# STUDY OF USE OF WASTE COOKING OIL AS A REJUVENATING AGENT FOR AGED BITUMEN

**Submitted in partial fulfilment of the requirements**

**of the degree of**

**MASTER OF TECHNOLOGY**

**In**

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**By**

**Ravi Datt Sharma**

**11507244**

**Supervisor**

**Mr. Amit Kumar Yadav**


**School of Civil Engineering**

**LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA**

**2017**

# DECLARATION

I, Ravi Datt Sharma (11507244), hereby declare that this thesis report entitled **"Study of use of waste cooking oil as a rejuvenating agent for aged bitumen"** submitted in the partial fulfilment of the requirements for the award of degree of Master of Civil Engineering, in the School of Civil Engineering, Lovely Professional University, Phagwara, is my own work. This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

**Date:** **Ravi Datt Sharma**

**Place:** Lovely Professional University, Phagwara

# CERTIFICATE

Certified that this project report entitled *"***Study of use of waste cooking oil as a rejuvenating agent for aged bitumen***"* submitted individually by student of School of Civil Engineering, Lovely Professional University, Phagwara, carried out the work under my supervision for the Award of Degree. This report has not been submitted to any other university or institution for the award of any degree.

**Signature of Supervisor**
Mr. Amit Kumar Yadav
**Assistant Professor**

# ACKNOWLEDGEMENT

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**Signature of Student**
**Ravi Datt Sharma**

# ABSTRACT

As we know that, after years of service, bitumen binder of bituminous concrete has become aged. So this research paper will observe the effect of using waste cooking oil (WCO) as a rejuvenating agent in aged bitumen which is a waste product and causes pollution in seas and land. This research paper also explains the properties of aged bitumen and fresh bitumen. So the objective of this research paper is to know the physical and chemical properties of untreated fresh bitumen, aged bitumen and rejuvenated bitumen by various tests like penetration test, viscosity test, softening point test, acid test, water content test. A property of aged bitumen and untreated fresh bitumen is also compared by these tests. In general this research shows that 3-4% of WCO can rejuvenate the bitumen of 30/40 group and resembles the properties of 60/70 group of bitumen.


**Keywords –** Waste cooking oil, Rejuvenating agent, Aged bitumen, Physical properties.

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# List of Abbreviation

| | |
|---|---|
| WCO | Waste Cooking Oil |
| RAP | Reclaimed Asphalt Pavement |
| CO | Cooking Oil |
| % | Percentage |
| CM | Centimetre |
| MM | Millimetre |

# CHAPTER 1
# INTRODUCTION

## 1.1 General

Since past many years, paving of flexible roads is being done by the use of most known petroleum based product which is bitumen. Bitumen's modified form known as asphalt is a best binder for flexible pavement. But after many years of service, binder material of road becomes aged and starts losing its properties. Aging causes increase in stiffness of bitumen and also affects its physiochemical properties. Therefore as a conclusion, aged bitumen becomes more brittle and reduces the pavement strength and decrease the service life of road. So as we know that rapid depletion of crude oil resources is leading to continuous increase in crude oil prices. Therefore, by recycling old bitumen layer, the overall service life of pavement can be extended as well as the use of new bitumen is reduced. A well designed reclaimed bitumen mixture can meet the properties of fresh asphalt. So to minimize the effect of aging from aged bitumen some rejuvenator should be included in the reclaimed mixture. So in past mainly two types of rejuvenating agent were used as a rejuvenator. Softening agent and rejuvenating agent. Softening agents are mostly used to decrease the viscosity of aged bitumen on other hand rejuvenating agent are used for regaining physical as well as chemical properties of aged bitumen. So due to demand of rejuvenator many waste product in used as a rejuvenator. Recently in Spain, waste motor oil is successfully used as rejuvenating agent in aged bitumen. The result of waste motor oil report that material in which motor oil used as rejuvenator can compete with the new material. Therefore successful uses of WMO also encourage the application of waste oils as a rejuvenator in the pavement. So this paper studies the use of WCO(waste cooking oil) in bitumen.

## 1.2 Terminology

### 1.2.1 Bitumen

Bitumen is black and highly viscous type of liquid or semi-solid form of petroleum. Bitumen is non-renewable material .The primary use of bitumen is in construction of roads, where it used as a binder mixed with aggregate particles to make asphalt concrete. Bitumen is produced from crude oil. Last residue in fractional distillation of crude petroleum is bitumen.

### 1.2.2 Aged Bitumen

After some year of service bitumen used in road construction becomes aged. As a result the pavement layer become more brittle and resulted in cracks. Aging of bitumen mostly affect the physiochemical properties of bitumen i.e. ductility and adhesion properties. The degree of aging of bitumen is typically based on a factor which is temperature changes. The other various components which cause aging is oxidation, evaporation, ultraviolet rays and physical hardening .These factors are reason behind aging of bitumen. Therefore aging cause hardening and results in lowering in penetration and hike in softening point

### 1.2.3 Aging of bitumen

Bitumen is influenced by factors like presence of oxygen, UV rays and changes in temperature. So aging results in:

- Reduction in penetration value
- Rise in softening point
- Reduction of ductility value.

### 1.2.4 Factors affecting aging of bitumen-

a. Oxidative hardening
b. Hardening due to loss of volatiles
c. Physical hardening
d. Exudative hardening
e. Hardening on the road

**a. Oxidative hardening**- Bitumen when remains in contact with atmosphere for a longer duration, oxygen starts reacting to its constituents leading to the formation of higher molecular weight particles. Larger molecules are less flexible and hence the hardness increases.

**b. Hardening due to loss of volatiles**- With advancement in life span the volatile components of bitumen evaporates. The rate of evaporation is dependent upon temperature. Which also cause hardening of bitumen.

**c. Physical hardening**- Molecules rearrange themselves at ambient temperatures which results to physical hardening.

**d. Exudative Hardening**- when oily components exits bitumen over a period of time exudative hardening takes place.

**e. Hardening of bitumen on road**- Bitumen aging may alsohappen due to oxidation which is dependent upon access to oxygen. Some factors which cause aging and influenced by some component is explained in table below.

