EFFECTS OF ADDING BURNT WASTE RUBBER PYROLYSIS OIL FOR MODIFICATION OF PROPERTIES OF BITUMEN

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A project report submitted in partial fulfillment of the requirement for the degree of
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All admirations to almighty ALLAH, the creator of infinite kingdom. The most beneficent and the most merciful, bestowed us the prophet of mercy Muhammad (PBUH) for our spiritual guidance and general amelioration.

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ABSTRACT

This paper studies the possibility of producing new material in bitumen properties range from combination of natural bitumen and waste burnt rubber pyrolysis oil. To achieve this goal first used some experiments to determine the physical properties of natural bitumen and then after combining more natural bitumen and pyrolysis fuel oil in different samples some test including penetration, softening point, flash and fire point, specific gravity and ductility test have been done and results have been compare to ASTM standard. To investigate and understand the influence of the engineering properties of Pyrolysis Oil Modified Bitumen, five groups of treated (pyrolysis oil modified bitumen) specimen were prepared and tested at different percentages of pyrolysis oil i.e. 0%, 5%, 10%,15%, 20%, by weight of the pure Bitumen.

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LIST OF ABBREVIATIONS

ASTM	American society for testing and materials
AASHTO	The American association of state highway and transportation officials
BSCT	Bachelor of Science in civil Technology
EFB	Empty Fruit Bunch
NHA	National Highway Authority
PFO	Pyrolysis Fuel Oil
PEN	Penetration
PI	Penetration Index

CHAPTER 1

INTRODUCTION

1.1 General

Demands of roads are increasing year by year. Ever increasing numbers of commercial vehicles with increased axle loads take their toll and it is clear that this trend will continue in the future. The highway engineers are thinking about the alternative solutions to meet this growing challenge. The addition of pyrolysis oil to enhance service properties in road paving applications was considered a long time ago and nowadays has become a real alternative. A variety of additives are used in order to obtain enhanced service properties. However, the main restriction in such modifications remains the incompatibility of pyrolysis oil and bitumen.

It is estimated that about 16 million tons of waste tires are generated every year worldwide, and the amount increases at a speed of 2–4% year by year. These organic solid waste tires are non-biodegradable. The disposal of scrap tires is becoming a growing environmental problem in the modern society. Pyrolysis, which is a promising way to transform waste tires into three valuable products: pyrolysis oil, steel wires, and carbon, cannot only maximize the utilization of used tires, but also decrease the amount of waste tires remarkably.

Fig. 1.1: Tire Pyrolysis Plant

Pyrolysis oil can replace on small or large scale combustion in natural gas, coal or heating oil fired boilers, furnaces and turbines. These systems are usually found in power plants where electricity, heat and steam are produced. Boilers, furnaces and turbines are also found at large industrial companies to supply their demand for electricity, heat and steam.

1.2 Objectives of the Research

The specific objectives of the study can the summarized as follows.

- To investigate and compare the properties of the bitumen modified by pyrolysis oil derived from wastes burnt rubber with that of the conventional bitumen.
- The aim of this study is to investigate the suitability of waste rubber pyrolysis oil for the modification of bitumen.

1.3 Scope of Study

This study focuses on the laboratory investigations on the effectiveness of the addition of pyrolysis oil for the modification of bitumen as a way to improve its properties and performance grade. In this research, bitumen made by partially replacement of bitumen with different ratio of pyrolysis oil ranging from 0%, 5%, 10%, 15% and 20% will take place. Then comparison of obtained results with conventional bitumen will be carried out. Laboratory testing which includes Penetration test, Softening Point test, Specific Gravity test, Flash Point and Fire Point test, Ductility test are parts of the study to investigate the behavior of the modified bitumen.

1.4 Problem Statement

The gradually exhausting crude oil reserves worldwide has led to the concern of the many experts in the field of asphalt industry to explore the new alternative resources to reduce the dependency on the petroleum products as the road construction materials. Challenges are also faced by the contractors who involved in road construction industry as the price of crude oil experienced continuous fluctuation recently due to the low availability and high demand of the crude oil. The utilization of pyrolysis oil derived from the waste burnt rubber could offer a cheaper and easily available material for the existing asphalt industry to deal with the current issues and problems related to the availability and price of crude oil. These properties has led them to be the unsuitable road material to cater for the increasing traffic loading on the road surface due to the soaring of traffic volume nowadays. The application of pyrolysis oil modified asphalt can give better improvements to the performance of the road layers so that they are able to withstand high temperature and moisture level without any defects in the long term. These organic solid waste tires are non-biodegradable. The disposal of scrap tires is becoming a growing environmental problem in the modern society.

1.5 Pyrolysis Oil Modified Bitumen

Pyrolysis, which is a promising way to transform waste tires into three valuable products: pyrolysis oil, steel wires, and carbon, cannot only maximize the utilization of used tires, but also decrease the amount of waste tires remarkably. Then pyrolysis oil and bitumen are mixed up each other in the form of result we prepare pyrolysis oil modified bitumen.

1.6 Thesis Overview

This present thesis includes six chapters:

Chapter-1: This chapter covers the general introduction of our project and the scope and objectives of our project.

Chapter-2: in the second chapter we will discuss about literature review, and type of slab that we design, and cost estimation.

Chapter-3: This chapter discusses the detail about material properties and the preceding articles presented a brief review of pyrolysis oil modified bitumen.

Chapter-4: This chapter covers the lab testing of the project to analyze the properties of pyrolysis oil modified bitumen.

Chapter-5: This chapter discusses about the results of our project and detail about the lab performance during practical in the lab.

Chapter-6: This chapter includes references of project and also includes annexure of different designs.

CHAPTER 2

LITERATURE REVIEW

Poh, C.C *et al* (2018) worked on the effect of oil palm waste pyrolysis bio-oil on modified bitumen properties. In this study, the oil palm EFB was first pyrolyzed using auger pyrolyzer to extract the bio-oil. The PEN 80/100 bitumen was used in this study as a control sample. Whereas percentages of pyrolysis EFB bio-oil were varies from 5% and10%.

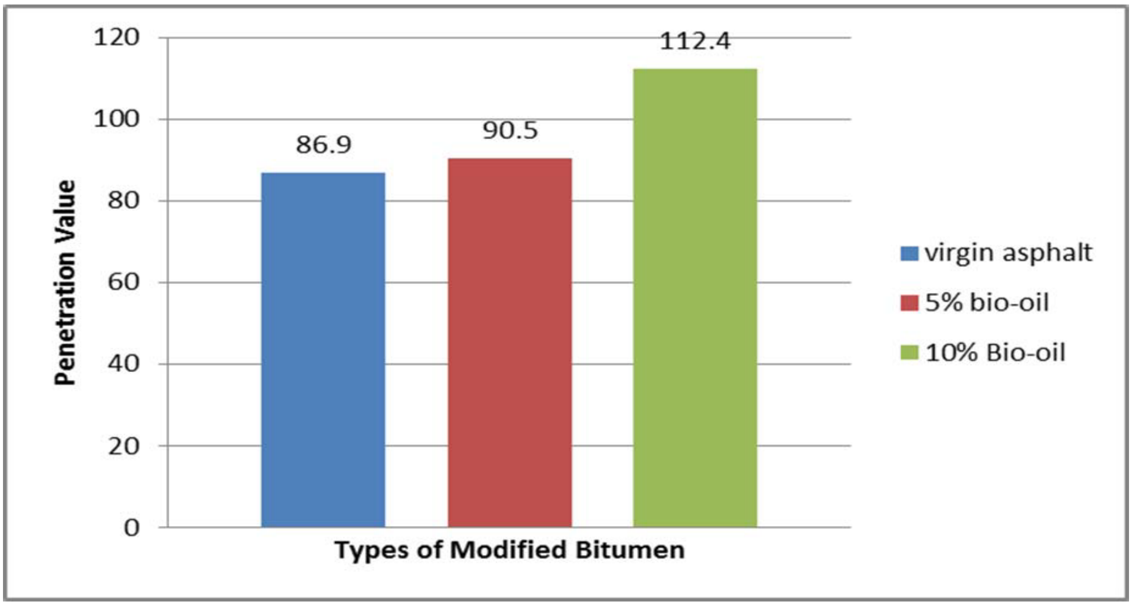

Fig. 2.1: Penetration Value for Different Percentage of Bio-Oil Content

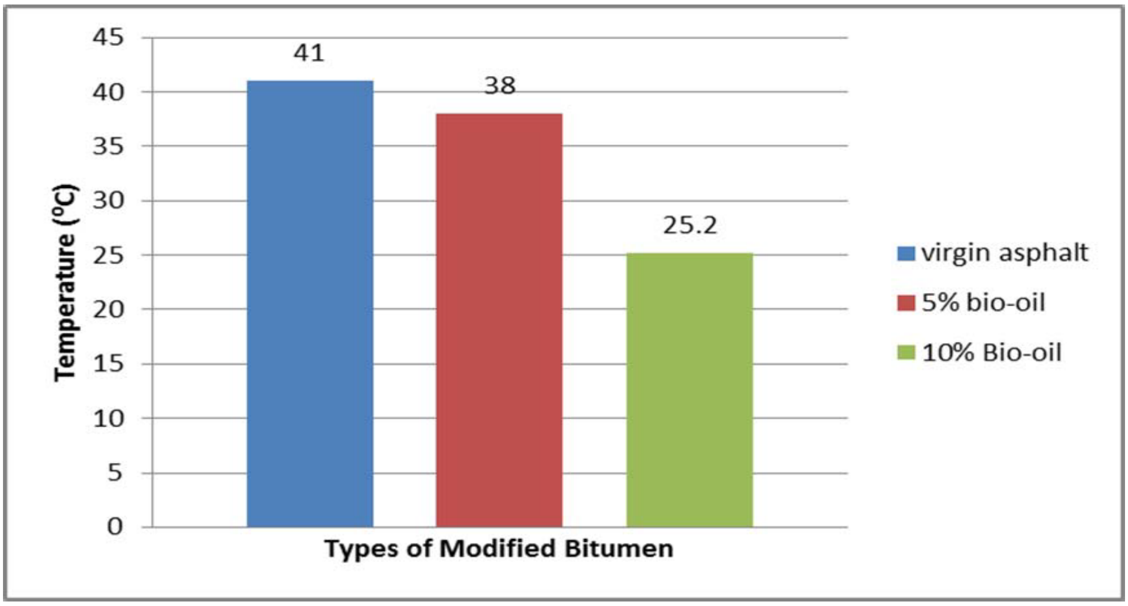

Fig. 2.2: Softening Point Value for Different Percentage of Bio-Oil Content

Table 2.1: Penetration Index (PI) for Modified Asphalt Binder

Sample (% Bio-oil)	PEN value (dmm)	Softening Point (^{0}C)	PI
0%	86.9	41.0	-2.52
5%	90.5	38.0	-3.53
10%	112.4	25.2	-9.86

