageing and short-term ageing, are reviewed . One of the most significant elements impacting the service life of asphalt mixtures is the ageing process . The numerous anti-ageing oxidant types that are most frequently investigated are listed in summary form, together with all of their effects [14].

The text makes clear the necessity of developing a standard to model bitumen ageing and the significance of determining the impact of UV light in any ageing study that uses field data . The bitumen's chemical makeup, which in turn depends on the fact that it is crude oil, greatly influences how quickly it ages . When bitumen is subjected to high temperatures, as occurs during the creation, transportation, and application of the mixture, the oxidation and volatilization processes, which are slow at room temperature, accelerate.

The dynamics of ageing are greatly influenced by temperature . Generally speaking, the rate of oxidation doubles for every 10 degrees Celsius increase in temperature . Given that it regulates how much oxygen can access the bitumen, the void percentage is a consideration to take into account while analysing the ageing phenomenon [14].

The tests that are currently most frequently employed are the pressure ageing vessel (PAS), thin film oven test (TFOT), rolling thin fil oven test (RTFOT), and ultraviolet testing (UVT). During storage, mixing, and transportation, the first two are used to simulate ageing . The other two, however, are utilised to simulate ageing over the course of the material's service life . However, it should be understood that not all of these methods accurately reflect what occurs in reality . Viscosity, penetration, and softening point all increase with age [14].

The most popular tests for simulating binder ageing are the RTFOT and PAV tests for short- and long-term ageing, respectively, and they exhibit high correlations with other tests of a similar nature . The service life of flexible pavements can be directly impacted by ageing asphalt [8]. To reduce the consumption of bitumen, a study was conducted to develop enhanced modified bitumen using recycled and waste engine oil coupled with polymers [16].

2.4 Rejuvenation of Asphalt Binder

The method of rejuvenating an asphalt binder involves returning the aged binder's mechanical qualities to their former state. In order to increase workability, reduce stiffness, and regain elasticity, rejuvenators are often applied to old asphalt binder. Physical and chemical rejuvenators fall into two groups. [17]

In order to make the old asphalt binder more workable and less stiff, physical rejuvenators, which are typically petroleum-based compounds, are added. These rejuvenators function by making the binder's elasticity and viscosity more elastic. In order to be compatible with the aged binder, physical rejuvenators are often applied in tiny amounts. [17]

Chemical revitalizors are created to interact with the deteriorated asphalt binder and reestablish its mechanical qualities. These rejuvenators frequently contain substances that can dissolve the chemical bonds created during ageing and revive the binder's suppleness. Reactive and non-reactive chemical rejuvenators can be further divided into these two groups. While non-reactive rejuvenators function by dissolving the old binder and replacing it with a new binder, reactive rejuvenators are made to chemically react with the aged asphalt binder and create new chemical bonds. [18]

The world is currently experiencing the worst environmental crisis in recorded history as a result of resource depletion, biodiversity loss, air, soil, and water pollution, and disproportionate land usage. Administrations, professionals, and researchers are paying increasingly close attention to the ideas of circular economy and sustainability in order to address these problems. With a sharp rise in publications and journals, these subjects have in fact become prominent research concerns. Road building, which necessitates the extraction of raw materials, the release of pollutants, and the creation of trash, is one of the industries that significantly impacts the environment. [10]

A colloidal model with a highly polar asphaltene phase dispersed in a maltene phase can be used to describe asphalt binders. The balance between the soluble and insoluble fractions of the colloid, which regulates its flow qualities, is referred to as binder compatibility. At a specific load and temperature setting, a more compatible binder has more mobility and better flow characteristics. A compatible binder is more ductile from a rheological standpoint, and binder phase angles are higher at any given modulus. By partially replacing lost lighter oil proportions and separating agglomerations brought on by ageing, recycling agents help recycled binders move molecules more easily. The mechanisms by which the recycling agent restores rheological properties can vary depending on its chemical makeup[17].

The viscosity of bitumen increases as bitumen ages, increasing the rigidity of asphalt pavement over the course of its lifespan. When some of the maltene medium is converted into the asphaltene phase, higher asphaltene and lower maltene levels follow. This is the typical, zero-order, description of ageing. Because the polar-polar interactions between the asphaltenes are stronger, this results in a higher viscosity and reduced ductility. In other words, "the resistance of asphalt binder to cracking or fracture is decreased when the asphaltene micelles are not sufficiently mobile to flow past one another under the applied stress." Ageing, on the other hand, is a more complicated process with numerous sub-mechanisms that often occur over a variety of timescales. It already happens during the installation of asphalt due to the volatilization of the maltene's light components. Then, due to a variety of factors, there is long-term ageing in the field:

- oxidative, as a result of compositional changes brought on by a reaction between bitumen constituents and oxygen in the atmosphere;
- Evaporative, as a result of the maltene's low-molecular weight components evaporating. These substances are more volatile and have a greater vapour pressure, allowing them to exit the maltene phase and affect both its composition and overall amount in the bitumen;
- Chemical reactions between molecular components that result in polymerization and subsequent structure creation within the bitumen cause structural ageing [18]

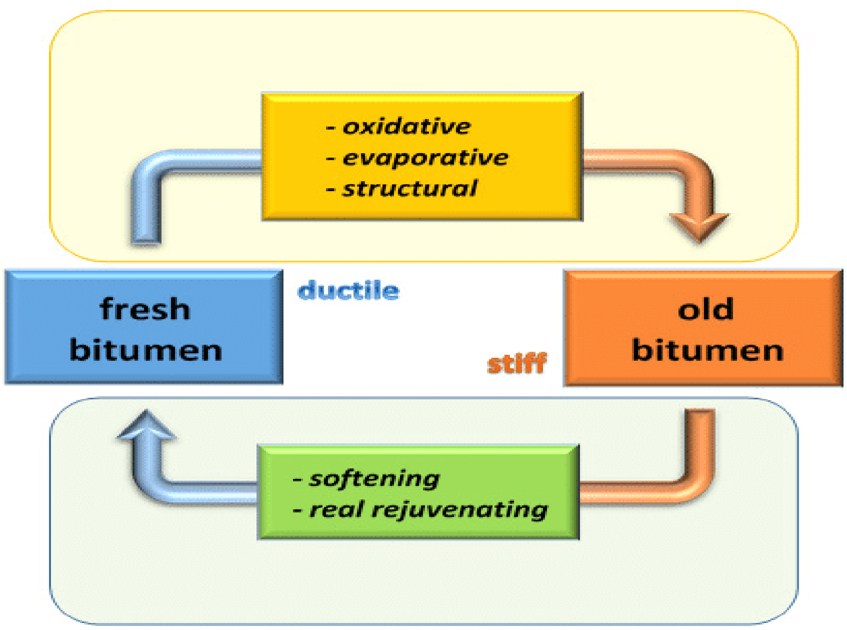


Fig 2.4 showing the main processes involved in bitumen ageing and its rejuvenation
1

Many additives have been introduced to enhance the bitumen's performance attributes. Bitumen's performance has been improved by the use of modifications and additives. The features of modified bitumen were obtained by studying the effects of adding many thermoplastics to the bitumen [1].

The bitumen also contains natural and synthetic rubber. It has been discovered that bitumen's elastomeric properties were enhanced by the addition of polymers . The main purpose of regenerators is to return the rheological characteristics of old bitumen to their pre-aged form . They are actually bioderivative additions with a high maltiness level . For pavement temperatures below 70 degrees Celsius, it is preferable to rejuvenate waste engine oil [2].

It was crucial to create new rejuvenators employing waste cooking oil (WCO) and waste engine oil (WEO) . Numerous research have been conducted in recent years to examine the effectiveness of WEO and WCO as a rejuvenator for asphalt binder [3]. The features and dosage of WEO, as well as the volume of old asphalt in the mixture, all affect the other qualities of WEO-rejuvenated asphalt [13].

The qualities of penetration, softening point, ductility, and viscosity must be recovered using a rejuvenator agent. Should increase cracking resistances without impairing performance at high temperatures . A rejuvenating agent needs to balance stiffness and rutting resistance while achieving acceptable stability [13].

When there is too much asphalt on the pavement's surface, it will flush or bleed. This circumstance also results from the addition of too much rejuvenating chemical . When rutting and flushing occur simultaneously, a serious issue arises . New asphalt binders are routinely employed in the recycling of asphalt pavements to make the old asphalt pliable [11].

By combining rejuvenating agents with the old mixes at high temperatures, the characteristics of the aged asphalt can be restored . Rejuvenating agents can improve the performance of the recycled mixture. Lower energy usage while mixing and compaction is the fundamental benefit of warm mix asphalt (WMA) combinations . WMA are also utilised under unfavourable circumstances, primarily in cold weather [15].

The technical summary of the many studies relating to the bitumen ageing process is provided in the paper. The most often utilised product in the paving sector is bitumen . The most frequently researched anti-aging compounds are reviewed, along with their results [14].

The higher maintained penetration and ductility values indicate that rejuvenated binders have higher ageing resistance than original asphalt [8]. examined the effect of various rejuvenators on the functionality of an old asphalt binder [19].

A 30/40 penetration grade old asphalt binder was mixed with virgin olive oil, virgin cooking oil, waste cooking oil, virgin engine oil, and waste engine oil at a fixed oil level of 4% for all types . The main substance utilised as a binder for the construction of roads is asphalt. Due to infrastructure development and construction operations, there is a strong need for asphalt binder .Due to the virgin olive oil's low rutting outcome, the high rejuvenator dosage may cause a rutting problem . Due to the ductility of waste engine oil, a low rejuvenator dosage may not be able to restore the physical attributes [19].