Table 1.1 Factors affecting bitumen aging (Source- reference 5)

| Factors | Time | Heat | Oxygen | Sunlight |
|---|---|---|---|---|
| Oxidation(in dark)_ | Yes | Yes | yes | No |
| Photo oxidation | Yes | Yes | yes | Yes |
| Photo chemical | Yes | Yes | no | Yes |
| Evaporation of oils | Yes | Yes | no | Yes |
| Action by water | Yes | No | yes | No |
| Chemical reactions | Yes | Yes | yes | Yes |

### 1.2.5 Properties of Rejuvenators

**1)** Holding the properties of aged binder

2) Enhancing the flexibilities of the mix

3) Decreasing the consumption of untouched materials.

### 1.2.6 Role of Rejuvenator

1. Restoring maltene characteristics

2. Reduce cracking and eliminating rut-resistance.

3. High flash point is used in HMA plant.

4. Existence of batch to batch variability

### 1.2.7 Cooking oil

CO(cooking oil)is animal, plant or synthetic fat used for frying action, baking, and other types of cooking. It is also used in the preparation of food and flavouring which does not require heat such as dressing of salad. CO(Cooking oil) is usually in its liquid form at room temperature, although some oil contains saturated fat, e.g palm oil, coconut oil and palm kernel oil are solid in nature. Heating oil alters its properties and characteristics. Oils that are healthy when heated above specific temperature makes it unhealthy. Therefore, it is necessary that the heat tolerance of the oil must match with its cooking method.

### 1.2.8 Waste cooking oil

Waste oil that is disposed off to land or sea without pre treatment which show negative impact on environment. This effect is visible when a thin layer of oil appears on the surface of a river or a lake which is also known as eutrophication. This thin layer blocks the sunlight, stops photosynthesis and disturbs oxygen supply to the aquatic life.


**Figure 1.1** Waste Cooking Oil (Source-During Testing)

### 1.2.9 Reclaimed Asphalt Pavement

Reclaimed asphalt pavement (RAP) is the recycled material produced from the removal of old asphalt highways.im this pavement the old road can either be completely removed or

partially this procedure called milling. In either case, this waste material, called RAP, is typically ground into aggregates, which are inherently coated with aged asphalt binder. This ground material can be added into new roads at the asphalt plant, to reduce the amount of virgin aggregates and virgin binder needed. The primary benefit of RAP is a direct cost savings due to the reduction in virgin materials. The aggregate in RAP replaces some of the aggregate in new asphalt pavement, and the aged binder attached to the aggregates is assumed to replace a portion of virgin binder required for new road construction. Some Research has shown that a secondary benefit of RAP is that a pavement containing recycled material ages more slowly when compared with pavements constructed entirely from virgin materials.

### 1.2.10 Tests on bitumen

a. Test for Penetration value
b. Test for Softening point
c. Test for Ductility value
d. Test for Viscosity

**a) Penetration Test (IS 1203-1978)**

This test explains the hardness or softness of bitumen by determining the depth in tenths of a millimetre to which a standard load needle will penetrate vertically in five seconds. The temperature of 25 degree Celsius is maintained for a sample. The apparatus used for this test is penetrometer.

**Figure 1.2** Penetrometer for Penetration Test. (Source- During testing)

**b) Softening Test(IS 1205-1978)**

The softening point is defined as the temperature(in degree celsius) where the substances attain a particular amount of softening under specified condition of test. The apparatus used for determine the softening point is ring and ball apparatus. In this test a brass ring which contains test sample of bitumen is suspended in water of glycerine at a given temperature .Steel ball is placed upon the bitumen sample and the liquid medium is then heated at a rate of 5 degree Celsius per minute .The temperature at which the softened bitumen touches the metal placed at a specified distance below the ring is recorded as a softening of bitumen.

...

**Figure 1.3** Ring and Ball Apparatus( Source- From Testing)

**c) Ductility Test**

In the flexible pavement construction where bitumen binder is used, it is important that the binder forms ductile thin films around the aggregates.. In ductility machine, bitumen is heated and poured in the mould assembly placed on a plate. The sample along with the moulds are cooled in air and then incubated in water maintained at temperature of 27 degree Celsius. The excess bitumen material is to removed and the surface is levelled using a hot

knife .The mould assembly sample is again incubated in water bath of the ductility testing machine for 85 to 95 minutes. The sides of mould are removed. The distance up to the breaking of thread is reported in centimetre as a ductility value.


**Figure 1.4** Ductility Machine (source- During testing)

**d) Viscosity Test**

It is describe in simple word as inverse of the fluidity. Viscosity is a measure of resistance to flow. The amount of fluidity of the binder at the application temperature greatly influences the strength characteristics of the resulting paving mixes.


**Figure.1.5** Rotational viscometer(Source-During Testing)

Brookfield Rotational Viscometer is used to determine the viscosity of bitumen. The viscosity for higher temperature at 135 degree Celsius is used to determine the workability of bitumen.

### 1.2.11 Tests on Waste cooking Oil

There are various tests to explain the properties of WCO but for this research purpose only acid test and water content test is required.

### 1.2.12 Acid Test

Acid Value of waste cooking oil determines its quality. Acid value test determines the acid value existed in the WCO sample by using titration method or by directly using by digital ph meter.. The acid value for titration based is calculated by the following Eq.:

$$\text{Acid Value} = \text{mL KOH} \times \frac{0.01\ \text{N KOH} \times 56.1}{\text{G WCO sample}}$$

### 1.2.13 Viscosity test

Brookfield rotational viscometer is used to determine the viscosity of waste cooking oil.Value determine by this test is in CPA(Centipoises).