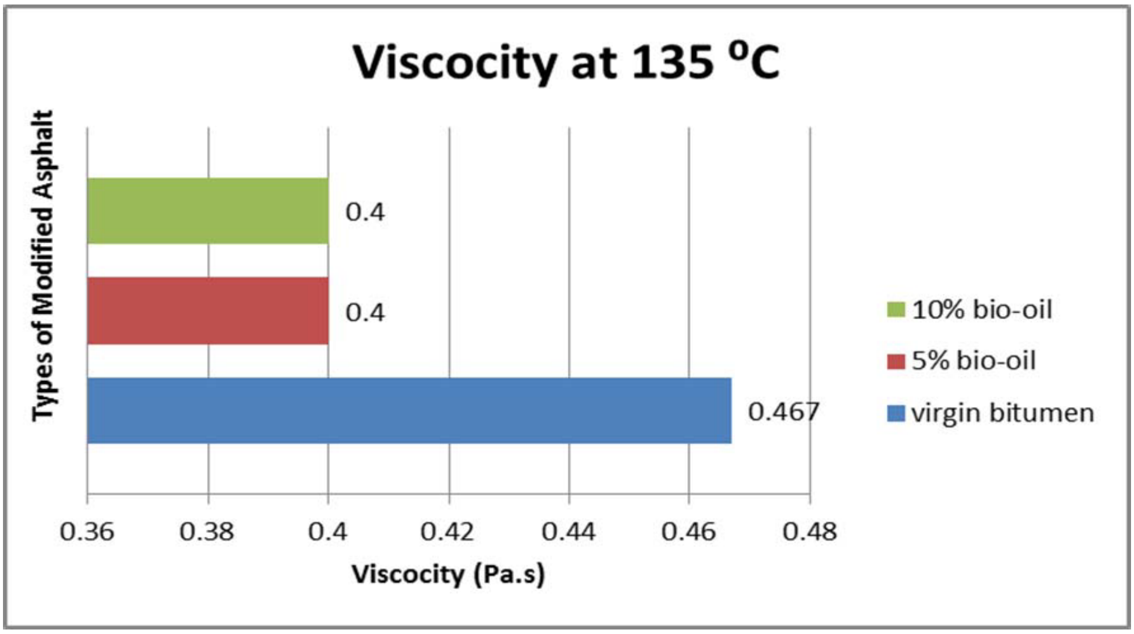

Fig. 2.3: Viscosity at Temperature 135^{0}C

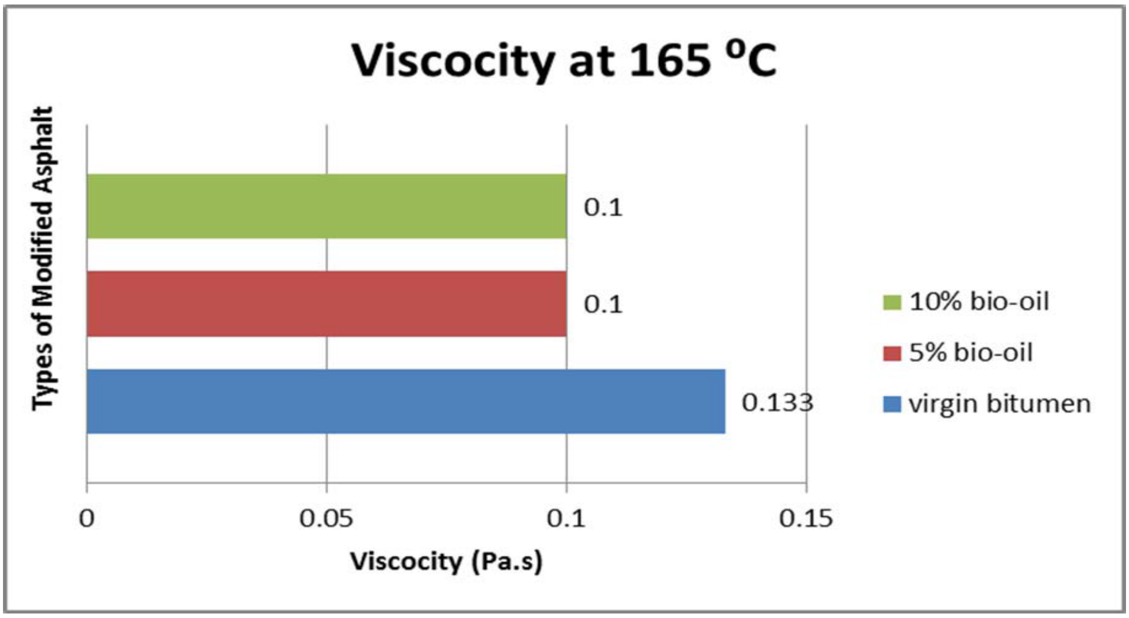

Fig. 2.4: Viscosity at Temperature 165^{0}C

Results concluded that Modified bitumen tends to become softer and more susceptible to temperature change as more percentage of pyrolysis EFB bio-oil is blended with the bitumen. Meanwhile, the viscosity value of bitumen sample decrease as more percentage of EFB bio-oil is blended which indicates the sample has lower internal friction and resistance to flow.

Esfeh, K.H *et al* (2017) worked on properties of modified bitumen obtained from natural bitumen by adding pyrolysis fuel oil. To achieve this goal first used some experiments to determine the physical properties of raw materials and then after combining more natural bitumen and pyrolysis fuel oil in different samples some test including penetration, softening point and ductility test have been done and results have been compare to ASTM and BS standard. Ultimately seen this combination can produce bitumen with R115/15 and R95/25 grade [2].

Table 2.2: Range Of Changes in Weight Percentage of P.F.O and NB

Component	Minimum Wt.%	Maximum Wt.%
Natural Bitumen	40	60
Pyrolysis Fuel Oil	40	60

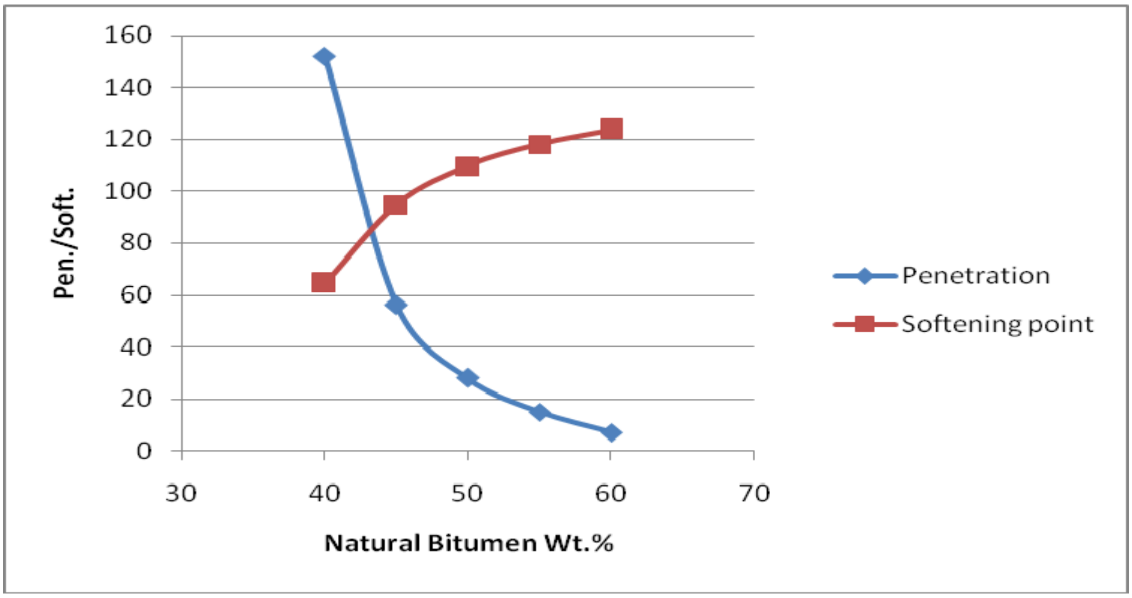

Fig. 2.5: Penetration and Softening Point Changes with Natural Bitumen

Results concluded that producing the new material which is a combination from the natural bitumen and the vacuum distillation tower residue are widely used in corrosion protective coatings and water proof coating. P.F.O in its cost equals to vacuum bottom so from the economical point of view, this displacement won't result in increasing the cost of the final product. Results of the tests performed on the different samples indicated that on expanded range of oxide bitumen can be produced from this combination. For instance, two kind of oxide bitumen grade 110/30, 115/15 were produced in accordance with the BS EN 1304 standard specification.

Sun, D.X *et al* (2011) worked on study of road bitumen modified with heavy fraction of tire pyrolysis oil. In this article, heavy fraction (>350℃) of tire pyrolysis oil was used to modify road bitumen. Experiments were carried out to investigate the effect of the modification conditions, such as blending temperature, shear rate, blending time, and admixing amount of heavy fraction on the properties of modified asphalt.