Despite the limited resources, the highway industry uses around 10 million tonnes of bitumen annually . Possibility of reviving the rheological characteristics of aged bitumen recovered from reclaimed asphalt pavement using WCO and WEO . The bitumen that had been regenerated exhibited less short-term ageing tendency[20].

In terms of Marshall stability and flow, it was discovered that revitalised 100% RAP mixes could meet Egyptian standards for high traffic as binder courses and medium traffic as wearing courses . Restaurants, the food sector, and centres for recycling and household disposables are just a few locations where WCO can be collected . On the other hand, local auto repair providers remove WEO from the vehicle when changing the oil regularly [20].

The usual penetration, softening point, ductility, dynamic shear rheometer (DSR), bending beam rheometer (BBR), and Fourier transform infrared spectroscopy (FTIR) tests, respectively, were used to characterise the asphalt binder's physical, ductility, rheological, and morphological properties [21].

2.5 Waste Engine Oil (WEO)

Recycling garbage into usable items has emerged as the key solution to waste disposal issues globally . One of the rejuvenators for the asphalt binders to enhance the characteristics is waste engine oil waste [2]. Aged asphalts' fundamental physical characteristics could be restored to their original state with WEO and WCO. WCO performed better than WEO as a regeneration agent. WCO or WEO were generally applicable regeneration agents to enhance the performance of aged asphalt [3].

The sector of recycled asphalt pavement offered good prospective uses for the new asphalt rejuvenator with mixed WEO and WCO . According to research, WEO and WCO share a molecular structure with asphalt, which is an advantageous circumstance for their reuse [6].

WEO and WCO have been developed as a novel type of regeneration agent, and results have been formulated . The findings suggested that WEO or WCO with the right content could restore ageing asphalt to achieve the original asphalt's qualities and satisfy all physical requirements [6]. A high WEO content can accelerate asphalt mixes' permanent deformation . To improve the performance of asphalt mixtures, it is advised to use WEO with other ingredients such as polymers [22].

One of the most popular renewing remedies is waste engine oil waste . WEO and asphalt share a similar molecular structure, making their combination simple .Following the rheological and microstructural characteristics of old asphalt, research summarising the effect of WEO on their physical properties has been given. The effect of adding WEO on the performance characteristics of aged mixtures has been added to the summary . On the other hand, the addition of WEO can improve flow and rutting depth while reducing stability [13].

Waste engine oil (WEO) and waste vegetable oil (WVO) have both been researched as potential rejuvenating agents for ageing asphalt binder retrieved from reclaimed asphalt pavement (RAP) [15]. WEO and WVO were added to 20/30 penetration grade aged asphalt at three different concentrations (1%, 2%, and 3%) .

The findings indicated that, in comparison to WVO, a higher concentration of WEO was required to regenerate the worn-out asphalt . The rejuvenation of ageing asphalt using WEO and WVO has been found to be feasible and can be regarded as a successful method of recycling both RAP and waste oils . The content of asphaltenes may decrease with the addition of both WEO and WVO [8].

The ideal WEO and WVO percentages for restoring aged asphalt with a penetration grade of 20/30 to its virgin penetration grade of 40/50 are, respectively, 1% and 3% . In comparison to the original asphalt binder, which had a relatively low percentage of mass loss, all of the revitalised asphalt binders have higher ageing resistance [8].

Aged asphalt's low penetration and ductility properties could increase with the addition of waste oils, but its high viscosity and softening point could decrease . The modified binders' excellent performance underlines their promise as cost-effective, green alternatives for road paving applications [16].

The qualities of the aged asphalt pavement will significantly change when different types of waste oils are applied . It is a wise choice to use waste cooking oil (WCO) to create sustainable road asphalt pavement because it can improve the ageing, safety, and pavement features of old asphalt [19].

The native, aged bitumen in Egypt can be revitalised and given back its original qualities by adding 3-4% WCO and 5-6% WEO . The rutting parameter of the aged bitumen was enhanced and nearly identical to the control bitumen by adding the optimal proportion, 3.5% of the WCO . The creep stiffness and rate of rejuvenated bitumen met the requirements of the super pave specification when WCO and WEO were added to aged bitumen. When compared to a combination made entirely of RAP, the examined rejuvenators were found to improve the mechanical qualities in terms of stability and moisture resistance . The successful application of WEO and WCO as a revitalising agent for worn-out bituminous pavements introduces a cost-effective and environmentally friendly alternative for reusing these wastes in the building of pavement [20].

Three soy-based bio-rejuvenators and one conventional petroleum-based oil have been tested to see how they affect ageing asphalt binders . By returning the chemical ageing indices at least partially to the state of the virgin binder, the Fourier transform infrared spectrum demonstrates that both petroleum-based oil and bio-oils were able to rejuvenate the aged binders . Because they were able to restore the virgin binder qualities utilising common agent contents, soy-based oils have a great potential to operate as asphalt rejuvenating agents . Lower optimal rejuvenator contents were discovered for bio-oils, pointing to potential financial advantages of using this type of substance if its price is comparable to that of the traditional agent [23].

The current study's findings, which include FTIR spectroscopy and rheological tests, indicate that the bio-oils cause a change in the aged binder's physical properties as well as its chemical composition. This reconstitution of the colloidal structure leads to the recovery of its rheological performance . Waste Engine Oil (WEO) from automobiles has been investigated for use as a bitumen recycling agent [24].

In order to imitate the ageing process, rolling thin film oven testing (RTFOT) and pressure ageing vessel testing (PAV) were used to prepare the aged bitumen . With the addition of WEO, the penetration value of mixed bitumen rose. This suggests that as WEO was added, the stiffness of the modified asphalt binder reduced .

As high penetration values were produced, the softening point test revealed a decreasing value for blended bitumen . The blended bitumen combined with WEO had lower viscosity values after the addition of WEO. According to the study, WEO can reverse bitumen stiffening and return the aged binder to its youthful properties [9].

In order to advance green asphalt and environmental conservatism, it can be advantageous to employ WEO to revitalise short-term aged asphalt binders [21].

2.6 Use of waste Engine Oil as an Asphalt Binder Rejuvenator

Numerous research have looked into the usage of WEO as an asphalt binder rejuvenator. These experiments have demonstrated that WEO can be a potent rejuvenator for asphalt binder, and its application can result in significant enhancements to the binder's mechanical properties. [21]

In recent research studies, the usage of WEO as a rejuvenator for asphalt binder has yielded promising results. When asphalt binders age, they frequently lose their elasticity and become more brittle, which causes cracking and pavement damage. However, it has been discovered that using WEO helps old asphalt binders regain their elasticity, enhancing the overall effectiveness and durability of asphalt pavements. [25]

The disposal of WEO, a petroleum refining byproduct with significant environmental hazards, presents environmental issues. However, its application as a rejuvenator for asphalt binder offers a chance for the waste product to be recycled and used again, lowering environmental pollution and waste management expenses. Furthermore, WEO has a high aromatic content, which makes it an excellent choice for use in asphalt binders because it can increase elasticity and viscosity. [10]

Improvements in the performance of asphalt pavements have been attributed to the use of WEO in asphalt binders. For instance, Oluwasola et al.'s (2020) study looked into how WEO affected the rheological characteristics of asphalt binders. According to the research, adding WEO to old asphalt binders enhanced their rheological characteristics, such as stiffness, ductility, and viscosity. The study's findings indicated that WEO might be used to rejuvenate asphalt binders, thereby enhancing the performance and longevity of asphalt pavements. [17]

examined the results of adding WEO to recycled asphalt pavement (RAP) mixtures as a rejuvenator. In terms of performance and durability, notably in terms of resistance to rutting and cracking, the study indicated that adding WEO to RAP combinations improved them. The study also found that using WEO as a rejuvenator for RAP mixtures has financial advantages, lowering the price of producing asphalt and enhancing the durability of the pavement. [21]

The use of WEO as an asphalt binder rejuvenator still raises certain questions. The possible environmental effects of using WEO, especially if it is not properly disposed of or recycled, are a big worry. Additionally, WEO quality and uniformity may vary, which may have an impact on how well asphalt binders work. Therefore, before employing WEO as a rejuvenator for asphalt binders, it is crucial to thoroughly analyse the source and quality of WEO. [21]

Waste cooking and engine oil can efficiently soften and restore the workability of old asphalt. Waste cooking oil (WCO) improved the rheological characteristics of aged asphalt more than waste engine oil (WEO). Overall, the good applicability gives waste oil a significantly larger variety of service options in the field of recovering asphalt pavement [6]. Waste engine oil is used as motor oil, crankcase oil, cylinder oil, and lubrication oil . Physical and chemical characteristics of WEO differ from those of fresh oil [22].

High quantities of petrol and heavy metals are present in WEO . Conclusion: Low doses of WEO applied to aged asphalt can boost penetration and ductility while lowering viscosity and softening point . WEO addition might increase the flow while decreasing the stability. With WEO present, the bonding between asphalt and aggregate may be severely impacted [22]. WEO as a rejuvenating agent has both favourable and unfavourable effects on the characteristics of old asphalt . Future difficulties in renovating worn-out asphalt with WEO can be predicted utilising the review presented in the study [13].