# CHAPTER-2
# REVIEW OF LITERATURE

**Haliza Asli et al.[1]**

He stated that rejuvenating agents are used to regain the original characteristics of aged bitumen.wco is generally aromatic and fully capable of improvise the temperature susceptibility and hardness of aged bitumen. He also state that after a long life span of HMA binder and aggregate still remains useable. Near about 25% of RAP can be used in HMA after rejuvenating with some rejuvenator.

**Majid Zargar et al. [2]**

He investigated that WCO can behave like rejuvenator in aged bitumen. According to this research rejuvenated bitumen have less tendency of aging as compare to new virgin bitumen. By using WCO successfully as a rejuvenator it also show positive impact on environment and also on economical aspect. He proves that proper quantity of WCO can change the physical properties of bitumen. He proved that 3-4% of WCO change the penetration value, softening point and ductility of aged bitumen.

**Aaron Villanueva et al. [3].**

He stated that according to data over 71 million litres of used oil (in 2003– 2004) in that province alone collected by the the AUOMA(Alberta Used Oil Management Association) while in the same time period other provinces, such as BCUOMA, have collected and recycled an estimated 39.9 million litres of used oil. Waste cooking oil can cause adverse environmental impact so it is compulsory to collect the waste oil for recycling

**Wan Nur Aifa Wan Azahar et al. [4]**

He stated that in general, the ending activity which is dumping activity of WCO into the landfill or river cause the adverse effect towards an environmental. One of the major environment issue arise is eutrophication process which occur when there is a restriction for sunlight to insert on the surface of river because of the blocking from the thin layer of oil. Due to this, oxygen supply for aquatic life is interrupted in river. According to a survey engine oil from vehicles or waste cooking oil from residential areas are the major sources of river pollution.

**Prajapati Harshad C et al. [5]**

He stated that hardening of bitumen has determined as the main reason that can affect the life span of bituminous paving materials. When bitumen become aged, then the bituminous concrete become brittle and its ability to support stresses and strain induced due to traffic may decrease. Deterioration may follow cracking of pavement. Adhesion between the bitumen and aggregate can also weaken due to excessive hardening, which resulting in degradation of materials from the surface layer and create weakening of bitumen mixture.

**Christopher Daniel DeDene et al. [6]**

He stated that RAP and WEO are two materials when used separately in flexible pavements they both have problems.RAP produce stiffer pavements with poor low temperature performance, while waste engine oil inside of bitumen mixture produce softer pavement and improve the low temperature PG grade of asphalt binder. When combined, the RAP and WEO could symbiotically make a highly viable pavement.

**Nurul Hidayah Mohd Kamaruddin et al.[7]**

He stated that the effects of Waste Engine Oil and Waste Cooking Oil shown good and adverse effects to the flexible pavement. These effects totally depend upon the appropriate amount of WCO/WEO used in the aged mixture material. He explained that For The high stiffness of mixture require high amount of Waste Oil.

**Dr Kemas Ahmad Zamhari et al. [8]**

Rejuvenator in asphalt recycling is divided as

1. Softening agent

- Bitumen/asphalt flux oil
- Lube stock
- Lubricating oil
- Slurry oil

2. Rejuvenating agent

- Lube extracts
- Extender oils

**Helen K Bailey et al. [9]**

He stated that the atmospheric exposure causes bituminous pavement to gradually aged due to weathering and oxidation action. The hike in hardness of the asphalt results in adverse consequences like flexural capacity (fatigue cracking) and thermal response (thermal cracking). Therefore, it is important to have timely and efficient maintenance of bituminous pavement .He also stated that the addition of rejuvenating agents in small and appropriate quantities can bring asphalt back to life through softening of the binder and restoring the flexibility of mix. The ability of rejuvenating agent to do this is totally depends on the viscosity and the quantity added to the aged bitumen mixture.

**Brajesh Mishra et al. [10]**

He investigated that Comparison can be made between RAP and crushed natural aggregates. RAP has a higher content of fines as a result of degradation of material during milling and crushing operations. Typical physical properties of RAP are tabled below-

**Table 1.2** Physical properties of rap (Reclaimed Asphalt Pavement)

| S.NO | PARAMETER | VALUES |
|---|---|---|
| 1 | Unit weight(kg/$m^3$) | 1900-2250 |
| 2 | Moisture content | Max 3-5% |
| 3 | Asphalt content | 5-6% |
| 4 | Asphalt penetration | 10-80 |
| 5 | Compacted unit weight(kg/$m^3$) | 1500-1950 |
| 6 | California bearing ratio | 100%Rap<br>20-25% |

# CHAPTER 3

# RESEARCH METHODOLOGY

In this research, the tests were conducted on three samples i.e. fresh bitumen, aged bitumen and rejuvenated bitumen. The entire methodology is illustrated below with a well explained flow chart.