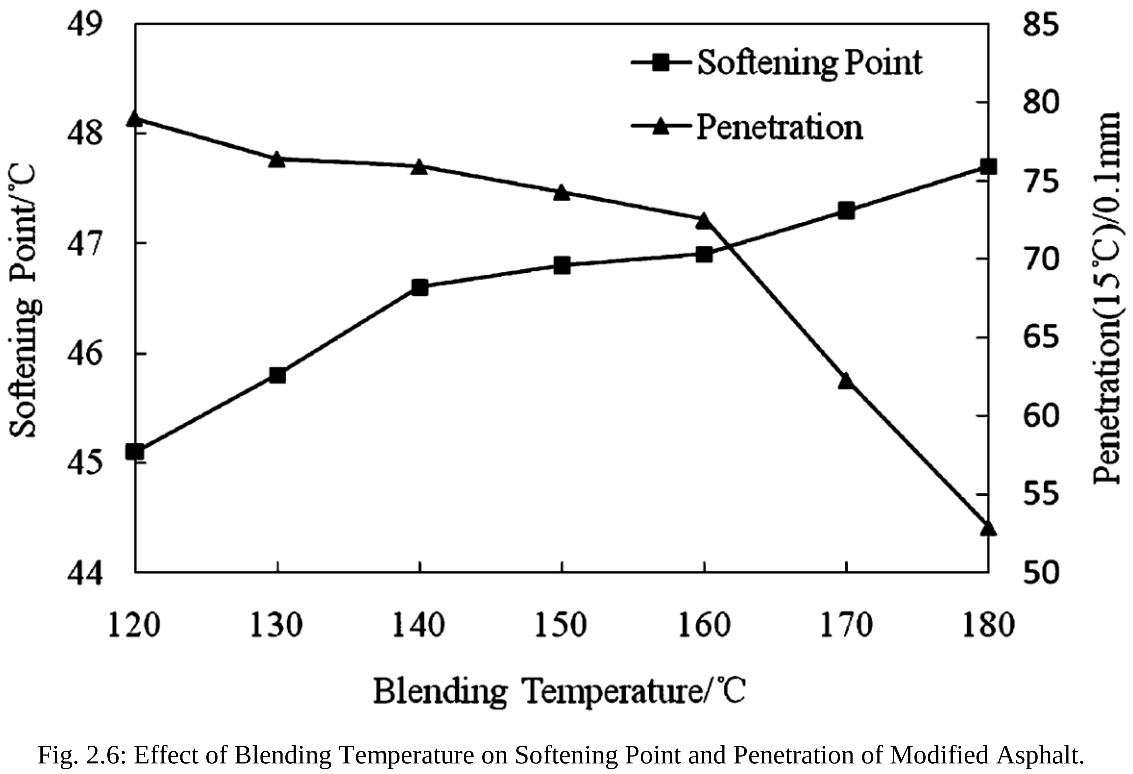

Fig. 2.6: Effect of Blending Temperature on Softening Point and Penetration of Modified Asphalt.

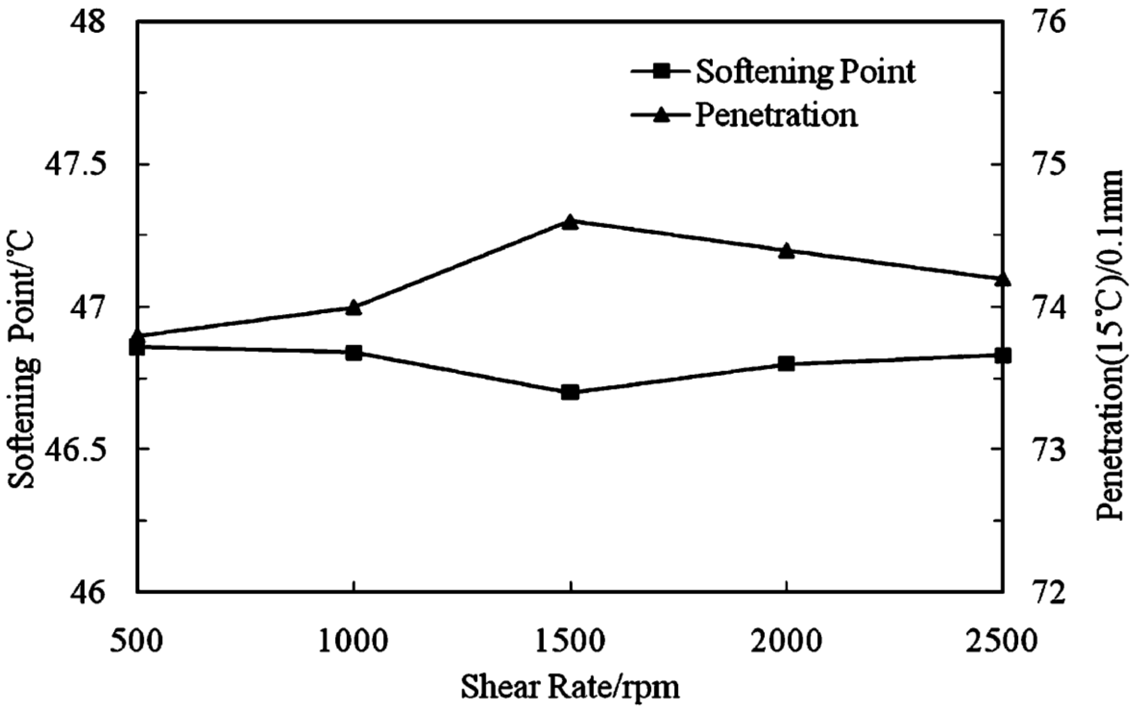

Fig. 2.7: Effect of Shear Rate on Softening Point and Penetration of Modified Asphalt.

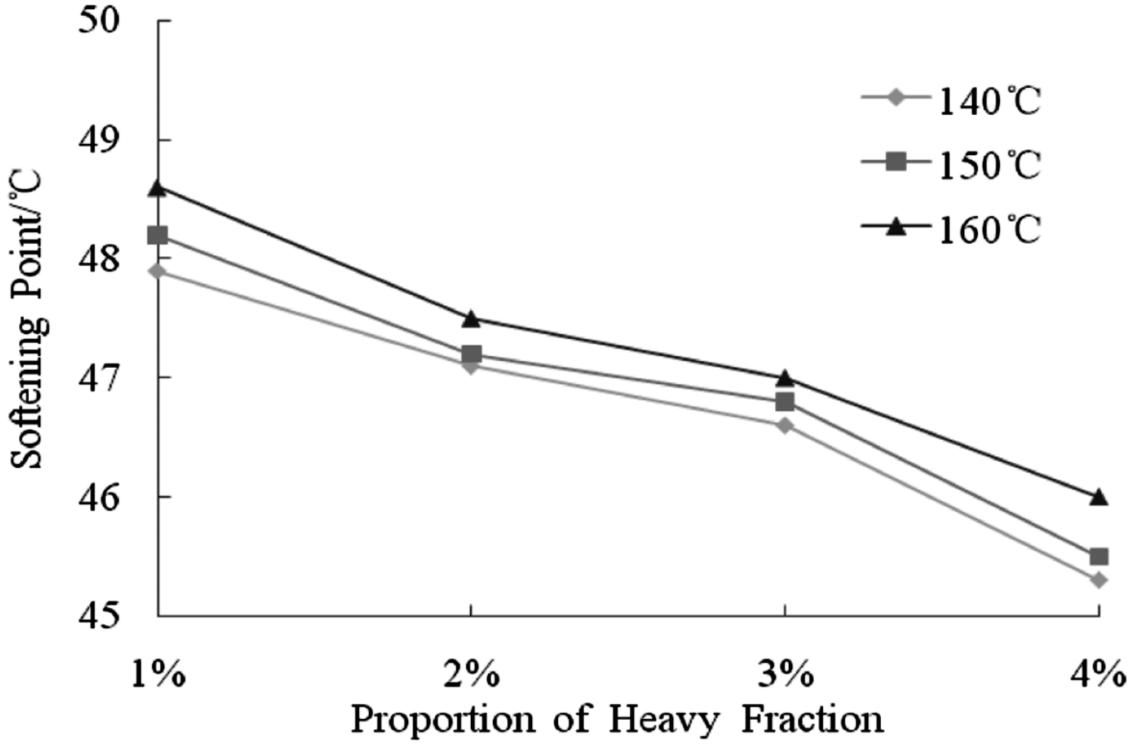

Fig. 2.8: Effect of Proportion of Heavy Fraction on the Softening Point of Modified Asphalt

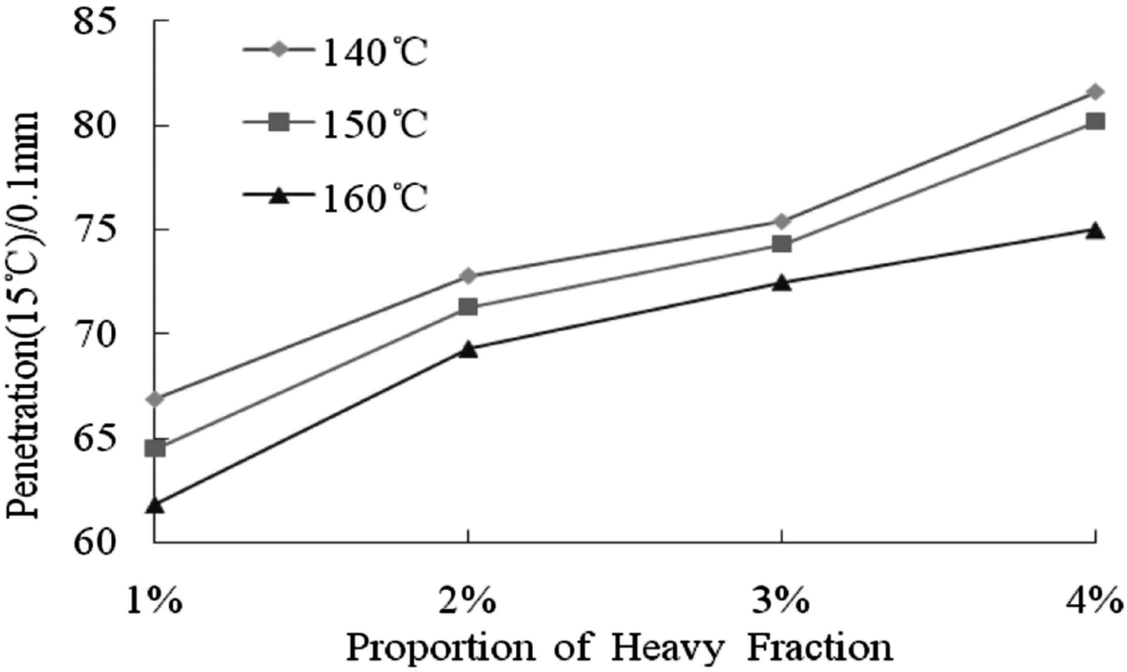

Fig. 2.9: Effect of Proportion of Heavy Fraction on the Penetration of Modified Asphalt.