Alkanes and cycloalkanes are present in WEO according to its FTIR spectra . According to the summary of the literature, applying low quantities of WEO to aged asphalt can improve its ductility and penetration . Aged asphalt's stiffness and complex modulus can likewise be reduced by it, and its phase angle and m-value can be increased . It is advised to combine the WEO with additional substances such polymers, maltenes, or antistripping compounds . A life cycle cost analysis (LCCA) of aged asphalt rejuvenated by WEO is advised [13]. Another crucial point is that economic study is required before putting the aged asphalt with waste oil in the industry.

Using warm mix technology, asphalt mixtures can be created and compacted at lower temperatures [15]. Numerous experiments have been done in the last ten years to renew asphalt pavement using used cooking oil that has been recycled . Furthermore, earlier research has found that WCO may improve the physical properties of the aged asphalt, such as penetration and softening point .

By providing the ideal oil proportion, the use of WCO or WVO can improve the properties of asphalt's viscosity . Additionally, the qualities of the worn-out asphalt binder are improved and restored by the use of WCO and WEO . Additionally, the failure temperature of an old asphalt might be lowered by adding WCO at a rate of 5% of the total weight of the asphalt . When a large amount of rejuvenator is added to an old asphalt binder, bleeding is one of the most frequent problems, which can cause poor skid resistance . Conclusion: Improved oil physical characteristics result in improved characteristics of aged asphalt [19].

Due to a chemical structure and molecular makeup that is identical to the asphalt binder, waste engine oil has a low storage stability value . When examining the effects of various rejuvenators on the behaviour of old asphalt binder, the rheology criteria provide precise insight . The unrecoverable deformation of an asphalt binder under a constant load at various temperatures is described by the rutting resistance parameter . With an increase in the quantity of oils, the penetration and softening point values increase and decrease, respectively [19].

For the 30/40 aged asphalt's characteristics to be restored, waste and virgin engine oils need to include more oil than 4% . By adding 4% of any type of oil, the physical properties of the aged asphalt were improved, and the viscosity values varied slightly depending on the oil's quality . By raising the maltene content while lowering the asphaltene content, rejuvenators are utilised to soften the old asphalt binders. [19]

Overall, the viscosity of the asphalt binder is reduced, and its ductility qualities are improved . The usage of numerous elements as asphalt binders' modifiers is well-documented in the literature . Numerous attempts have been made to utilise WEO in the rejuvenation of old asphalt binders due to some similarities in the physical and chemical properties of WEO and asphalt binder . If the original WEO is utilised directly as the rejuvenator, the rejuvenated asphalt binder exhibits deficiencies [10].

3 Chapter:3

Methodology

3.1 Introduction:

Bitumen rejuvenation is a significant problem in the construction industry since bitumen quality determines how well asphalt pavement performs. Temperature, sunlight, oxygen, and other environmental factors all promote the aging process that occurs naturally over time. Short-term aging of bitumen could lead to the loss of desired properties including ductility and elasticity, which is a severe concern. To decrease the effects of short-term aging, rejuvenators can be employed to restore the physical and rheological properties of bitumen.[4]

The objective of this study is to see if waste engine oil may rejuvenate bitumen that has temporarily aged. The study's main focus will be on bitumen's physical properties, specifically its penetration, softening point, viscosity, and ductility. The rolling thin film oven (RTFO) test will be used to artificially age bitumen samples, and varied quantities of waste engine oil will be used to rejuvenate them. An experimental method will be used to conduct the inquiry.

The research methodology used for this project is presented in this chapter. The chapter gives a brief introduction to methadology. It will be deliberate to select bitumen samples that have passed the RTFO test, and laboratory testing will be used to analyze the samples' physical qualities both before and after aging and rejuvenation. Different concentrations of used engine oil waste will be blended into the bitumen samples to revitalize them.

The results of this study will expand our knowledge of bitumen rejuvenation and provide significant building industry insights. The rejuvenation of bitumen using used engine oil is a sustainable and cost-effective method that can minimize the demand for virgin resources and maximize waste reduction. The findings of this study can also be applied to improve the performance and layout of asphalt pavement, which is essential for ensuring the safety and comfort of road users.

In conclusion, this chapter has offered the methodology for the study on the rejuvenation of short-term aged bitumen using waste engine oil. The study's findings, which illuminate how effective waste engine oil is as a bitumen rejuvenator, are described in the chapter that follows.

3.2 Research Approach:

For this examination, an experimental research design will be used. This study aims to investigate the impact of waste engine oil on bitumen's aging. The experiment will be conducted in a laboratory setting utilizing bitumen samples that have been artificially aged using the rolling thin film oven (RTFO) test and then rejuvenated using different quantities of waste engine oil.

3.3 Choosing Bitumen Samples

The selection of bitumen samples will be based on consistency, which will guarantee the validity of the investigation. Since road construction projects frequently use this grade, we will select bitumen samples from the 60/70 penetration grade. After being obtained from a nearby refinery, the physical characteristics of the samples will be examined to confirm uniformity.

3.4 Methadology:

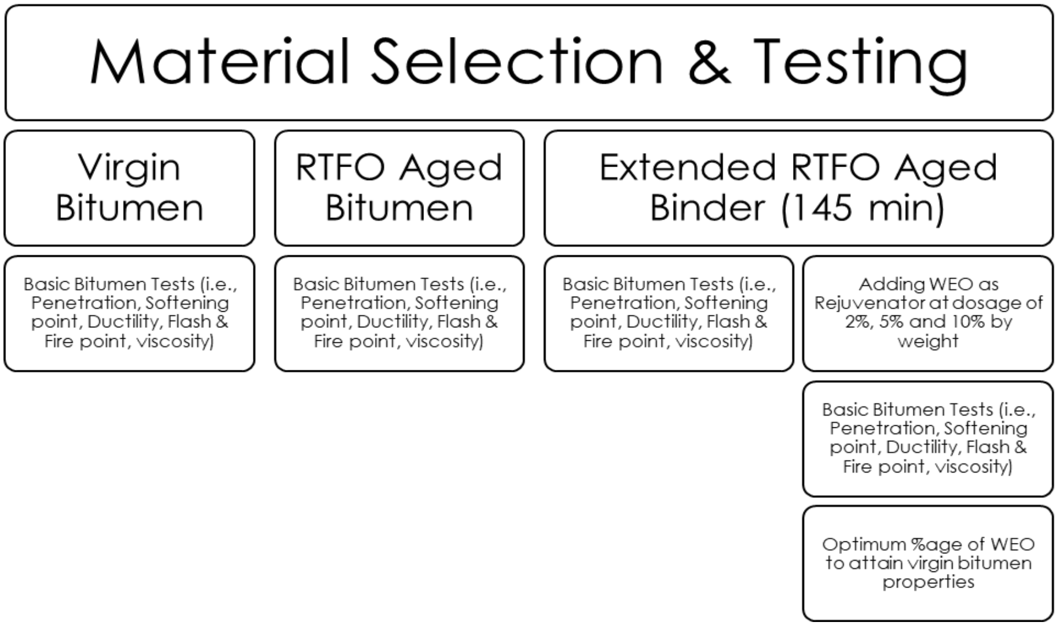


Fig 3.4 test matrix of methodology

3.4.1 Tests on virgin bitumen

Virgin bitumen tests are examinations of the physical characteristics of bitumen samples that have not undergone any aging or rejuvenation procedures. These tests are performed to establish a baseline for comparison with the characteristics of the bitumen samples after they have aged and regenerate.

Determining the penetration, softening point, and ductility of fresh bitumen samples is a common step in testing procedures. The penetration test looks at how hard the bitumen is, whereas the softening point test determines the temperature at which the bitumen turns soft. How far a conventional bitumen briquette can be stretched before breaking is measured by its ductility.

One of the frequently studied rheological characteristics of virgin bitumen samples is viscosity. The viscosity test measures the difficulty of bitumen samples flowing under gravity.

To evaluate the characteristics of bitumen samples that have been aged and rejuvenated, the results of tests performed on virgin bitumen are noted and used as a benchmark. The comparison helps determine how well waste engine oil revitalizes the bitumen samples.

3.4.2 Testing the Rolling Thin Film Oven (RTFO)

The RTFO test simulates the short-term aging of bitumen in the field. The test will be conducted in accordance with ASTM D2872 standard. The bitumen samples are continuously rolled for 85 minutes during the RTFO test while being exposed to hot air and temperatures (163°C). Bitumen begins to age quickly when asphalt pavements are constructed and used. This procedure rates that process more quickly.

3.4.3 Samples of Bitumen Aging

After the RTFO test, the aged bitumen samples will be stored at room temperature for an additional 24 hours to continue aging. As bitumen samples age, their physical and rheological characteristics change, including a decrease in ductility and an increase in viscosity.

3.4.4 RTFO Extended Test:

The 145-minute extended RTFO test will be conducted in accordance with the specifications of ASTM D2872. For this test, the bitumen sample will be heated to a temperature of 163°C and exposed to a constant airflow of 4000 ml/min for 145 minutes. In order to achieve even heating throughout the test and prevent localized overheating, the bitumen sample will be rotated.

After the 145-minute aging period, the bitumen sample will be removed from the RTFO and allowed to cool to room temperature. The physical and rheological characteristics of the aged samples will then be examined in order to provide a baseline for comparison with the age of the bitumen samples after they have been rejuvenated using waste motor oil.