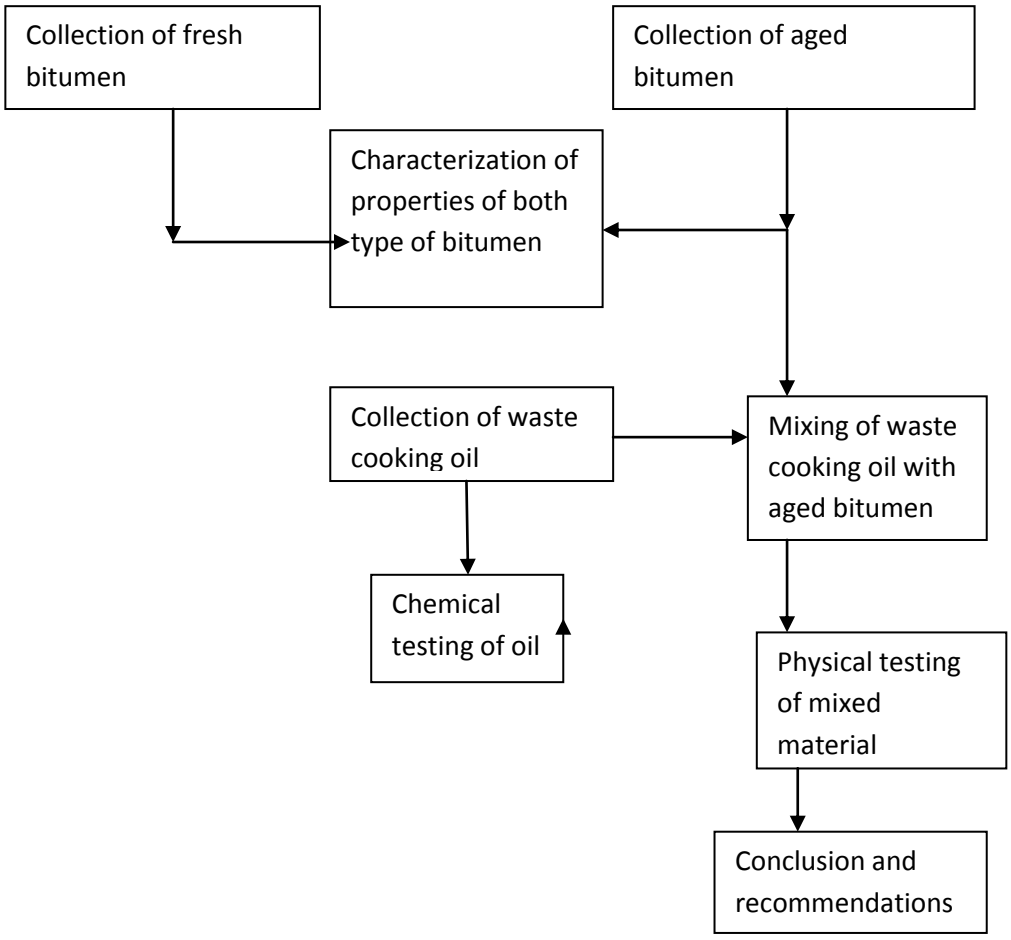



Figure 1.4 Flow chart of the experimental program

## 3.1 Types of Testing

Bitumen and Waste cooking oil were subjected to certain tests. The test conducted on Bitumen is known as physical testi ng and the test conducted on waste cooking oil is chemical testing.

### 3.1.1 Testing on bitumen

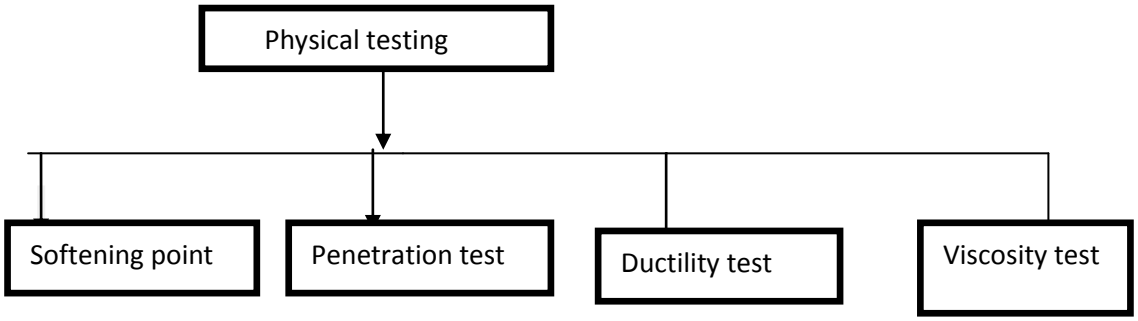



**Figure 3.1** Flow chart for physical testing

### 3.1.2 Testing on waste cooking oil

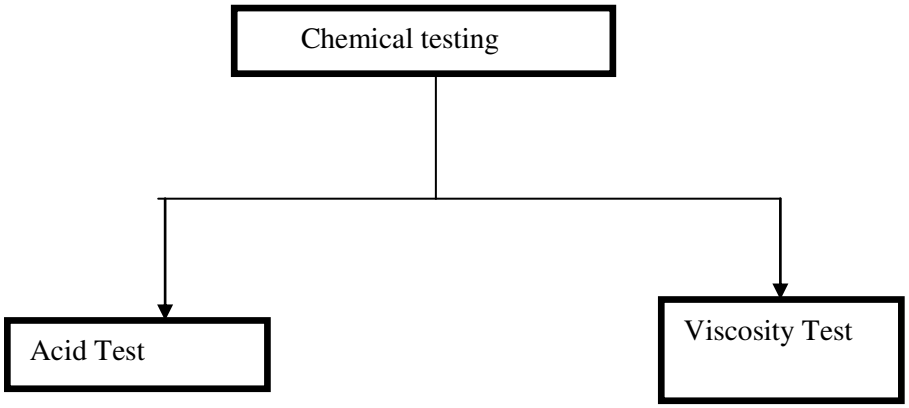



**Figure 3.2** chemical Testing of mixed material

## 3.2 Expected Outcomes

The experimental program for this research is designed for characterizes the use of WCO (waste cooking oil) in aged bitumen as a rejuvenator. So the expected outcome of this research are-

- Different properties of aged bitumen
- Performance of aged bitumen when treated with WCO(waste cooking oil) which act as a rejuvenator
- Properties of fresh bitumen
- Acid Value (in mg/l) of WCO(waste cooking oil)

- Viscosity in WCO(waste cooking oil).
- Positive effect on environment.
- Effective percentage of waste cooking oil used in aged bitumen so that its properties seems equivalent to fresh bitumen.
- Positive and negative effect of aging on bitumen.

### 3.3 Objective

- To determine properties of aged bitumen
- To determine the performance of aged bitumen when treated with waste cooking oil as a rejuvenator
- To determine the effective amount of WCO(waste cooking oi) used in bitumen which is aged so that its properties seems equivalent to fresh bitumen.
- To determine the effect of aging on bitumen.

# CHAPTER 4
# EXPERIMENTS AND DISCUSSION

## 4.1 Material

Untreated bitumen of 60/70 grade is collected from near trader to compare its properties with aged bitumen. Aged bitumen which was of 60/70 penetration grade collected from near stockpile . Waste cooking oil is collected from near restaurant.