Results concluded that Heavy fraction of tire pyrolysis oil was used to modify AH-70 road bitumen, and the results of the investigation of the modification conditions were as follows:

With the increase of blending temperature, the penetration of modified asphalt descended, the softening point ascended, and the ductility was above 200 cm (15°C). When the blending temperature was higher than 160°C, the modified asphalt began to age obviously. The shear rate had a small effect on the properties of modified asphalt in the range of 500–2,500 rpm. With the increase of blending time, the penetration of modified asphalt reduced, the softening point ascended, and the ductility was more than 200 cm (15°C). When the time was longer than 10 min, modified asphalt began to age apparently. With the increase of the proportion of heavy fraction oil in the modified asphalt, the softening point declined, and the penetration ascended. When the proportion was 4%, the penetration of modified asphalt went beyond the quality standard of AH-70 petroleum asphalts for heavy traffic road pavement.

So the proper modification condition was blending temperature range from 140 to 160°C for 10 min, shear rate of 2,000 rpm, and the proportion of heavy fraction lower than 4%. The ductility of all modified asphalt was more than 200 cm (15°C) before the aging test, and was more than 130 cm (25°C) after the aging test. Road bitumen modified with heavy distillate (>350°C) of tire pyrolysis oil showed excellent ductility.

CHAPTER 3

MATERIAL PROPERTIES

3.1 General

This chapter includes the description of the Waste Rubber Tire Pyrolysis oil & Natural Bitumen. common sources of polymers and its application around home and abroad. The history of polymer modification, its benefits and drawbacks and field performance evaluation are also highlighted in this chapter. The use of polymer as a modifier of bitumen is not very new. Polymer modified bitumen (PMB) is becoming an increasingly important material for building and maintaining roads. Many countries have been using polymer with bitumen from the last few decades. Scientific research is going on the modification of bitumen with different types of polymer and new types of polymers are being invented. Besides, some countries are trying to use scarp tire, waste polythene bag, pet bottle and other waste plastic materials from the economic and environmental considerations. This chapter includes a brief discussion on these study reports. It also contains, a comprehensive review of literatures collected from different international journals as well as down loaded from the web site of different pavement construction and chemical companies. Finally, a summary of the literature review is given at the end of this chapter.

3.2 Modifier

Additives, which are used to modify or improve the quality of virgin materials is simply called the modifier of it. Modifiers are blended directly with the binder or added to the asphalt concrete mix during production to improve the properties and or to performance of the pavement. It should be mentioned here that a huge quantity of bituminous binder is required every year for pavement construction. This quantity of bitumen terms from the petroleum product and natural sources. The sources of bituminous materials are not unlimited. Hence the researchers have been thinking of quality improvement of bitumen and trying to extend the life span of bituminous pavement since long ago. To improve the rheological and mechanical properties of bituminous binder different types of additives are added to it in different forms and in different ways. Bitumen itself is a complex mix of different compound. Due to the similar in nature pyrolysis oil are being used as the modifier of bitumen for its overall quality improvement.

3.3 Rubber Tire

Rubbers are materials that display elastomeric properties. This means they can be stretched and will spring back when the stress is removed. Rubber is produced from the juice of a tropical plant or manufactured artificially. Natural rubber is found as a milky liquid in the bark of the rubber tree, Hevea Brasiliensis. This raw rubber is called latex. Latex contains about 30 percent dry rubber content. Latex is centrifuged to increase the percentage of rubber content in it. Natural rubber is vulcanized with Sulphur and other materials to make it less susceptible to temperature. The tires of vehicles and automobiles are made of vulcanized rubber. To produce the raw rubber used in tire manufacturing, the liquid latex is mixed with acids that cause the rubber to solidify. Presses squeeze out excess water and form the rubber into sheets, and then the sheets are dried in tall smokehouses, pressed into enormous bales, and shipped to tire factories around the world. Synthetic rubber is produced from the polymers found in crude oil. Rubber is more elastic than polymer. Both natural rubber and the crumb rubber from the used tires of vehicles can be used for the modification of bituminous binder.

3.4 Pyrolysis Oil

Pyrolysis is the thermal decomposition of materials at elevated temperatures in an inert atmosphere. It involves a change of chemical composition. The word is coined from the Greek-derived elements pyro "fire" and lysis "separating". Pyrolysis is most commonly used in the treatment of organic materials. Pyrolysis oil, sometimes also known as bio crude or bio-oil, is a synthetic fuel under investigation as substitute for petroleum. It is obtained by heating dried biomass without oxygen in a reactor at a temperature of about 500 °C with subsequent cooling. Pyrolytic oil (or bio-oil) is a kind of tar and normally contains levels of oxygen too high to be considered a hydrocarbon. This high oxygen content result in non-volatility, corrosiveness, and immiscibility with fossil fuels, thermal instability, and a tendency to polymerize when exposed to air. As such, it is distinctly different from petroleum products. Removing oxygen from bio-oil or nitrogen from algal bio-oil is called upgrading.

3.4.1 Types of Pyrolysis Oil

Pyrolysis is a well-established technique for decomposition of organic material at elevated temperatures in the absence of oxygen into oil and other constituents. A simple classification of pyrolysis oil based on their properties can be as follows:

a) Wood Pyrolysis: When wood is heated above 270 °C it begins a process of decomposition called carbonization. If air is absent the final product, since there is no oxygen present to react with the wood, is charcoal. If air, which contains oxygen, is present, the wood will catch fire and burn when it reaches a temperature of about 400-500 °C and the fuel product is wood ash. If wood is heated away from air, first the moisture is driven off and until this is complete, the wood temperature remains at about 100-110 °C. When the wood is dry its temperature rises and at about 270 °C it begins to spontaneously decompose and, at the same time, heat is evolved. This is the well-known exothermic reaction which takes place in charcoal burning. At this stage evolution of the by-products of wood carbonization starts. These substances are given off gradually as the temperature rises and at about 450 °C the evolution is complete.

The solid residue, charcoal, is mainly carbon (about 70%) and then of tarry substances which can be driven off or decomposed completely only by raising the temperature to above about 600 °C to produce Biochar, a high-carbon, fine-grained residue that today is produced through modern pyrolysis processes, which is the direct thermal decomposition of biomass in the absence of oxygen, which prevents combustion, to obtain an array of solid (biochar), liquid—Pyrolysis oil (bio-oil/pyrolysis-oil), and gas (syngas) products. The specific yield from the pyrolysis is dependent on process conditions. such as temperature, and can be optimized to produce either energy or biochar. Temperatures of 400–500 °C (752–932 °F) produce more char, while temperatures above 700 °C (1,292 °F) favor the yield of liquid and gas fuel components. Pyrolysis occurs more quickly at the higher temperatures, typically requiring seconds instead of hours. High temperature pyrolysis is also known as gasification, and produces primarily syngas. Typical yields are 60% bio-oil, 20% biochar, and 20% syngas. By comparison, slow pyrolysis can produce substantially more char (~50%). Once initialized, both processes produce net energy. For typical inputs, the energy required to run a "fast" pyrolyzer is approximately 15% of the energy that it outputs. Modern pyrolysis plants can use the syngas created by the pyrolysis process and output 3–9 times the amount of energy required to run.

b) Algal Pyrolysis: An Algae may be subjected to high temperatures (~500 °C) and normal atmospheric pressures. The resultant products include oil and nutrients such as nitrogen, phosphorus, and potassium.

There are numerous papers on the pyrolysis of lignocellulosic biomass. However, very few reports are available for algal bio-oil production via pyrolysis. Miao et al. (2004b) performed fast pyrolysis of Chllorella protothecoides and Microcystis areuginosa at 500 °C, and bio-oil yields of 18% and 24% were obtained, respectively. The bio-oil exhibited a higher carbon and nitrogen content, lower oxygen content than wood bio-oil. When Chllorella protothecoides was cultivated heterotrophically, bio-oil yield increased to 57.9% with a heating value of 41 MJ/kg (Miao et al., 2004a). Recently when microalgae become a hot research topic as the third generation of biofuel, pyrolysis has drawn more attention as a potential conversion method for algal biofuel production. Pan et al. (2010) investigated slow pyrolysis of Nannochloropsis sp. residue with and without the presence of HZSM-5 catalyst and obtained bio-oil rich in aromatic hydrocarbons from catalytic pyrolysis. Algal pyrolytic liquids separate into two phases with the top phase called bio-oil (Campanella et al., 2012; Jena et al., 2011a). The higher heating values (HHV) of algal bio-oil are in the range of 31−36 MJ/kg, generally higher than those of lignocellulosic feedstocks. Pyrolytic bio-oil consists of compounds with lower mean molecular weights and contains more low boiling compounds than bio-oil produced by hydrothermal liquefaction. These properties are similar to those of Illinois shale oil (Jena et al., 2011a; Vardon et al., 2012), which may indicate that pyrolytic bio-oil is suited for petroleum fuel replacement. In addition, the high protein content in microalgae led to a high N content in the bio-oil, resulting in undesirable NOx emissions during combustion and deactivation of acidic catalysts when co-processed in existing 10 crude oil refineries. Algal bio-oil had better qualities in many aspects than those produced from lignocellulosic biomass. For example, algal bio-oil has a higher heating value, a lower oxygen content and a greater than 7 pH value. However, upgrading towards the removal of nitrogen and oxygen in the bio-oil is still necessary before it can be used as drop-in fuels.

c) **Bio crude oil:** Bio-oil typically requires significant additional treatment to render it suitable as a refinery feedstock to replace crude oil derived from petroleum, coal-oil, or coal-tar. Tar is a black mixture of hydrocarbons and free carbon obtained from a wide variety of organic materials through destructive distillation. Tar can be produced from coal, wood, petroleum, or peat.