3.4.5 Bitumen Sample Rejuvenation

The degraded bitumen samples will be revived with waste engine oil. At different concentrations (i.e., 2%, 5%, and 10% by weight), the aged bitumen samples will be blended with the used waste engine oil. A nearby auto repair shop will supply the used waste engine oil.

The physical characteristics of the rejuvenated samples will be compared to those of the unrejuvenated samples, and variable waste engine oil concentrations will be used. As part of the rejuvenation procedure, the aged bitumen samples' physical and rheological characteristics, such as ductility and viscosity, will be restored.

The bitumen samples will be selected for this study based on consistency, put through the RTFO test to simulate short-term aging, aged for 24 hours to allow for additional aging, and then rejuvenated using waste engine oil.

As part of the rejuvenation procedure, the physical and rheological properties of the aging bitumen samples will be restored. The method outlined in this section will ensure the study's validity and reliability. Finding the ideal quantity of waste engine oil required to produce virgin bitumen characteristics is a crucial component of this study. It will provide crucial details on the effectiveness of waste engine oil as a rejuvenating agent for bitumen samples and help develop more environmentally friendly and financially feasible bitumen rejuvenation techniques.

3.4.6 Mixing methods:

To create samples of rejuvenated bitumen, aged bitumen was mixed with three concentrations of WEO (2%, 5%, and 10% by mass of binder). Using an electric stirrer running at a constant speed of 2000 rpm, the mixture was blended for 15 minutes at 135-150 °C. The time and temperature were held constant throughout the mixing process to ensure accurate experimental results. After blending, the homogenous rejuvenated asphalt binders were produced for the property testing.

Fig 3.5 mixing the WEO with asphalt binder

3.5 Testing of Physical Properties:

3.5.1 Penetration Test:

The penetration test of bituminous materials, which gauges the material's consistency at room temperature, is covered by the ASTM D5 standard. The test determines, under particular temperature, load, and time circumstances, the depth in tenths of a millimeter to which a standard needle will penetrate vertically into a bituminous material.

3.5.1.1 Scope:

The test determines if bituminous materials are hard or soft, and it can be applied to quality assurance and product development. Bituminous substances, including asphalt, tar, and bitumen, are used for the test.

3.5.1.2 Procedure:

As to ASTM D5, the following stages are involved in executing the penetration test on bituminous materials:

- A certain temperature is reached by heating the bituminous sample.
- The sample is next allowed to cool for an hour to room temperature, usually 25°C (77°F).
- The needle, base plate, and weight are assembled as part of the penetration test apparatus. Before usage, the device needs to be leveled and stabilized.
- The needle is carefully lowered onto the sample's surface until it touches it but does not pierce it.
- Five seconds of load are applied once the weight is placed on top of the needle.

- The needle is then let go, and using the scale on the device, the depth of penetration is measured in tenths of a millimeter.
- The sample is subjected to the test two more times, and the average of the three results is presented.

Overall, the penetration test of bituminous materials is a commonly used and reasonably straightforward technique for measuring the consistency of bituminous materials at room temperature, and ASTM D5 offers a thorough process and safety measures for carrying out the test precisely and consistently.[26]

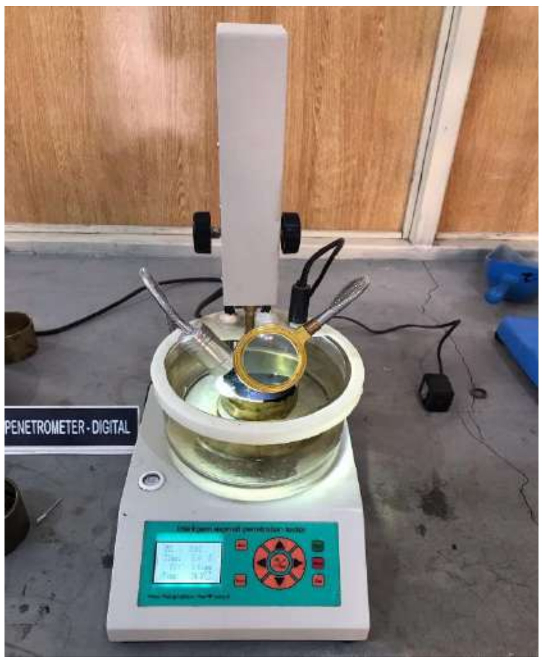


Fig 3.6.1: Digital pentrometer

3.5.2 Softening Point Test: [2]

The bituminous materials softening point test, which determines the temperature at which a bituminous material becomes soft enough to permit a steel ball to fall a set distance under particular circumstances, is covered by the ASTM D36 standard.

3.5.2.1 Scope:

The test is used to figure out when bituminous materials, like bitumen, start to soften. Bituminous material samples are put to the test to see if they are suitable for different purposes.

3.5.2.2 Procedure:

According to ASTM D36, the following stages are involved in completing the softening point test on bituminous materials:

- The bituminous sample is put inside a metal ring that is round and has a predetermined diameter and height.
- On top of a metal support, the ring is heated at a predetermined rate—typically 5°C per minute.
- On top of the sample is a steel ball with a specific diameter and weight.

- The temperature is measured when the steel ball reaches a predetermined depth in the sample, usually 2.5 mm or 5.0 mm.
- Two more samples are used for the test, and the average of the three results is presented.

Overall, ASTM D36 offers a thorough technique and safety measures for carrying out the test accurately and reliably. It is a commonly used method for evaluating the softening point of bituminous materials. [27]

FIG 3.6.2:checking the temperature of water during softening point test

3.5.3 Ductility Test:

The ductility test of bituminous materials is covered by ASTM D113, which is a measurement of the length in centimeters to which a standard bitumen briquette will be extended before breaking at a specific temperature and pulling rate.

3.5.3.1 Scope:

When two ends of a briquet specimen of the material are pulled apart at a specific speed and at a specific temperature, the distance that the material will stretch before breaking is used to determine the ductility of the material. Unless otherwise stated, the test must be conducted at a speed of 5 cm/min +/- 5.0% and a temperature of 25 °C. The speed should be set for various temperatures.

3.5.3.2 Procedure:

According to ASTM D113, the following stages are involved in completing the ductility test on bituminous materials:

- A mold of a specific size is used to create a briquette out of bituminous material.
- The sample is prepared by submerging the briquette in a water bath at a predetermined temperature, commonly 15°C or 25°C, for a predetermined period of time.
- The briquette is clamped at the ends and placed horizontally in the ductility machine.
- The briquette is broken by being pulled apart at a predetermined rate, usually 5 cm/min.
- The lengthened length of the briquette before it broke is measured and noted in centimeters.

All things considered, the ductility test of bituminous materials is a commonly used technique for figuring out the ductility of bituminous materials, and ASTM D113 offers a thorough process and safety precautions for carrying out the test accurately and reliably. [28]

Fig 3.6.3:monitoring the temperature during ductility test

3.5.4 Flash and fire point test:

The minimal temperature at which a bitumen sample's vapor may momentarily ignite in the presence of a test flame is found using the flash and fire point test of bitumen. The ASTM D92 standard procedure is followed for conducting the test.

3.5.4.1 Scope:

Bituminous materials with a flash point higher than 79°C (175°F) can have their flash and fire points measured using the flash and fire point test. Bitumen having a flash point lower than 79°C (175°F) cannot be tested.

3.5.4.2 Procedure:

- The bitumen sample is heated to a temperature that is 50°C higher than its predicted flash point.

- Every few degrees Celsius, the sample's surface is in contact with the test flame.
- The flash point is the temperature at which the bitumen briefly ignites.
- The test is carried out until the sample catches fire and maintains a flame for at least five seconds. The fire point is the temperature at which sustained combustion takes place.[29]

Fig 3.6.4:perfoming the flash and fire test

3.5.5 RTFO test:

In order to imitate the short-term aging of bitumen that takes place during the mixing and laying of asphalt, the rolling thin film oven (RTFO) test of bitumen is utilized. The ASTM D2872 standard procedure is used to conduct the test.

3.5.5.1 Scope:

The short-term aging of bitumen that takes place during the mixing and laying of asphalt is simulated by the RTFO test. The test is designed to assess how bitumen's rheological and physical characteristics are affected by brief aging.

3.5.5.2 Procedure:

- To guarantee homogeneity, the bitumen sample is heated to a temperature of 163°C (325°F) and stirred.
- The bitumen sample is put into the RTFO test device and exposed to an uninterrupted stream of air for 85 minutes at a temperature of 163°C (325°F).
- After being taken out of the RTFO test device, the bitumen sample is allowed to cool to room temperature.
- The aged bitumen sample is subjected to physical and rheological tests in order to determine how short-term aging has affected it.
- Normally, the RTFO test lasts for 85 minutes, however extended times (such 135 minutes or 145 minutes) can be utilized to mimic more severe short-term aging conditions.[30]

Fig 3.6.5: perfoming the rtfo test

3.5.6 VISCOCITY TEST: [6]

Using a rotational viscometer, the bitumen viscosity test measures the viscosity of bitumen at a specific temperature. The ASTM D2171 standard procedure is used to conduct the test.

3.5.6.1 Scope:

Bitumen viscosity at a given temperature is measured using the viscosity test. The test is used to assess bitumen's flow characteristics, which is crucial in figuring out whether or not it may be used in asphalt paving.