## 4.2 Experimental procedure

Initially, untreated bitumen of 300gm is heated at 100-150 degree Celsius and melted into its viscous form. Then this viscous form is considered as sample 1 and subjected to all physical tests. Later, aged bitumen of 300 gm is heated at 100-150 degree Celsius and melted into its viscous form. This viscous form is considered to be sample 2 and subjected to all physical tests. Then WCO(Waste cooking vegetable oil) is blended in the 30/40 grade aged bitumen at the proportion of 1%, 2%, 3%, 4%, 5% for 1 hour with the rpm of 100 at the temperature of 150 degree. This WCO mixed aged bitumen is considered as sample 3. Then that sample is poured in the container for further physical testing.

## 4.3 Testing on samples

### 1) Sample 1

Untreated bitumen of 300gm is heated at 100-150 degree Celsius and melted into its viscous form .Sample 1 is pure sample of untreated fresh bitumen. So result for sample1 is described here.

**Table 4.1** Testing on fresh bitumen(Source- Primary Source)

| Bitumen tests | Value |
|---|---|
| Penetration value(in cm) | 65 |
| Softening point(in degree Celsius) | 50 |
| Ductility(in cm) | 75 |

### 2) Sample 2

Aged bitumen of 300 gm is heated at 100-150 degree Celsius and melted into its viscous form. Then the applied aged bitumen is tested and properties are illustrate

**Table 4.2** Testing on aged bitumen (source-Primary Source)

| Bitumen test | Values |
|---|---|
| Penetration test(in cm) | 39 |
| Softening point(in degree Celsius) | 58 |
| Ductility(in cm) | 42 |

### 3) Sample 3

In this sample aged bitumen collected from stockpile is blended with WCO at 1%, 2%, 3%, 4%, and 5% by weight of bitumen.

**Figure 4.1** Mixing of aged bitumen with WCO (source- During Testing)

**a) Penetration test**

This test determines the hardness or softness of bitumen.. The apparatus used for this test is penetrometer

**Table 4.3** Value of Penetration Test. (Source- primary source)

| WCO blended with aged bitumen by weight in different proportion | Penetration value(0.1mm) |
|---|---|
| 1% | 46 |
| 2% | 54 |
| 3% | 64 |
| 4% | 78 |
| 5% | 89 |

**b) Softening point-**

The apparatus used for determine the softening point is ring and ball apparatus.The relationship between temperature for softening point value and 30/ 40 group aged bitumen which is mixed with different percentage of WCO is given in table below

**Table 4.4** Test on different % of WCO with aged bitumen for softening Point

| WCO blended with aged bitumen by weight in different proportion | Softening point value(in degree Celsius) |
|---|---|
| 1% | 50 |
| 2% | 45 |
| 3% | 42 |
| 4% | 39 |
| 5% | 35 |

**c) Viscosity**

In general term viscosity is the measurement of the internal friction of the bitumen. Viscosity is defined as inverse of fluidity, viscosity thus defines the fluid property of bituminous material, viscosity is the general term for consistency and it measures the resistance to flow. The instrument used to conduct the test was Brookfield Viscometer.

**Table 4.5** Test on different % of WCO with aged bitumen for viscosity

| WCO blended with aged bitumen by weight in different proportion | Viscosity(centipoises) |
|---|---|
| 1% | 525 |
| 2% | 475 |
| 3% | 400 |
| 4% | 353 |
| 5% | 305 |

### d) Ductility

Ductility is a solid material's ability to deform under tensile stress; this is often characterized by the material's ability to be stretched into a wire. The ductility for sample of aged bitumen and other incorporated WCO is different.

**Figure 4.2** Threads of Bitumen in Ductility Machine

The relationship between ductility value and 30/ 40 group aged bitumen which is mixed with different percentage of WCO is given in table below

**Table 4.6** Ductility Value of WCO blended aged bitumen

| WCO blended with aged bitumen by weight in different proportion | Ductility value(in cm) |
|---|---|
| 1% | 48 |
| 2% | 58 |
| 3% | 65 |
| 4% | 75 |

### 4.4 Tests on Waste cooking oil-

#### 4.4.1 Acid test-

The acid value results are based on the digital PH instrument is 3.5504 mL/g.

#### 4.4.2 Viscosity test-

For this test, the instrument used was Brookfield viscometer. The value obtained was 39.8 cpa.

# CHAPTER 6

# RESULT AND DISCUSSION

## 5.1 Comparison between the properties of sample 1 and 2-

### 1) Sample 1

**Table 5.1** Testing on fresh bitumen

| Bitumen tests | Value |
|---|---|
| Penetration value(in cm) | 65 |
| Softening point(in degree) | 48 |
| Ductility(in cm) | 75 |

So by this testing it was proved that this sample of bitumen is of 60/70 grade.

### 2) Sample 2

**Table 5.2** Testing on aged bitumen

| Bitumen test | Values |
|---|---|
| Penetration test | 39 |
| Softening point | 58 |
| Ductility | 42 |

By this testing it was proved that this sample of bitumen is of 30/40 grade.