- Pine tar is a sticky material produced by the high temperature carbonization of pine wood in anoxic conditions (dry distillation or destructive distillation). The wood is rapidly decomposed by applying heat and pressure in a closed container; the primary resulting products are charcoal and pine tar. Pine tar consists primarily of aromatic hydrocarbons, tar acids and tar bases. Components of tar vary according to the pyrolytic process (e.g. method, duration, temperature) and origin of the wood (e.g. age of pine trees, type of soil and moisture conditions during tree growth).
- Birch tar is a substance (liquid when heated) derived from the dry distillation of the bark of the birch tree. It is compounded of phenols such as guaiacol, cresol, xylenol and creosol (not to be confused with cresol).
- Wood-tar creosote is a colourless to yellowish greasy liquid with a smoky odor, produces a sooty flame when burned, and has a burned taste. It is non-buoyant in water, with a specific gravity of 1.037 to 1.087, retains fluidity at a very low temperature, and boils at 205-225 °C. When transparent, it is in its purest form. Dissolution in water requires up to 200 times the amount of water as the base creosote. The creosote is a combination of natural phenols: primarily guaiacol and creosol (4-methylguaiacol), which will typically constitute 50% of the oil; second in prevalence, cresol and xylenol; the rest being a combination of monophenols and polyphenols.
- Pitch is a name for any of a number of viscoelastic polymers. Pitch can be natural or manufactured, derived from petroleum, coal tar or plants.
- Black liquor and Tall oil is a viscous liquid by-product wood pulp manufacturing.
- Rubber oil is the product of the pyrolysis method for recycling used tires.

d) **Biofuel:** Biofuels are synthesized from intermediary products such as syngas using methods that are identical in processes involving conventional feedstock's, first generation and second generation biofuels. The distinguishing feature is the technology involved in producing the intermediary product, rather than the ultimate off-take. A Bio refinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, heat, and value-added chemicals from biomass. The bio refinery concept is analogous to today's petroleum refinery, which produce multiple fuels and products from petroleum.

- Biodiesel is a diesel fuel derived from animal or plant lipids (oils and fats). A variety of oils can be used as biodiesel feedstock.
- Wood diesel. A new biofuel was developed by the University of Georgia from woodchips. The oil is extracted and then added to unmodified diesel engines. Either new plants are used or planted to replace the old plants. The charcoal byproduct is put back into the soil as a fertilizer. This biofuel can actually be carbon negative not just carbon neutral. Carbon negative decreases carbon dioxide in the air reversing the greenhouse effect not just reducing it.
- Algae fuels, can be produced from various types of Algae, and are dependent on the technique and the part of the cells used, some species of algae can produce 50% or more of their dry weight in the form of oil. The lipid, or oily part of the algae biomass can be extracted and converted into biodiesel through a process similar to that used for any other vegetable oil, or converted in a refinery into "drop-in" replacements for petroleum-based fuels. Alga culture can use waste materials such as sewage and without displacing land currently used for food production.

3.4.2 Waste Burnt Rubber Pyrolysis Oil Process

Before pyrolysis, whole tires need to be shredded into small pieces by tire shredder machine. Pull out the steel wire in tire sidewall, and then cut the tires into bulks. If the tires' diameter less than 1200mm, they don't need this step. Then the tires can be cut into small pieces by using the next comprehensive shredder. Crush the tire bulks or the whole tires diameter less than 1200mm into 2-5cm small pieces.

Feeding tire pieces into pyrolysis reactor by the sealed screw conveyor. Fire the fuels in the burning room, and the fuels could be diesel, natural gas, LPG. The pyrolysis reactor of we Beston Machinery waste tire recycling plant adopting high technology has long service life time. The hot air will flow into the reactor for heating. When the inner temperature of the reactor reaches the related degree, the oil gas will be generated. Then the oil gas goes into the manifold firstly. In the manifold, the heavy particles will be liquefied into heavy oil and drop in the heavy oil tank. The light oil gas rises up. The damping tank will reduce the oil gas moving speed and then the oil gas goes into condensers uniformly.

In the horizontal tubular condensers, the oil gas will be liquefied into fuel oil. A large scale of oil gas will be liquefied into fuel oil and enter oil tank. In the hydro seal, the combustible gas will be desulfurized and cleansed then recycled to the burning room to provide heat, which can save a lot of fuel in the process of pyrolysis of tires. Hot smoke gets out from the reactor through the inner pipe of heat exchange system. Air (oxygen) enters through the out pipe of the heat exchange system. In this process, the air will be heated by the hot smoke, then transferred to the burning room to provide the oxygen. This is the function of the heat exchange system.

In the flue condenser, the smoke will be cooled down, then enters the degusting system. In the spraying tower, the smoke will go through the water washing, water spray, ceramic ring adsorption and activated carbon adsorption. After four filters, the clean smoke can meet the EU environmental protection and emission standards. We are absolutely professional one of waste tire recycling plant suppliers. The carbon black with steel wire will be discharged by the auto screw discharger. Through the magnetic separator, the steel wire and carbon black will be separated and then transported into the storage tank.

Table 3.1: Tire Pyrolysis Plant Detail

Item	**Details**
Model	BLJ-6
Daily Capacity	1-6T
Working Method	Batch
Raw Materials	Waste Plastic, Tire, Rubber, Oil Sludge
Reactor Size	D2.2*L6.0m
Pattern	Horizontal & Rotary
Heating Materials	Charcoal, Wood, Fuel Oil, Natural Gas, LPG, etc.
Total Power	24kw/h

Floor Area (L*W*H)	30*10*8m
Operating Pressure	Normal Pressure
Cooling Method	Water Cooling
Life span	5-8 Years

Fuel Oil (about 45%): The main oil product of pyrolysis of tires is the fuel oil, about 45% of the final products, can be widely used for industrial and commercial purposes. For wide applications and higher values, the tire oil can be further refined into diesel or gasoline by tire to diesel machine.

Carbon Black (about 35%): Carbon Black is the another product we can get through the pyrolysis technology. The carbon black is about 35% (depending on the types of tires) of the total amount of the final products. Carbon black can be used as raw material or main ingredient in many industries. Carbon black produced by tires recycling machines is more economical compared with that produced primarily from petroleum.

Steel wire (about 12%): Can be sold directly or reprocessed.

Combustible gas (about 8%): Can be recycled to heat the reactor as fuel, which can save fuel energy for the whole production process.

3.4.3 Pyrolysis Oil Act as Modifier

Different types of pyrolysis are used in modifying bitumen for road applications. Waste tire pyrolysis oil, Fruit bunch pyrolysis oil, Heavy Friction Pyrolysis oil etc. Heavy Friction Pyrolysis oil, increase of blending temperature, the penetration of modified asphalt descended, the softening point ascended, and the ductility was above 200 cm. Fruit bunch pyrolysis oil and waste tire pyrolysis oil modified bitumen tends to become softer and more susceptible to temperature change as more percentage is blended with the bitumen.

3.4.4 Benefits of Pyrolysis Oil Modified Bitumen

The purpose of making modified bitumen by the waste burnt rubber tire pyrolysis oil. It is important to recycle any solid waste including tires to ensure that the environment is clean. The benefits include reducing landfills space, releases less toxic chemicals into the air, Prevent the spread of diseases which could occur by piling of the tires in the landfills sites.

Quality Improvement of Binder:

- It has tendency to resist the cracks due to temperature changes on the pavement.
- It increases the binder's qualities to better cope with cracking and dynamic deformation of the pavement internal layers.
- It improves the binder's behavior to fatigue by increasing its mechanical resistance particularly to tractive force.

Environmental Improvement

Use of waste rubber tires pyrolysis oil in road construction could lead a significant consumption of waste rubber tires daily generated which would be helpful in, keeping the environment clean, reducing landfills space, releases less toxic chemicals into the air, Prevent the spread of diseases which could occur by piling of the tires in the landfills sites.

CHAPTER 4

METHODOLOGY

4.1 General

Traditional bituminous materials are extensively used in road constructions particularly in flexible pavement. Its demand is increasing day by day. But it has some limitations regarding the performances which are evaluated by rheological properties. Binder modification by pyrolysis oil to it is a major issue and continuous research in this area is aiming produce new binders with better rheological and mechanical properties, which allow the manufacturing and application of road bituminous mixes with performance. Waste rubber tires pyrolysis oil modified bituminous materials can bring real benefits to highway maintenance/construction, in terms of better and longer lasting roads, savings in total road life costing and improvement of environmental hazards. Waste rubber tires pyrolysis oil changes the properties of bitumen when it is blended with it and brings how much and what kind of changes in the geological behavior of bitumen. This is one of the main objectives of this investigation. To investigate this set of examinations of reference binder and waste rubber tires pyrolysis oil modified binder is required.