3.5.6.2 Procedure:

- To achieve homogeneity, the bitumen sample is heated to a predetermined temperature (usually 60°C or 135°C) and agitated.
- The bitumen sample is put inside the viscometer and given at least 30 minutes to acclimate to the required test temperature.
- The bitumen sample's viscosity is determined at a specific shear rate using a rotational viscometer.
- To ensure accuracy, the viscosity measurement is taken at least three times.
- The value of average viscosity is computed and noted.

To assess the flow characteristics of bitumen under varied circumstances, the viscosity test can be carried out at different temperatures and shear rates. Based on bitumen's viscosity at a particular temperature, the findings of the viscosity test can be used to categorize it into distinct grades.[31]

Fig 3.6.6:checking the viscocity of bitumen

3.6 Conclusion:

This chapter described the procedure for examining waste engine oil's potential as a short-term bitumen rejuvenator. The bitumen samples will be artificially aged using the rolling thin film oven (RTFO) test, and varied concentrations of waste motor oil will be used for rejuvenation. Before and after ageing and rejuvenation, measurements of physical and rheological characteristics such penetration, softening point, viscosity, and ductility will be made. The findings of this research will further our understanding of bitumen rejuvenation and provide crucial insights for the construction sector.

4 Chapter-4

RESULTS AND CALCULATIONS:

4.1 Introduction:

Bitumen is an essential material for building infrastructure including roads, bridges and pavements. However, bitumen ages with time as a result of exposure to environmental elements, which impairs its physical qualities. It's not always a sustainable or economical choice to employ virgin bitumen or pricey additives in traditional rejuvenation treatments for ageing bitumen. (1)

Physical tests were used in this study to examine the efficacy of waste engine oil in renewing bitumen. This study set out to determine whether waste engine oil could be a practical substitute for the more conventional bitumen rejuvenation processes.

Physical tests, such as penetration, softening point, ductility, flash, and fire tests, were performed using the original and rejuvenated bitumen samples as part of the research approach. The efficiency of waste engine oil in renewing bitumen was determined by analysing and comparing the test data.

This chapter's goal is to present and go through the findings from the physical tests done on the bitumen samples. The significance of these findings and their implications for the use of waste engine oil in bitumen rejuvenation will also be covered.

The overall goal of this study is to provide light on the viability of using waste engine oil to rejuvenate bitumen in a sustainable and affordable manner.

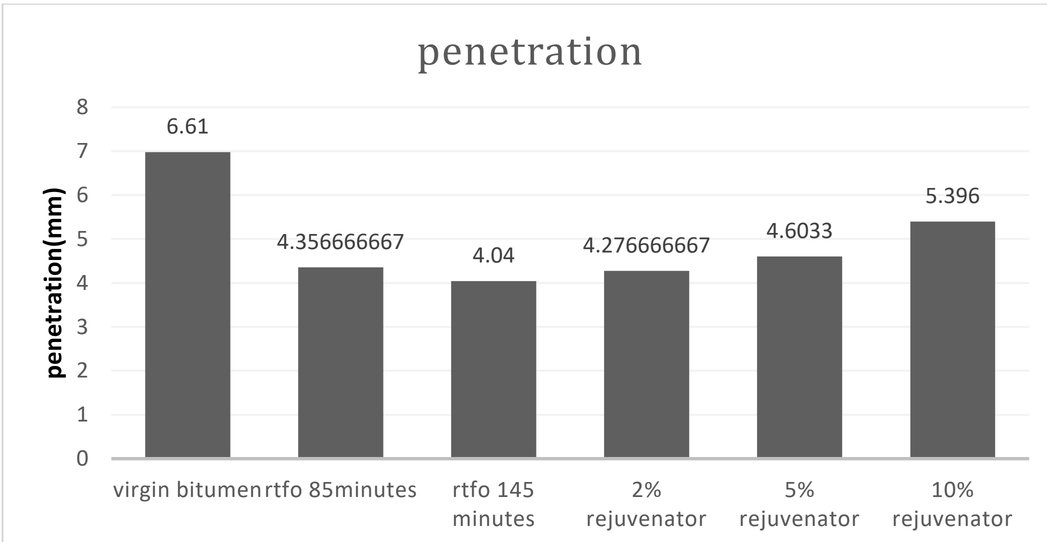
.The results of laboratory studies conducted to ascertain waste engine oil's effectiveness in rejuvenating bitumen under various ageing conditions and concentrations are covered in this chapter. The experiments made use of physical testing for things like penetration, softening point, ductility, flash, and fire and viscocity test.

4.2 Results Of Bitumen Samples

In order to examine the physical characteristics of the bitumen before and after rejuvenation, various ageing circumstances and concentrations of waste engine oil were utilized to analyze the bitumen samples.The outcomes from the physical tests are discussed below

4.2.1 Penetration Test:

The penetration test was used to evaluate the consistency or hardness of the bitumen samples. The findings showed that the penetration value for all bitumen samples increased following rejuvenation using waste engine oil in comparison to the virgin and aged bitumen samples.

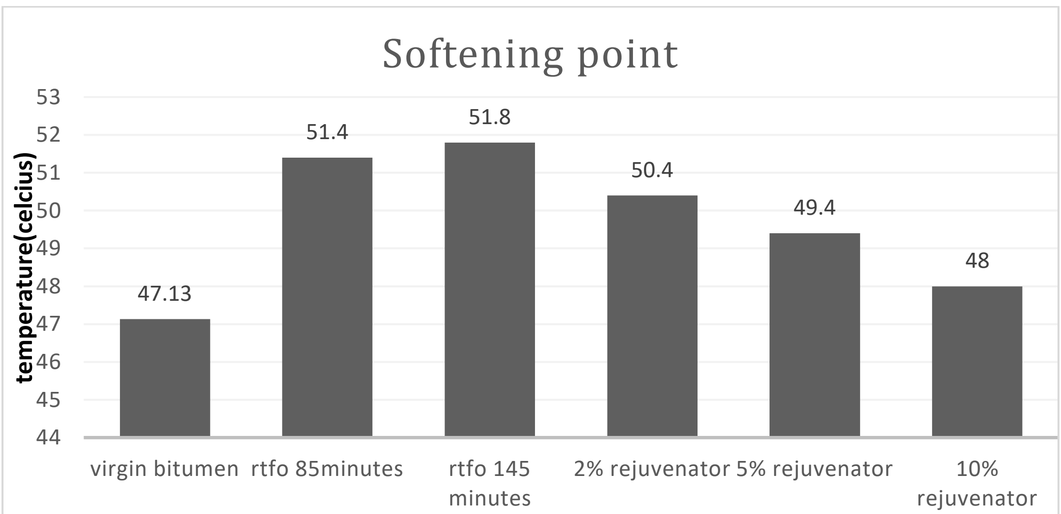


Graph 4.2.1: penetration test graph

The virgin bitumen had a penetration value of 6.98 mm.Extended RTFO-aged bitumen aged for 145 minutes had a penetration value of 4.04 mm compared to literature, where RTFO-aged bitumen aged for 85 minutes had a penetration value of 4.38 mm and literature had a value of 2.93 mm. Following rejuvenation using 2% waste engine oil concentration, the penetration value increased to 4.27 mm, whereas in the literature it was 3.79 mm. In comparison to previous literature, the penetration increased to 4.61 mm with a 5% waste engine oil concentration and to 5.396 mm with a 10% waste engine oil concentration.[2]

4.2.2 Softening Point Test:

The softening point test was used to determine the temperature at which bitumen starts to soften. The findings showed that the softening point value for all samples increased after rejuvenation with waste engine oil compared to the original and aged bitumen samples.



Graph 4.2.2:softening point test graph

The virgin bitumen sample's softening point value was 47.2°C, while previous literature had it at 47°C. The softening point value climbed to 51.5°C for bitumen that had undergone RTFO ageing for 85 minutes compared to past data it was 51.2°C , and to 51.7°C for bitumen that had undergone prolonged RTFO ageing for 145 minutes in comparison with past literature it was 51.4°C. These findings show that the bitumen's softening point value grew as it aged.

The softening point value dropped after rejuvenation with waste engine oil to 50.5°C for 2% waste engine oil concentration, 49.4°C for 5% waste engine oil concentration, and 48°C for 10% waste engine oil concentration. If we compare it to the past literaturte the values was 50.1°C ,49.5°C and 48.4°C respectively.

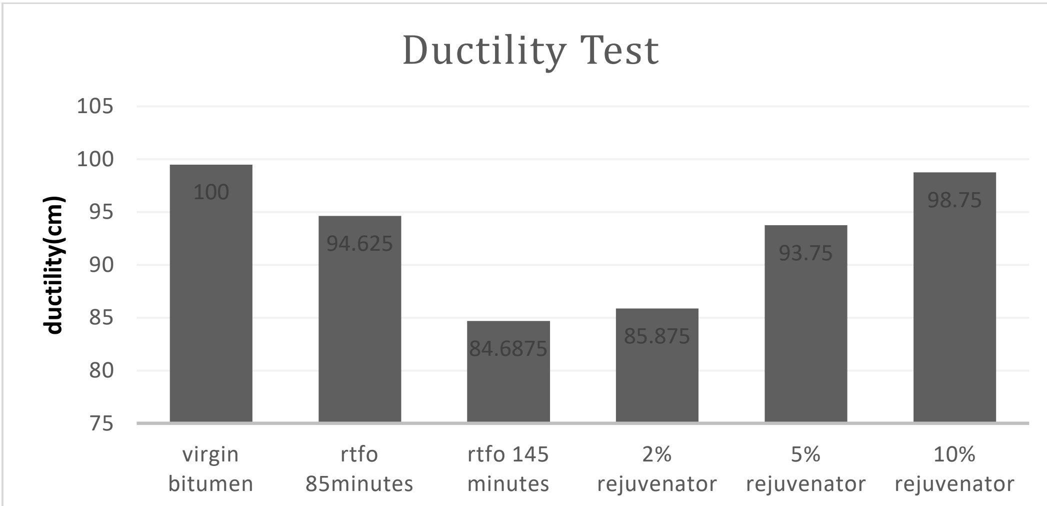
4.2.3 Ductility Test

The lengthened length of the bitumen samples prior to rupture was measured using the ductility test. In comparison to the original and aged bitumen samples, the results showed that the ductility value rose for all samples after rejuvenation using waste engine oil. To find the temperature at which bitumen begins to soften, the softening point test was performed. As compared to the original and aged bitumen samples, the results demonstrated that the softening point value rose for all samples after rejuvenation using waste engine oil.