## 5.2 Comparison by Graph-

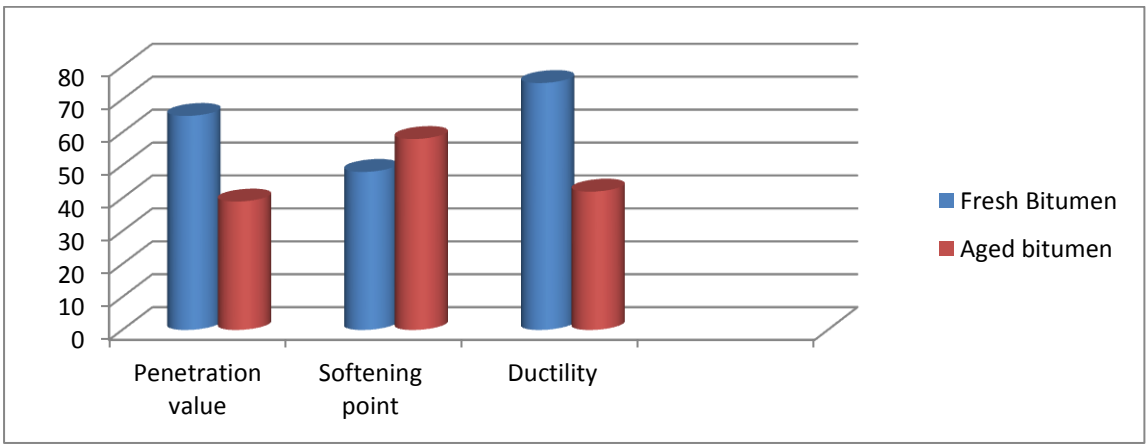


**Figure 5.1** Comparisons of Sample 1 and Sample 2

So by comparison it is proved that there is lot of variation in the properties of bitumen after aging. Penetration value of 60/70 grade of bitumen is reduced from 65 to 39 after aging. Softening point is increased from 50 to 58 because of aging. Ductility value also affected because of aging.

### 5.3Analysis of WCO incorporated samples-

### 5.3.1 For Penetration test-

**Table 5.3** Values of Penetration Test

| WCO blended with aged bitumen by weight in different proportion | Penetration value(0.1mm) |
|---|---|
| 1% | 46 |
| 2% | 54 |
| 3% | 64 |
| 4% | 78 |
| 5% | 89 |

### 5.3.2 Analysis by Graph-

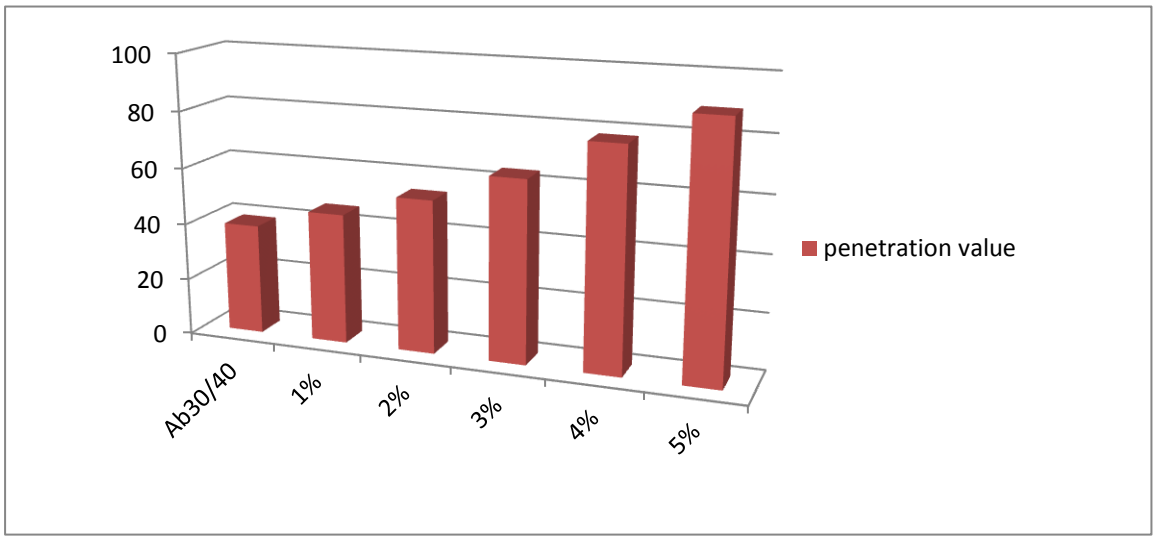



**Figure 5.2** Penetration versus different rejuvenated WCO aged bitumen

By analysis it is proved that adding of WCO increase the penetration value of aged bitumen.WCO softens the aged bitumen and increase its penetrartion value.

### 5.4 Comparison between fresh bitumen(sample 1), aged bitumen(sample 2) and 3%WCO blended bitumen.

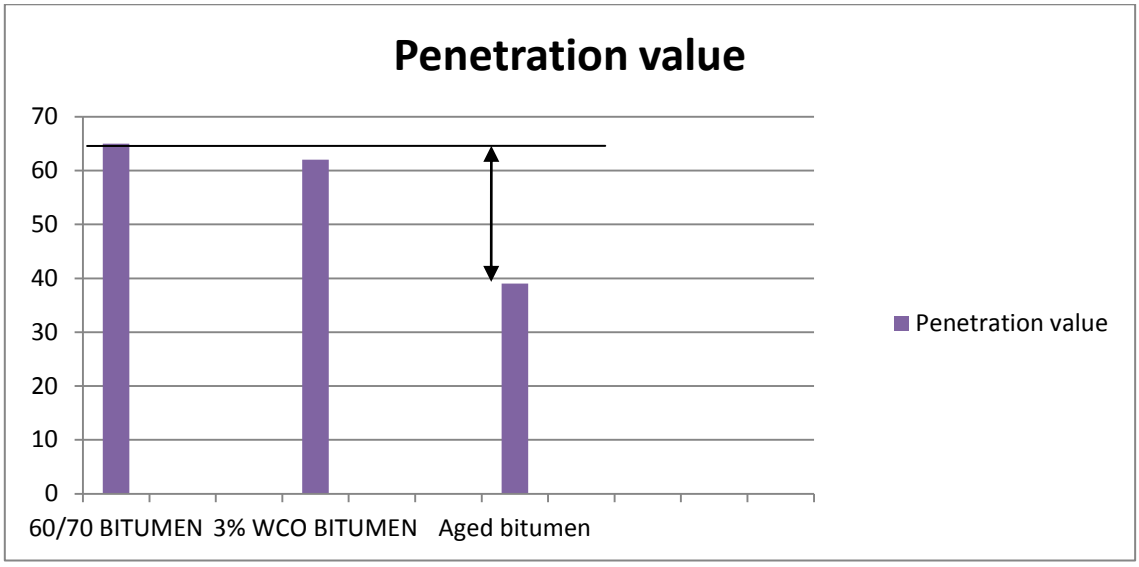



**Figure 5.3** Comparisons of Penetration Values

Dark lines show that 3% of WCO in aged bitumen can enhance its properties which resemble the penetration value of aged bitumen near about 60/70 grade bitumen.