4.2 Blending of Bitumen with Pyrolysis Oil

Blending the higher and lower viscosity residues in the required proportions can take place at the refinery, at terminals or at a third party facility, where blend components and finished products can be easily transported and distributed for use. The wet method is termed as "Cooking Method". The method requires a simple cooking device. The device comprises of a container, a stirrer and a heater. The stirrer should have shear blade to produce required shear force in the mixer during blending process.

Blending can be performed by way using.

- Manual cooking device

4.2.1 Manual Cooking Device

It is a manual method of blending polymer with bitumen. It works in the same principle as that of a commercial blending system. In this device the required shear force is produced by means of manual stirring. Since it is difficult to control the blending temperature and produce the required shear force, all type of polymer cannot be blended in this process. Some selected polymers, which require low shear force can be blended in this device.

Advantages of manual cooking method:

- Low cost
- Easy to manufacture
- Easy to operate

Limitation of manual cooking method:

- Difficult to control temperature
- Cannot produce high shear force
- Produces smoke
- Suitable for small-scale production

4.3 Process of Evaluation of Modified Binder and Mixes

In order to evaluate the properties of pyrolysis oil modified binder, a sample of virgin bitumen would be taken as reference binder. The reference binder would be modified by different proportion of the selected waste rubber tires pyrolysis oil. A comparative study would be performed on the reference binder and modified binder. The physical and rheological properties of both the reference and modified binders would be investigated by performing Specific gravity, Softening point, Penetration, Ductility and Flash point and Fire point tests would be performed to evaluate the properties of mixes prepared with modified and unmodified binder. In preparing the mixes, other factors such as test procedures and specification would be strictly followed. A short description of the test is given in the following Article.

4.4 Tests on Binder Material

4.4.1 General

The tests that would be performed in order to evaluate the properties of binders (pure and modified) are Softening point, Specific gravity, Penetration, Ductility tests on pure bitumen and Flash point and Fire point test performed by using both pure and modified binder. All of these tests would be carried out following the AASHTO/ASTM standard procedure. A brief description of these tests methods and their significance are presented here.

4.4.2 Penetration Test

The penetration test measures the **consistency of binders**. It is expressed as a distance in tenths of a millimeter that a standard needle vertically penetrates into a sample of the material under specified conditions of loading, time, and temperature. The higher value of penetration indicates softer consistency. To determine the penetration, sample should be melted properly and cooled and maintained specified temperature. The penetration is measured with Penetrometer (penetration apparatus) at standard temperature of 25ºC.

4.4.3 Ductility Test

Ductility is a measure of **elasticity of bitumen**. The ductility of paving asphalt is measured by the distance to which it will elongate before breaking or fracture when two ends of a briquette specimen are pulled apart at a specified speed and temperature.

4.4.4 Softening Point Test

The softening point test is also the measure of consistency of binder. It is the temperature at which the binder changes its semi solid state to liquid state. Temperature susceptibility of binder can be evaluated by softening point test.

Between two binders having the same penetration value, one will be less susceptible to temperature which has higher softening point. Samples of bitumen loaded with steel balls are confined in brass rings suspended in a beaker of water and glycerin or ethylene glycol at 25 mm (1 inch) above a metal plate. The liquid is then heated at a prescribed rate. As the bitumen softens, the balls and the bitumen gradually sink toward the plate. At the moment the asphalt touches the plate, the temperature of the water is determined, and this is designated as ring and ball (RB) softening point of asphalt.

4.4.5 Flash and Fire Point Test

The flash and fire point test is **purely a safety test**. It indicates the maximum temperature to which the materials can be safely heated. The flash point is the temperature at which a bituminous material, during heating will evolve vapors that will temporally ignite or flash when small frame is brought in contact with them. The fire point is the temperature at which the evolved vapors will ignite and continue to burn.

4.4.6 Specific Gravity Test

In paving jobs, to classify a binder, density property is of great use. In most cases, bitumen is weighed, but when used with aggregates, the bitumen is converted to volume using density values. The density of bitumen is greatly influenced by its chemical composition. Increase in aromatic type mineral impurities causes an increase in specific gravity.

The specific gravity of bitumen is defined as the ratio of the mass of given volume of bitumen of known content to the mass of the equal volume of water at 25 ºC. The specific gravity can be measured using either pycnometer or preparing a balls specimen of bitumen in the semi-solid or solid state. The specific gravity of bitumen varies from 0.97 to 1.06.

4.6 Materials Properties

4.6.1 General

Flexible pavement consists of major two materials. These two materials are aggregate and binder. The performance of pavement is greatly influenced by binder. Generally, bitumen is used as binder in pavement construction. The properties of Waste burnt rubber tires pyrolysis oil Modified Bitumen would be studied in this research work. The research work would require virgin bitumen and Waste burnt rubber tires pyrolysis oil. In order to study only the effect of Waste burnt rubber tires pyrolysis oil on binder and mixes other ingredients are kept same throughout the whole experiment process. A short description of these ingredients and their characteristics are presented below.

4.6.2 Bitumen

Bitumen is a class of amorphous, solid, semi-solid or viscous, cementations substances, natural or manufactured, composed generally without limitation of high molecular weight hydrocarbons, as typically found in asphalts and tars. Bituminous materials are typically derived from asphalt or coal tar, with asphalt found naturally or attainable as a by-product of crude oil refining. The compositional make up of coal, coal tar pitches, crude oils and natural asphalts vary depending upon the geological origin and geographical source. As a result, the physical characteristics of bituminous material, whether natural or manufactured can differ markedly from another. The variety of bitumen gives it wide utility in the building and construction industry.

Bitumen holds the aggregate together in a bituminous pavement. The quality of bitumen depends on its crude source, refining process and chemical composition. The chemical composition affects the compatibility of bitumen with polymer. Bitumen is normally designated by "grade" though it does not indicate the overall qualities of bitumen. The characteristics of base bitumen affect the quality improvement of the modified bitumen. In this research 60/70 penetrations grade bitumen is used.

4.6.3 Waste Burnt Rubber Tires Pyrolysis Oil

Pyrolysis, which is a promising way to transform waste tires into three valuable products: pyrolysis oil, steel wires, and carbon, cannot only maximize the utilization of used tires, but also decrease the amount of waste tires remarkably.

Pyrolysis oil can replace on small or large scale combustion in natural gas, coal or heating oil fired boilers, furnaces and turbines.

4.7 Sample Preparation and Tests

The tests that are performed on the binders are softening point, penetration, ductility, flash and fire point etc. A brief description of these tests is also included in this chapter. In this research work two different types of specimens namely (a) reference specimen using conventional bitumen and (b) modifier specimen using various proportion of Waste burnt rubber tires pyrolysis oil were prepared and necessary tests were performed.

4.7.1 Preparation of Bitumen, Pyrolysis Oil

The waste rubber tires is collected. While preparing the modified binder, the electric heater is turn on. When temperature of the heater shows about 90 to 110 ºC the required quantity of liquid bitumen, which is heated in another container is poured into the container attached to the heater. After that by manual stirrer mixed bitumen with Waste burnt rubber tires pyrolysis oil.

4.8 Test Procedures

4.8.1 General

Five conventional tests are performed on the five samples of binder (one pure and four modified) in order to analyze the effects of Waste burnt rubber tires pyrolysis oil in the bitumen. All of the tests are performed following the ASTM designation. In order to obtain representative results, all the tests are carried out as preciously as possible following the standards test procedures.

4.8.2 Penetration

Test Method: ASTM Designation D5

Summary of the Method: The sample is melted and cooled under controlled condition. The penetration is measured with a Penetrometer by means of which a standard needle is applied to the sample under the specified condition.

Test Condition:

The accuracy of the test result is dependent on closely controlled temperature condition. The test is performed at 25°C temperature. The test load and loading time are 100 gm and 5 seconds respectively.

4.8.3 Softening Point

Test Method: ASTM Designation D36

Summary of the Method: The sample is melted and thoroughly stirred to avoid incorporation of air bubbles and to ensure homogeneity in case of modified binder.

Then the sample is poured into the ring which was rested on an amalgamated brass plate. After cooling for 1 hr., the excess material is cut off with a slightly heated knife.

Test Condition:

The temperature of the freshly boiled distilled water in the glass vessel is maintained at 5°C for 15 minutes. The ring with sample is placed 2.54 cm above the bottom of the glass vessel. The rate of heating is 5°C per minute.

4.8.4 Flash and Fire Point

Test Method: ASTM DESIGNATION D92

(Cleveland Open Cup Method)

Summary of the Method: The sample is heated pin an open cup and at intervals a small flame is applied near its surface. The flash point and fire point are recorded very carefully.

4.8.5 Ductility

Test Method: ASTM Designation D113

Summary of the Method: The sample is melted, stirred and poured into the mold as per specification. After cooling to room temperature for 30-40 minute, the excess material is cut off with a slightly straight edged putty knife. The mold is then set in the testing apparatus and ductility is measured at standard test condition.

Test Condition:

Test is performed at 25°C±0.5°C temperature, at pulling rate 5 cm/minute.

4.8.6 Specific Gravity

Test Method: ASTM Designation D70

Summary of the Method: The sample of bitumen prepared into ball shapes of weight almost 20gm to 25gm, then take a weight of bituminous ball in air and weight in water so calculate the specific gravity.

Test Condition:

The accuracy of the test result is dependent on closely controlled temperature condition. The test is performed at 25°C temperature.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 General

The main objectives of the project work are to determine the engineering and rheological properties of waste burnt rubber tires pyrolysis oil modified binder. Analyze the effect waste burnt rubber tires pyrolysis oil modified bitumen on road quality and assess the field performance of waste burnt rubber tires pyrolysis oil blended bituminous pavement section. In this project, waste burnt rubber tires pyrolysis oil is used as modifier. For the assessment of quality improvement and comparison of reference binder (Virgin bitumen) with waste burnt rubber tires pyrolysis oil modified bitumen, Penetration, Ductility, softening point, Flash & Fire point tests are carried out. It is mentioned here that waste burnt rubber tires pyrolysis oil has been used as a modifier for preparing all the test samples of Modified Binder.