The softening point value for the virgin bitumen sample was 47.2°C,compared to the past literature it was 47°C. The softening point value climbed to 51.5°C for bitumen that had undergone RTFO ageing for 85 minutes compared to past data it was 51.2°C , and to 51.7°C for bitumen that had undergone prolonged RTFO ageing for 145 minutes in comparison with past literature it was 51.4°C. These findings show that the bitumen's softening point value grew as it aged.

The softening point value dropped after rejuvenation with waste engine oil to 50.5°C for 2% waste engine oil concentration, 49.4°C for 5% waste engine oil concentration, and 48°C for 10% waste engine oil concentration. If we compare it to the past literaturte the values was 50.1°C ,49.5°C and 48.4°C respectively.

The lengthened length of the bitumen samples prior to rupture was measured using



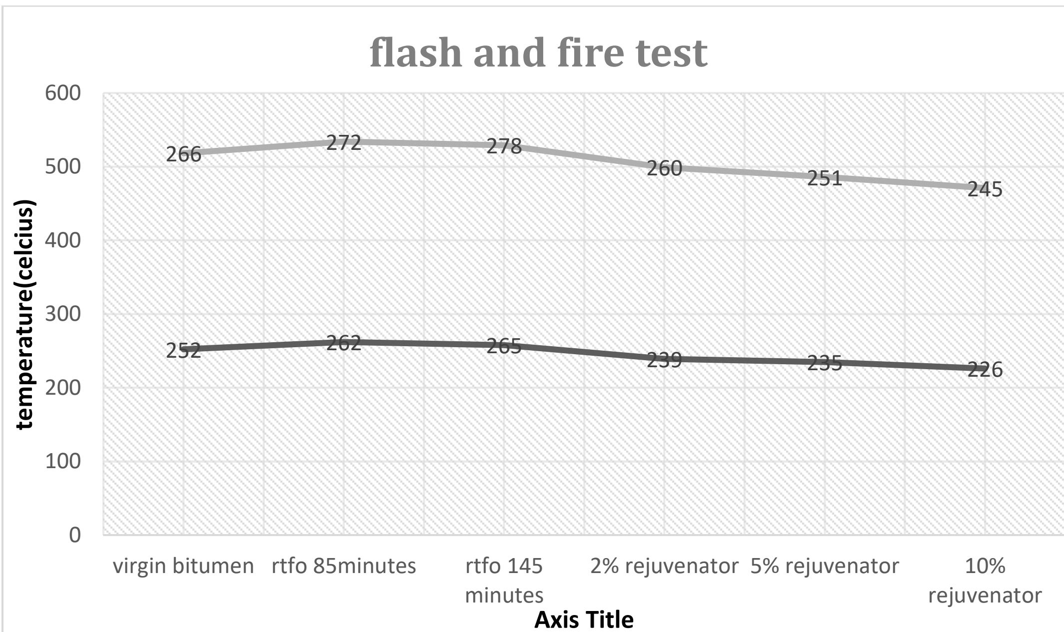
Graph 4.2.3: ductility test graph

The ductility value for the virgin bitumen was 100 cm. RTFO-aged bitumen that was aged for 85 minutes increased in ductility to 93.5 cm, whereas extended RTFO-aged bitumen that was aged for 145 minutes increased ductility to 83.75 cm.if we compare it to the past data the values was 100cm,88cm and 80cm respectively. After rejuvenation with waste engine oil, the ductility value for prolonged RTFO-aged bitumen aged for 145 minutes increased to 85.5 cm with a concentration of 2% waste engine oil, 93.75 cm with a concentration of 5% waste engine oil, and 98.75 cm with a concentration of 10% waste engine oil.in the past data with rejuvenation of 2%,5% and 10% the values was 86cm, 90cm 96.8cm[3]

The bitumen's flexibility and durability have improved, which is ideal for usage in roads and pavements, as indicated by the increase in ductility value. The findings indicated that the ductility value decreased with increasing age, and increased waste engine oil concentration increased ductility value.

4.2.4 Flash and Fire Point Tests

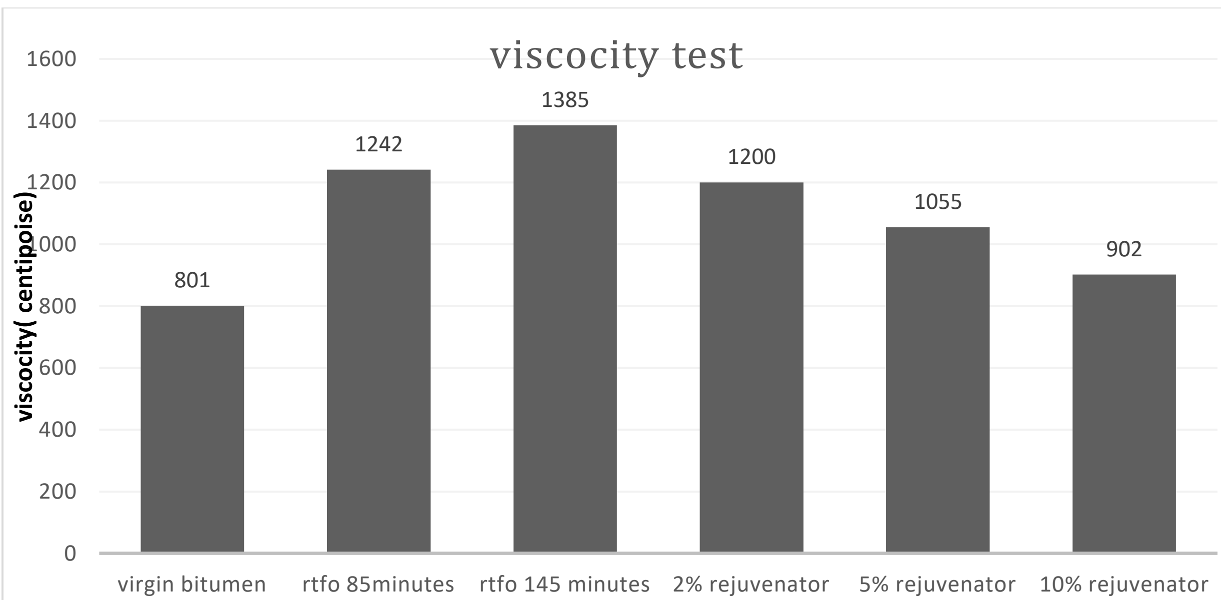
The safety of the bitumen samples was assessed using the flash and fire point tests. The findings demonstrated that after ageing, the flash and fire point values increased for all samples, but when we used waste engine oil, the values reduced.



Graph 4.2.4: Flash And Fire Test Graph

The flash point and fire point values for neat bitumen were 240°C and 266°C, respectively if we compare it with the past data the values was 265°C and 280°C respectively. For RTFO-aged bitumen aged for 85 minutes, the fire point value grew to 273°C, whereas the flash point value increased to 262°C and from the past data the values was 285°C and 300°C. Extended RTFO-aged bitumen matured for 145 minutes resulted in a 258°C flash point value and a 275°C fire point value from the past data the values was 270°C and 310°C . The flash point and fire point values for all samples reduced with increasing waste engine oil concentration after rejuvenation using waste engine oil. The flash point and fire point of extended RTFO-aged bitumen with 2% waste engine oil concentration were 245°C and 260°C, respectively and from the past data the values was 260°C and 275°C. With a 5% waste engine oil concentration, the prolonged RTFO-aged bitumen aged for 145 minutes had a flash point of 235°C and a fire point of 250°C and from the past data the values was 255°C and 275°C . With a 10% waste engine oil concentration, the flash point was 226°C and the fire point was 245°C and from the past data the values was 240°C and 270°C.

4.2.5 Viscocity test:



Graph 4.2.5: Viscocity Test Graph

The findings of the viscosity tests shed important light on how the viscosity properties of the asphalt binder are affected by ageing and the addition of rejuvenators. The virgin bitumen had a viscosity of 801 centipoises (cP) at first. The viscosity increased to 1,242 cP after 85 minutes of RTFO ageing, showing a considerable alteration in the binder's flow characteristics. A subsequent ageing for an additional 145 minutes led to a viscosity increase to 1,385 cP.if we compare it to the past data the values was 900(cP),1300(cP) and 1500(cP).