### 5.5Analysis for Softening Point-

**Table 5.4** Values of Softening Point

| WCO blended with aged bitumen by weight in different proportion | Softening point value |
|---|---|
| 1% | 54 |
| 2% | 50 |
| 3% | 45 |
| 4% | 39 |
| 5% | 35 |

### 5.5.1 Analysis by graph-

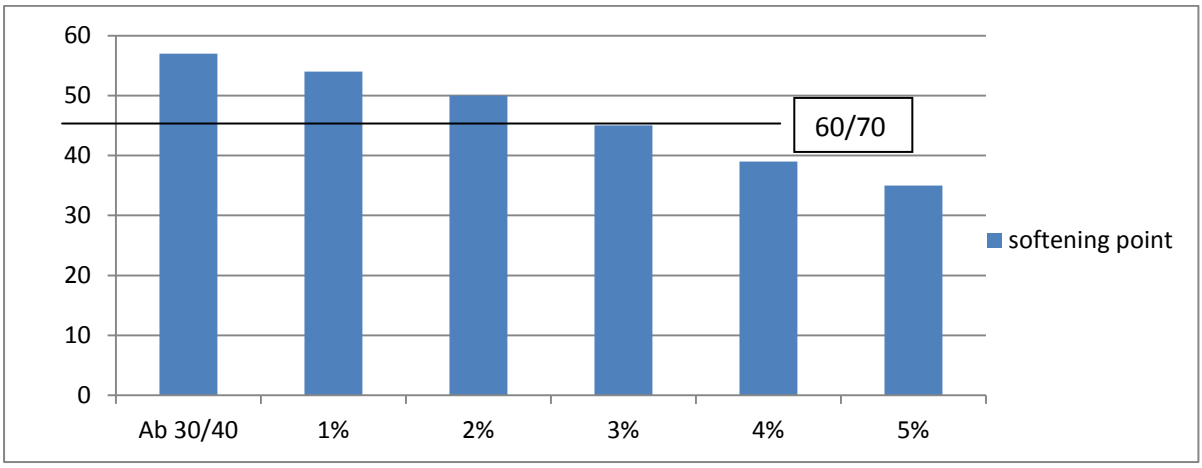
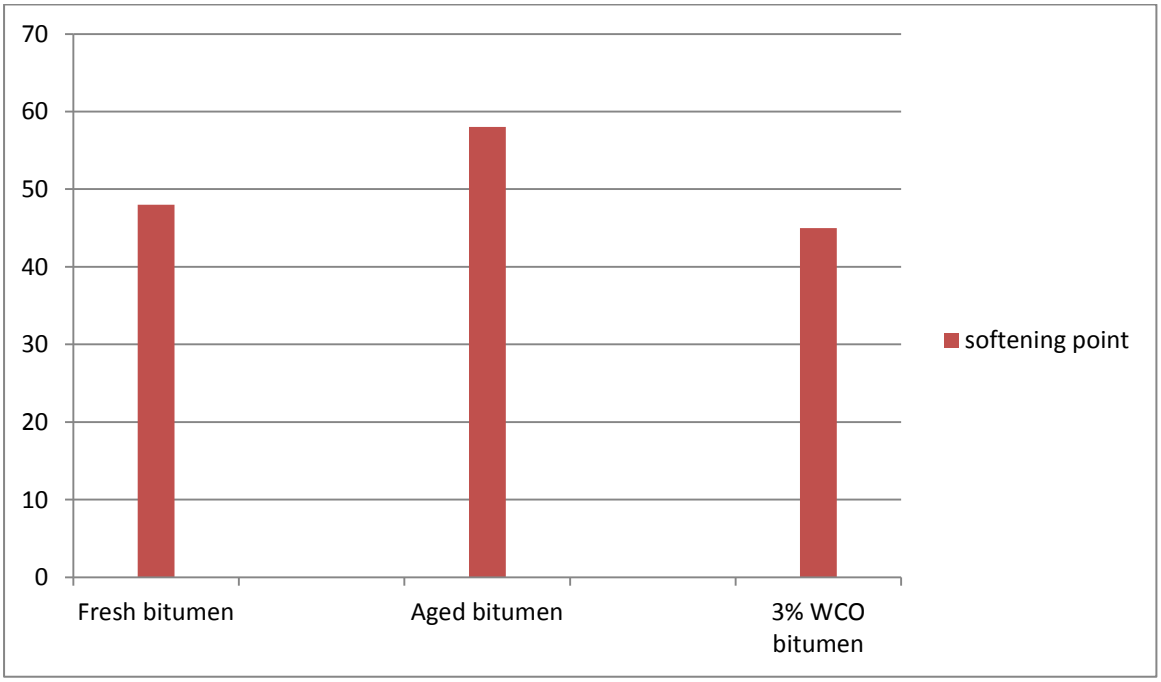



**Figure 5.4** Analysis of Softening Point

Due to aging the bitumen become hard and its softening point is tends to increase but by graph it is proved that softening point is tends to decrease gradually as WCO is added in aged bitumen .

### 5.6 Comparison between fresh bitumen (sample 1) Aged bitumen (sample 2),3% WCO blended bitumen-



So by comparing it is proved that by adding 3% of WCO in aged bitumen softening point of 30/40 grade aged bitumen become equals to the softening point of the 60/70 grade bitumen.