5.2 Binder Test Result

Five conventional tests are performed on the binder. Some important properties of binder such as temperature susceptibility, consistency, adhesive quality, etc. are assessed from these test results.

5.2.1 Penetration Test Result

In general, the penetration is used to measure the consistency of semisolid and solid bituminous materials. It is used to classify semisolid bituminous materials into standard consistency grade. Since grade does not signify quality. The penetration test has no relation to quality of binder. It is an empirical test. The result of penetration test on bitumen is shown in Table.

Table 5.1: Penetration Results

Sr.no	Bitumen Sample	Bitumen Wt. %	Pyrolysis oil wt. %	Penetration Value
1	**B0**	100	0	66
2	**B1**	95	5	115
3	**B2**	90	10	260
4	**B3**	85	15	285
5	**B4**	80	20	Above 300

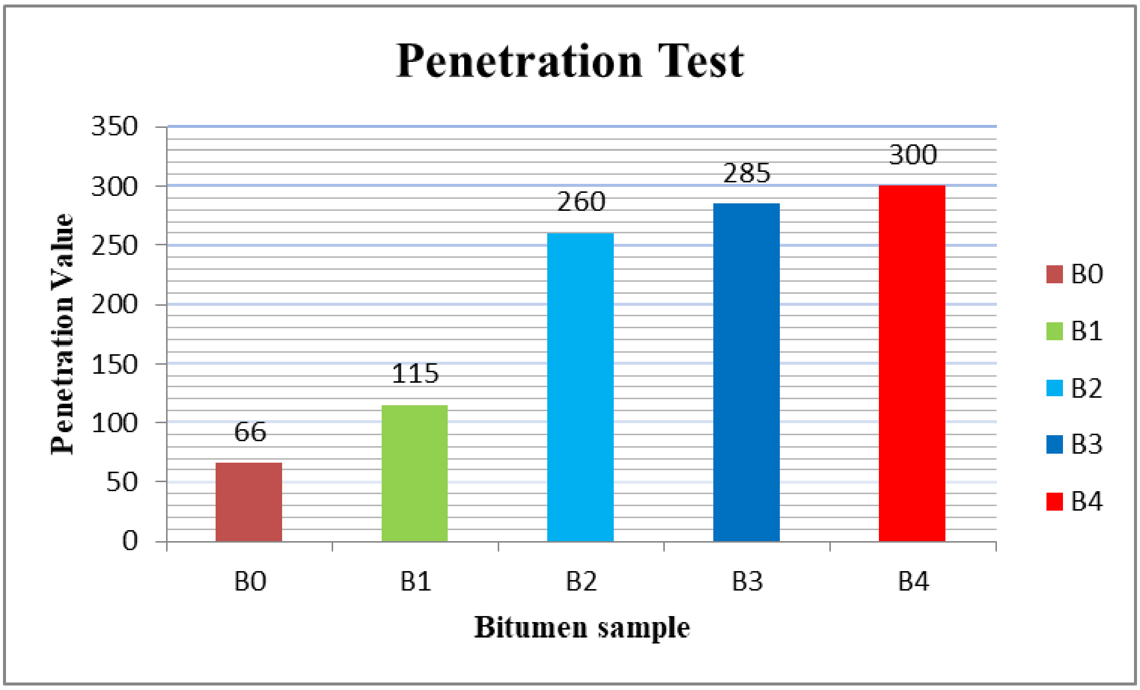

Fig. 5.1: Penetration Result

5.2.2 Ductility Test Result

Table also represents the ductility test result. The ductility of original bitumen was 100 + cm. Ductility is the measure of internal cohesion of binder which impacts cementing properties in bituminous mixes. It generally thought that bituminous materials with high ductility values have good binding properties.

Table 5.2: Ductility Results

Sr.no	Bitumen Sample	Bitumen Wt. %	Pyrolysis oil wt. %	DUCTILITY (cm)
1	**B0**	100	0	Above 100
2	**B1**	95	5	Above 100
3	**B2**	90	10	Not able to perform ductility test due to bitumen is very soft & can't retain its shape for testing at 25 ºC
4	**B3**	85	15	
5	**B4**	80	20	

5.2.3 Softening Point Test Results

The softening point test result is also presented in Table. Softening point is a measure of temperature at which binder changes from semi-solid to liquid state under the weight of a standard steel ball. It is not a measure of melting point.

Actually softening point test is performed to measure the binder temperature susceptibility.

Table 5.3: Softening Point Results

Sr.no	Bitumen Sample	Bitumen Wt. %	Pyrolysis oil wt. %	Softening Point
1	**B0**	100	0	50 ºC
2	**B1**	95	5	44 ºC
3	**B2**	90	10	39 ºC
4	**B3**	85	15	35 ºC
5	**B4**	80	20	24 ºC

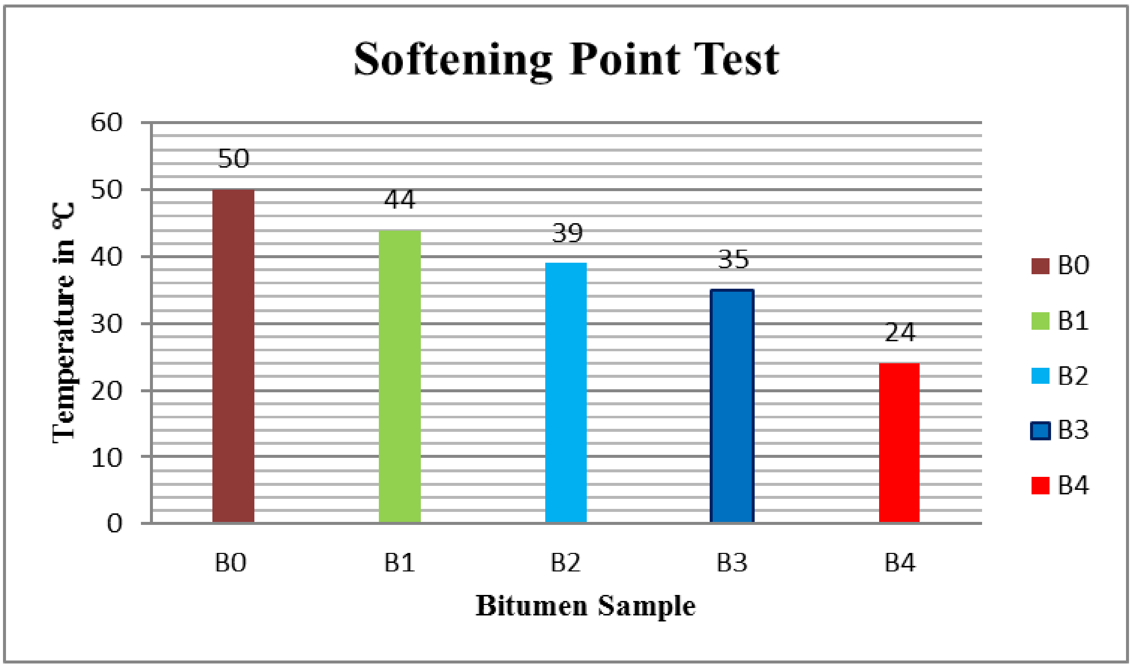

Fig. 5.2: Softening Point Results

5.2.4 Flash and Fire Point Test Results

The flash and fire point test is purely safety test. The test result is presented in table.

Table 5.4: Flash Point and Fire Point Results

Sr.no	Bitumen Sample	Bitumen Wt. %	Pyrolysis oil wt. %	Flash Point	Fire Point
1	**B0**	100	0	300 ºC	350 ºC
2	**B1**	95	5	290 ºC	330 ºC
3	**B2**	90	10	210 ºC	240 ºC
4	**B3**	85	15	200 ºC	220 ºC
5	**B4**	80	20	180 ºC	200 ºC

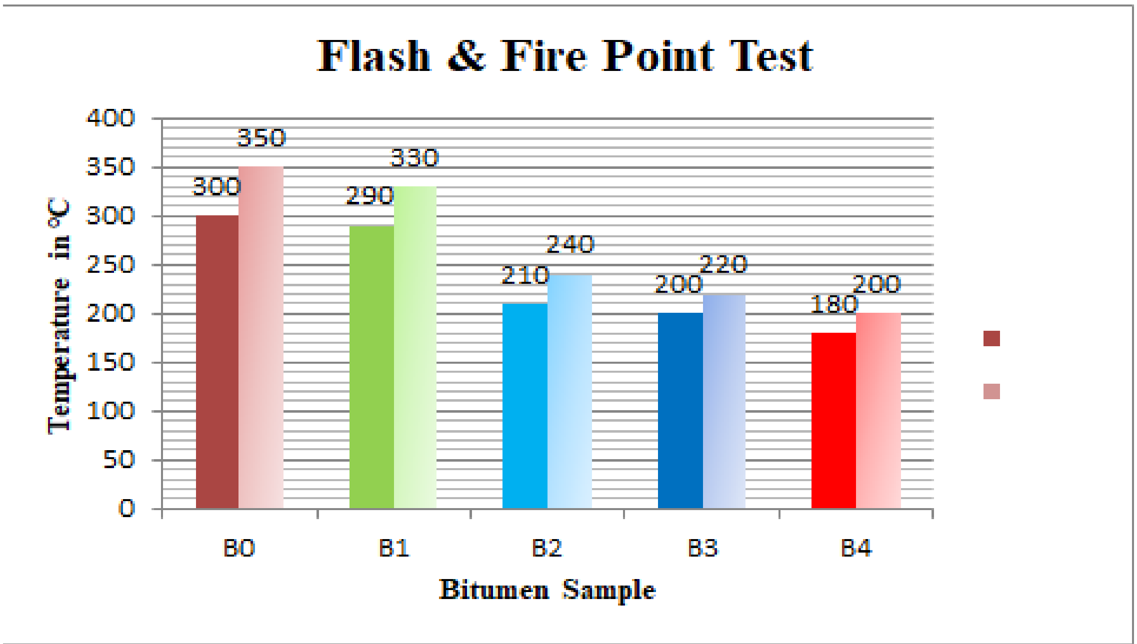

Fig. 5.3: Flash and Fire Point Results

5.2.5 Specific Gravity Test Results

Table 5.5: Specific Gravity Results

Sr.no	Bitumen Sample	Bitumen Wt. %	Pyrolysis oil wt. %	Specific Gravity
1	**B0**	100	0	1.0079
2	**B1**	95	5	1.0047
3	**B2**	90	10	1.0010
4	**B3**	85	15	0.9989
5	**B4**	80	20	0.9931

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

According to other objectives of the research, the modified binder was investigated through extensive laboratory experimentation. A comparative analysis of waste burnt rubber pyrolysis oil modified bitumen and virgin bitumen regarding rheological properties were carried out

Besides, a field demonstration was carried out on the two adjoining segments lay in front of BSc. Tech department to compare the performances of the road segments.