However, viscosity readings showed a noticeable drop when rejuvenators were added at various dosages. The viscosity decreased to 1,200 cP at a 2% rejuvenator dosage, demonstrating a partial restoration of the binder's flow properties. The viscosity further fell to 1,055 cP at a rejuvenator dosage of 5%, indicating a more notable increase in flowability. The viscosity dropped to 902 cP with a rejuvenator dosage of 10%, which indicated a significant improvement in the flow qualities of the asphalt binder. This had the biggest effect.if we compare it to the past literature review the values decred to 1410(cP), 1230(cP) and 950(cP)

4.2.6 Conclusion:

The results of this study showed that adding waste engine oil as a rejuvenating agent can significantly improve the physical qualities of bitumen that has undergone ageing through the RTFO test. The penetration value decreased while the softening point, ductility, flash point, and fire point values increased as the concentration of waste engine oil increased. The bitumen's functionality and service life in applications like roads and pavements could be improved by these improvements in its physical properties.

Overall, the results point to waste engine oil as a potentially efficient and cost-effective rejuvenator for bitumen that has aged due to the RTFO test. Further study is needed to determine the resilience and long-term performance of the rejuvenated bitumen in real-world conditions, as well as the viability of using waste motor oil as a sustainable alternative to current rejuvenating agents.

5 Chapter:5

Analysis of reults

5.1 Introduction:

This chapter aims to provide a complete analysis of the results of experimental research on the rejuvenator properties of waste engine oil. The prior chapters provided the backdrop, goals, methodology, and technique of data collection. It is now crucial to do study into the findings and outcomes of the experiment. This inquiry will provide a more thorough understanding of the ramifications and viability of using waste engine oil as a rejuvenator.

5.2 Analyzing Samples Of Bitumen

It was important to evaluate how the bitumen's physical qualities changed under various aging scenarios and waste engine oil concentrations in order to analyze the bitumen samples. The analysis of physical testing is discussed below.

5.2.1 Analysis Of Virgin Bitumen

Important conclusions about the virgin bitumen's penetration, softening point, ductility, flash point, fire point, and viscosity qualities were drawn from the analysis. The virgin bitumen's first penetration value, which reflects its relative hardness, was 6.98 mm. This value serves as a benchmark for contrasting how bitumen penetration is affected by aging and rejuvenation.

The virgin bitumen showed a value of 47.2°C for the softening point, which sheds light on its thermal behavior. This value is significant because it provides a starting point for assessing how aging and Rejuvenation affect the softening point.

Additionally, the virgin bitumen's ductility test result of 100 cm indicated that it could be stretched before breaking. This value determines the bitumen's initial ductility level and provides a benchmark for assessing how aging and rejuvenation affect ductility.

The virgin bitumen's measured flash point and fire point were found to be 240°C and 266°C, respectively. These numbers show the temperature at which bitumen can start to burn and continue to burn. They offer crucial information on the bitumen's flammability traits.

The virgin bitumen had an initial viscosity value of 801 centipoises (cP), according to the viscosity test. This number represents the bitumen's resistance to flowing at the specified temperature and shear rate. For assessing the changes in flow behavior brought on by aging and rejuvenation, it is essential to comprehend the initial viscosity.

A thorough grasp of the virgin bitumen's initial features is obtained by looking at these aspects. In later research, comparisons and evaluations of the impacts of aging and rejuvenation on the bitumen's properties will be based on this knowledge.

5.2.2 RTFO-Aged Bitumen Analysis (85 minutes):

After 85 minutes of aging, the study of RTFO-aged bitumen offers important insights into the changes that take place in its characteristics when compared to virgin bitumen. The evaluation focused on the qualities of penetration, softening point, ductility, flash point, fire point, and viscosity.

When compared to the virgin bitumen's initial penetration value of 6.98 mm, the RTFO-aged bitumen showed a lower value of 4.38 mm. The fact that there has been a decline in penetration shows that the bitumen has grown harder and less pliable over time.

After 85 minutes of aging, the softening point value increased to 51.5°C, showing a rise in the temperature at which the bitumen begins to soften. This modification shows that bitumen has grown stiffer with age and is more resistant to temperature-induced softening.

In addition, the RTFO-aged bitumen's ductility value increased to 93.5 cm after 85 minutes of aging, compared to the virgin bitumen's ductility of 100 cm. This increase suggests that the bitumen's ductility has slightly improved with age and that its ability to stretch before breaking has slightly increased.

In comparison to the values of the virgin bitumen, which were 240°C and 266°C, the flash point and fire point values for the RTFO-aged bitumen aged for 85 minutes increased to 262°C and 273°C, respectively. These higher readings demonstrate that the bitumen has become less flammable as it has aged by indicating an increasing barrier to ignition and sustained combustion.

The RTFO-aged bitumen had a viscosity of 1,242 cP after 85 minutes of aging, which was higher than the virgin bitumen's viscosity of 801 cP. The aged bitumen is more flow-resistant, which is indicated by the bitumen's large increase in viscosity and corresponding noticeable change in flow behavior.

In comparison to virgin bitumen, the study of RTFO-aged bitumen after 85 minutes shows considerable changes in its penetration, softening point, flash point, and viscosity parameters. These results provide insight into how aging affects bituminous performance and provide a foundation for future research that will assess the efficacy of rejuvenation therapies.

5.2.3 Extended RTFO-Aged Bitumen Analysis (145 minutes):

Extended RTFO-aged bitumen is analyzed after 145 minutes of aging to further explore the differences in its properties from virgin bitumen. The penetration, softening point, ductility, flash point, fire point, and viscosity qualities were assessed in a manner similar to the prior examination.

In comparison to both virgin bitumen and RTFO-aged bitumen aged for 85 minutes, the extended RTFO-aged bitumen's penetration value dropped to 4.04 mm, showing a further increase in hardness. This decrease shows that the bitumen's resistance to penetration has increased due to the prolonged aging process.

After 145 minutes of aging, the softening point value increased to 51.7°C, demonstrating a steady increase in the temperature at which the bitumen begins to soften. This result backs with the earlier investigation and demonstrates that extended age has produced bitumen that is stiffer and more resistant to temperature-induced softening.

In addition, compared to RTFO-aged bitumen aged for 85 minutes, the extended version's ductility value dropped to 83.75 cm. This drop shows that the bitumen's capacity to expand before breaking has been reduced as a result of the prolonged aging process, adding to the material's already heightened brittleness.

In comparison to the values obtained for the RTFO-aged bitumen aged for 85 minutes, the flash point and fire point values for the extended RTFO-aged bitumen increased to 258°C and 275°C, respectively. These higher values support the idea that the prolonged aging process has rendered the bitumen less flammable by indicating an even greater resistance to ignition and sustained combustion.

The extended RTFO-aged bitumen had a viscosity of 1,385 cP, which was higher than the RTFO-aged bitumen's viscosity of 85 minutes. The bitumen's major change in flow behavior as a result of the prolonged aging process is highlighted by the steady increase in viscosity, which denotes a further decline in its flowability.

In comparison to both virgin bitumen and RTFO-aged bitumen aged for 85 minutes, the study of prolonged RTFO-aged bitumen after 145 minutes shows further evidence of the escalating alterations in its penetration, softening point, flash point, and viscosity properties. These results contribute to our understanding of how prolonged aging affects bituminous performance and provide a foundation for future research that will assess the efficacy of rejuvenation procedures.

5.2.4 Analysis of Rejuvenator Results:

The aged bitumen samples were rejuvenated in the experiment by the addition of waste engine oil. The bitumen's penetration, softening point, ductility, flash point, fire point, and viscosity were all improved throughout the rejuvenation process in an effort to recapture some of its original qualities. Analysis and comparison of the rejuvenation treatment outcomes with old bitumen samples were conducted at various waste engine oil concentrations.

Compared to the aged bitumen samples, the penetration value increased to 4.27 mm with the addition of 2% waste engine oil concentration. This suggests that the bitumen's capacity to permit penetration has slightly improved. Additionally, penetration increased further when waste engine oil concentrations rose, reaching values of 4.61 mm and 5.396 mm at 5% and 10%, respectively, of waste engine oil concentrations. These findings imply that bitumen's penetration qualities were substantially improved by the rejuvenation process, making it less brittle and more prone to penetration.

Waste engine oil was added, and the results showed that the softening point values decreased. The softening point dropped to 50.5°C with a 2% concentration of waste engine oil, restoring the bitumen's capacity to endure greater temperatures before softening. This pattern persisted as the waste engine oil concentration rose; at 5% and 10% waste engine oil concentrations, respectively, softening points of 49.4°C and 48°C were attained. These results show the rejuvenation treatment's effectiveness in lowering the bitumen's sensitivity to temperature-induced softening.

The rejuvenation procedure improved the bitumen's capacity to stretch before breaking, which is a measure of ductility. In comparison to the old bitumen sample, the ductility value rose to 85.5 cm with a 2% concentration of waste engine oil. Further improvements were seen at higher waste engine oil concentrations, with ductility values of 93.75 cm and 98.75 cm being attained at 5% and 10%, respectively, of waste engine oil concentrations. According to these results, the bitumen's ductility was successfully restored by the rejuvenation procedure, making it more flexible and less prone to breaking.

As the concentration of waste motor oil rose, the values for the flash point and fire point dropped. The flash point and fire point of the aged bitumen sample were 245°C and 260°C, respectively, at a 2% waste engine oil concentration. At 5% waste engine oil content, these values further dropped to 235°C and 250°C, respectively. The flash point and fire point dropped to 226°C and 245°C, respectively, at 10% waste engine oil concentration. These findings imply that the rejuvenation process using waste engine oil increased the bitumen's resistance to ignition and sustained combustion while reducing its flammability.

Waste engine oil was added, which reduced viscosity values and suggested better flowability in terms of viscosity. The viscosity decreased to 1,200 cP at a waste engine oil concentration of 2%, indicating a partial restoration of the bitumen's flow properties. The viscosity further fell to 1,055 cP and 902 cP, respectively, with increased waste engine oil concentrations of 5% and 10%, showing a significant improvement in the bitumen's flow characteristics. These results demonstrate the efficiency of the rejuvenation process in lowering the viscosity and increasing the flowability of the bitumen.

In conclusion, the rejuvenator results analysis shows that the addition of waste engine oil successfully restored the bitumen's characteristics. The rejuvenation procedure successfully increased viscosity, decreased flammability, increased ductility, decreased softening point, and decreased flammability.

5.3 Conclusion:

Aged bitumen was rejuvenated using waste engine oil. The outcomes demonstrated that the characteristics of the bitumen were improved by the use of waste engine oil. It boosted ductility, decreased flammability, lowered flammability, improved penetration, and decreased softening point. It also improved flowability. The characteristics of the bitumen were better restored when waste engine oil concentrations were higher. These results demonstrate waste engine oil's potency as a bitumen rejuvenator and offer suggestions for environmentally friendly and economically sensible techniques for reviving asphalt pavements.

6 CHAPTER-6

BUDGETING & COSTING OF THE PROJECT

All costs were incurred in Pakistani Rupees (PKR). The unit rates used to compile this table were those in effect at the execution of the final year design projet.

Sr. #	Item Description	Qty	Unit	Unit Rate	Amount
1.	Bitumen	10	Kg	450	4500
2.	K2 Kerosine Oil Local	5	Liter	280	1400
3.	Medicated Dressing Cloth	2	Roll	50	100
4.	Bitumen Storage Tank 16 Kg	1	No	120	120
5.	Storage Tank 5 Kg	6	No	70	420
6.	Iodized Salt	1	Packet	60	60

7.	Printing Facility	300	No	9	2700
8.	Waste Engine Oil	1	Liter	100	100
9.	Travelling/Fuel Expense (Petrol)	20	Liter	282	5640
10.	Miscellaneous	-	-	-	3000
	GRAND TOTAL				**18,040/=**

Table 6.1 : Budget And Costing Table

The table provides a breakdown of various items and their corresponding quantities, unit rates, and amounts. The items include Bitumen, K2 Kerosine Oil Local, Medicated Dressing Cloth, Bitumen Storage Tank, Storage Tank, Iodized Salt, Printing Facility, Waste Engine Oil, Travelling/Fuel Expense (Petrol), and Miscellaneous expenses. The quantities listed represent the quantity or number of units for each item. The unit rates indicate the cost per unit of each item, and the amounts are calculated by multiplying the quantity by the unit rate. The "GRAND TOTAL" at the bottom shows the cumulative cost of all the items, amounting to 18,040/=. Additionally, there is a miscellaneous expense category with an amount of 3,000, which covers any additional or miscellaneous costs not specifically assigned to a particular item.

7 Chapter-7

Conclusion:

The primary objective of this study was to evaluate the short-term aging effect of asphalt binder under lab-simulated conditions.

- Several experiments were conducted to assess the penetration, viscocity, and ductility of the asphalt binder before and after aging in order to achieve the first objective.checking
- The penetration index of 61.3% in the Rolling Thin Film Oven Test (RTFOT) indicates significant aging in the asphalt binder. After the test, it was discovered that the penetration value was lower, pointing to a firmer binder and more aging.

- The 15.4% ductility loss percentage offers additional proof of the asphalt binder's serious aging. The binder's capacity to extend before breaking is assumed to be diminished with aging and increasing stiffness, which is demonstrated by a decrease in ductility.
- The viscosity loss of the aged asphalt binder, which was discovered to be 55.1%, provides further support for short-term aging. The viscosity reduction, which displays a change in the binder's flow behavior, illustrates the aging process.

Optimizing the dosage of waste engine oil (WEO) as a rejuvenator in lab-simulated short-term aged asphalt binder was the study's second objective, and it was successfully accomplished.

- When a 10% rejuvenator dosage was administered after 145 minutes of aging, the penetration value of the aged binder rebounded to roughly 81%. This implies that the flow characteristics of the binder have greatly improved.
- the ductility value recovered to around 100% with the same 10% rejuvenator dosage, indicating a considerable increase in the binder's ability to stretch before breaking.

- The binder's softening point recovered by 100% with the addition of a 10% rejuvenator dosage, suggesting a reduction in stiffness and an increase in workability.
- the percentage recoveries for the parameters of the flash point and fire point were around 92% and 89%, respectively.
- virgin bitumenoptimal 10% rejuvenator dosage, the viscosity recovered is around 88.8%. This means that the flow properties of the asphalt binder have greatly improved. After the 10% rejuvenator dosage was administered, a significant decrease in viscosity was observed, indicating a partial recovery to the binder's prior flow qualities.

These findings show how well the rejuvenator works in recovering some of the old binder's physical properties, notably in terms of penetration, ductility, and softening point.When determining the proper dosage of WEO to restore degraded asphalt binders, it is critical to take these facts into consideration because recovery percentages for different quality might vary.In terms of the asphalt sector and pavement planning, the ideal WEO rejuvenator dosage has the ability to increase the usefulness and toughness of asphalt mixes.

8 Chapter-8

Future reccomendations

- The utilization of waste engine oil as a rejuvenator in bitumen has significant promise in the building industry. The functionality and sustainability of bitumen can be improved by using waste engine oil, a waste product of several industrial and automotive processes. To counteract the effects of aging and improve the material's overall quality, waste engine oil may be added to bitumen to renew it. This rejuvenation procedure can increase the pliability, toughness, and resistance to deformation of bituminous materials, such as asphalt pavements. The utilization of spent engine oil as a rejuvenator also aids sustainable waste management practices by preventing waste from going into landfills and reducing pollution. It is crucial to carefully evaluate optimal engine dosages, compatibility with bitumen, and long-term performance evaluation in order to ensure the effective utilization of waste engine oil as a rejuvenator in bitumen applications. This approach can enhance the functionality and sustainability of bituminous materials in the construction industry.
- Several performance tests should be conducted at this stage to assess the impact of WEO rejuvenators on the asphalt binder's characteristics. In tests, variables including ductility, viscosity, penetration, softening point, and aging traits like RTFO and PAV may be examined. The goal is to compare the improvements made by WEO rejuvenators to those made by conventional additives or untreated binders.

- The WEO rejuvenator dose that will enhance the improvement in asphalt binder properties is being determined at this time. It requires evaluating the effects of different doses on crucial performance measures such moisture susceptibility, fatigue performance, thermal fracture resistance, and rutting resistance.

- It is crucial to research how different binder types, such as differing penetration grades, and additives routinely employed in asphalt mixes interact with WEO rejuvenators. Two examples of compatibility tests that may be performed to find possible interactions and compatibility issues between WEO rejuvenators and other components of asphalt binders are the solubility test and the blending test.

- Environmental evaluations must be carried out as part of this component in order to look into any potential environmental problems resulting from the usage of WEO rejuvenators. Examining the dangerous component concentration and composition of old engine oil is necessary for this. It is also possible to conduct environmental impact evaluations to identify any potential risks related to the production, processing, and storage of WEO rejuvenators.

- According to this study, employing WEO rejuvenators can help the environment in the long term by recycling spent engine oil and reducing the need for new resources. Any possible drawbacks, such as pollution from waste engine oil generation and transportation, should also be considered. Through life cycle studies and sustainability evaluations, it is feasible to acquire a thorough knowledge of how utilizing WEO rejuvenators in asphalt pavements would affect the environment.

- Conduct long-term aging studies, such as the thin film oven test (TFOT) and the pressure aging vessel (PAV) test, to evaluate the lifespan and aging resistance of asphalt mixes including WEO rejuvenators. Understanding the stability and durability of the regenerated binders requires an analysis of the changes in characteristics over extended periods of time.

- Run experiments using a dynamic shear rheometer (DSR) and a bending beam rheometer (BBR) to assess the rheological properties of asphalt binders utilizing WEO rejuvenators. Consider variables like complex modulus, phase angle, and rutting potential to assess the binder's resistance to deformation under varied loading conditions.

- Conduct investigations, such as the tensile strength ratio (TSR) test and the indirect tensile strength (ITS) test, to ascertain how moisture-sensitive asphalt mixes with WEO rejuvenators are. Analyze how the aggregates adhere to the binder, as well as the possibility of stripping and strength loss.

- Examine how WMA technology interacts with WEO rejuvenators, which reduce the temperatures at which asphalt mixes are created and compacted. Examine how WMA mixtures affect mechanical attributes such as workability and compactability as well as any possible energy and emission cost reductions.

- To verify the laboratory findings and assess the WEO rejuvenator's effectiveness in practical situations, conduct field experiments and case studies on actual asphalt pavement projects. Track the long-term performance of the rehabilitated pavements and compare it to control areas using conventional methods.

- Conduct a detailed cost analysis to establish whether adding WEO rejuvenators to asphalt mixes is economically viable and cost-effective. Consider factors including material prices, building procedures, maintenance needs, and life cycle costs when estimating the potential financial benefits of using WEO rejuvenators.

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