6.1 Conclusion

Conclusion have been drawn on natural bitumen & Waste burnt rubber pyrolysis oil modified bitumen.

- Modified bitumen tends to become softer and more susceptible to temperature change as more percentage of pyrolysis oil.
- 5% replacement of bitumen by waste pyrolysis oil gives the optimum value. More than 5% of waste pyrolysis oil makes the sample softer and not eligible for many applications in the construction of flexible pavement in warmer region.
- 10% replacement of bitumen by waste pyrolysis oil have been used successfully in cold region.
- Modified bitumen is able to use in cold areas because it has tendency to resist the cracks due to temperature changes on the pavement.
- Modified Bitumen is economical due to mixing of pyrolysis oil in natural bitumen because mixing of pyrolysis oil reduces the cost of bitumen. It is used for waterproofing & corrosion protection.

6.2 Recommendations

The study findings show that use of waste burnt rubber pyrolysis oil as modifier to the bituminous surfacing of the conventional road pavement in Pakistan would improve the performance of Pakistan road network significantly. The following are the recommendations.

- Government agencies like NHA, C&W, and City Development Authorities should come up with at least one comprehensive project of processing waste burnt rubber pyrolysis oil and constructing roads using the waste burnt rubber pyrolysis oil modified bituminous mix;
- The collection of pyrolysis oil by the private plant situated in Mureedkay.
- To ensure the use of specified waste burnt rubber pyrolysis oil in road works with proper specification road agencies along with academic institutions should develop Standard Test Procedures and set up laboratory facilities to do the specified tests.
- Professional and academic training should be given to different appropriate levels in the implementing chain Engineers, Technicians, Foreman and up to field level Laborers with regard to the new technology.
- For future research, it is suggested that more sets of percentage of pyrolysis oil with small percentage intervals have to be carried out so that the change in properties of the modified bitumen can be study in a more detail manners.
- It is also suggested that hot mix asphalt should be designed by using the pyrolysis oil modified bitumen through Marshall Mix Design method and then tested under Marshall Stability and Flow test to study the practicability of the modified bitumen in real situation of road construction.
- Bitumen grade 60/70 is recommended to be used instead of bitumen grade 80/100 as the former is harder and more practical to be blended with pyrolysis oil.

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ANNEXTURES Material Testing

Fig. 7.1: Waste Rubber Tires

Fig. 7.2: Waste Tire Pyrolysis Plant

Fig. 7.3: Oil Collector Tank

Fig. 7.4: Cooling Tank

Fig. 7.5: Storage of Dry Carbon Powder

Fig. 7.6: Steel Wires

Fig. 7.7: Different Ratio Pyrolysis Oil With Bitumen Sample

Fig. 7.8: Pouring Sample In Test Apparatus

Fig. 7.9: Flash Point and Fire Point Test

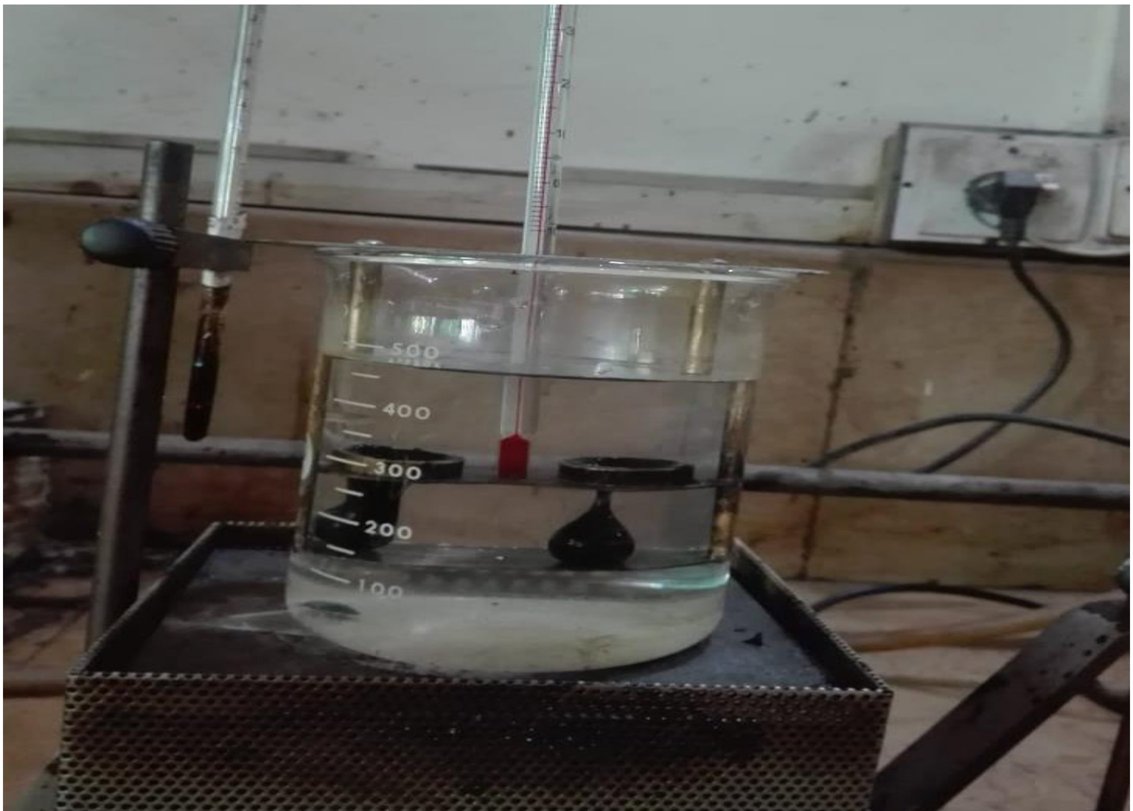

Fig. 7.10: Softening Point Test

Fig. 7.11: Penetration Test

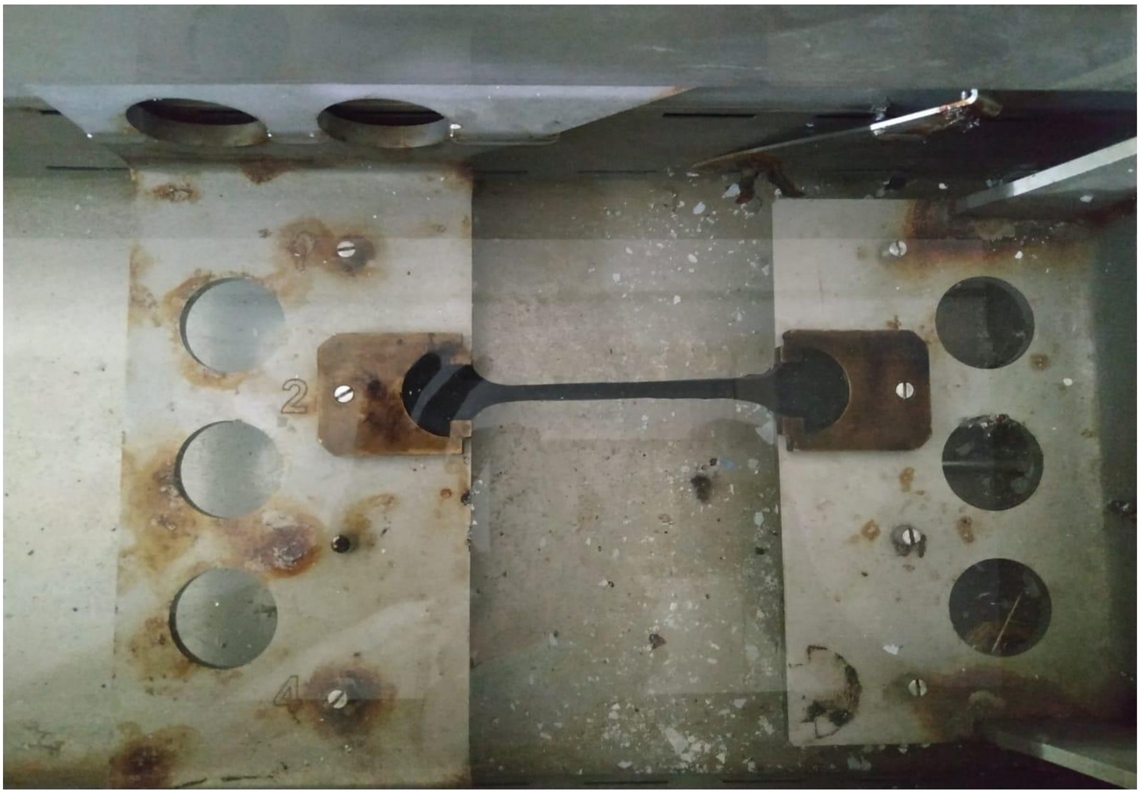

Fig. 7.12: Ductility Test

Fig. 7.13: Specific Gravity Test Apparatus