### 5.7 Analysis for Ductility-

**Table 5.5** Values of Ductility Test

| WCO blended with aged bitumen by weight in different proportion | Ductility value |
|---|---|
| 1% | 48 |
| 2% | 58 |
| 3% | 65 |
| 4% | 75 |

### 5.7.1 Analysis by Graph

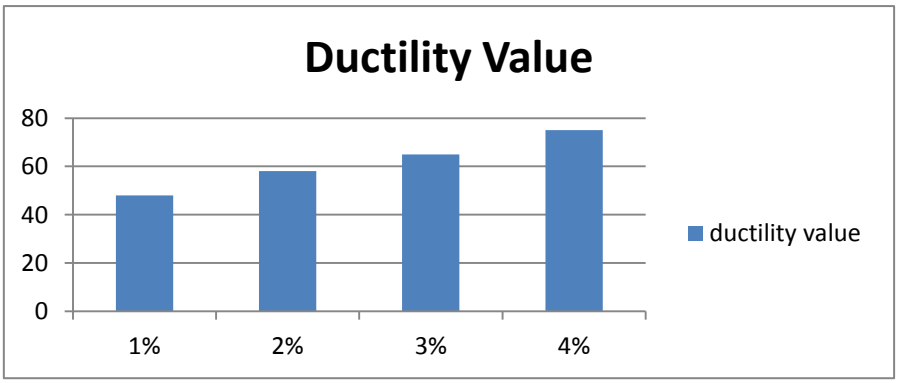



**Figure 5.5** Analysis of Ductility by Graph

As content of WCO increases in aged bitumen its ductility is tends to increase. At 4% of WCO ductility value of 30/40 aged bitumen reach nearer to ductility value of 60/70 bitumen.

### 5.7.2 Comparison between WCO Bitumen and Aged Bitumen

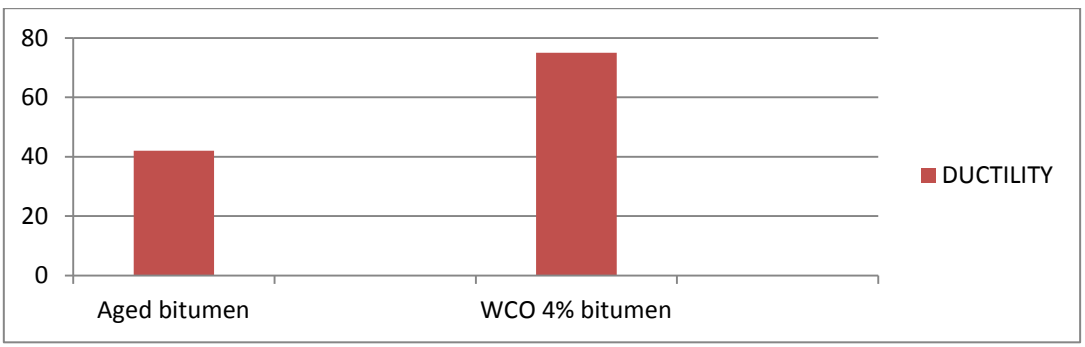


**Figure 5.6** Graph for comparison of WCO bitumen and aged bitumen

### 5.8 Analysis for Viscosity-

**Table 5.6** Values of viscosity Test

| WCO blended with aged bitumen by weight in different proportion | Viscosity(centipoises) |
|---|---|
| 1% | 525 |
| 2% | 495 |
| 3% | 400 |
| 4% | 353 |
| 5% | 305 |

### 5.8.1 Analysis by Graph-

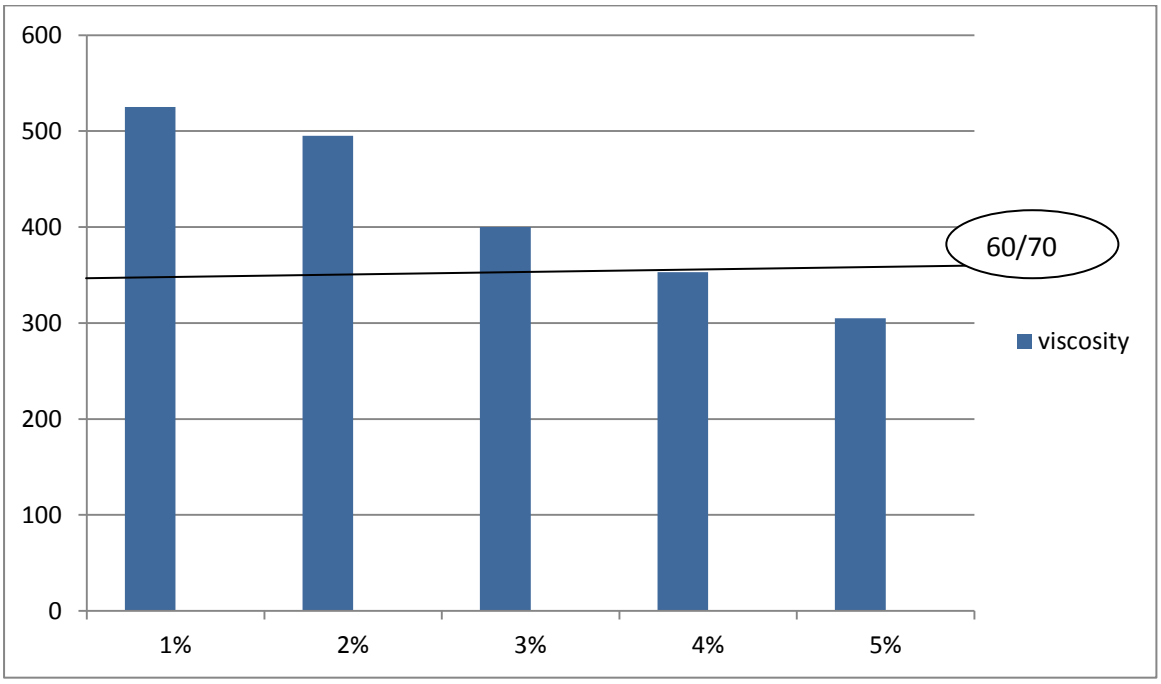



**Figure 5.7** Analysis of viscosity by graph

### 5.8.2 Comparison between Fresh bitumen,WCO blended bitumen and aged bitumen-

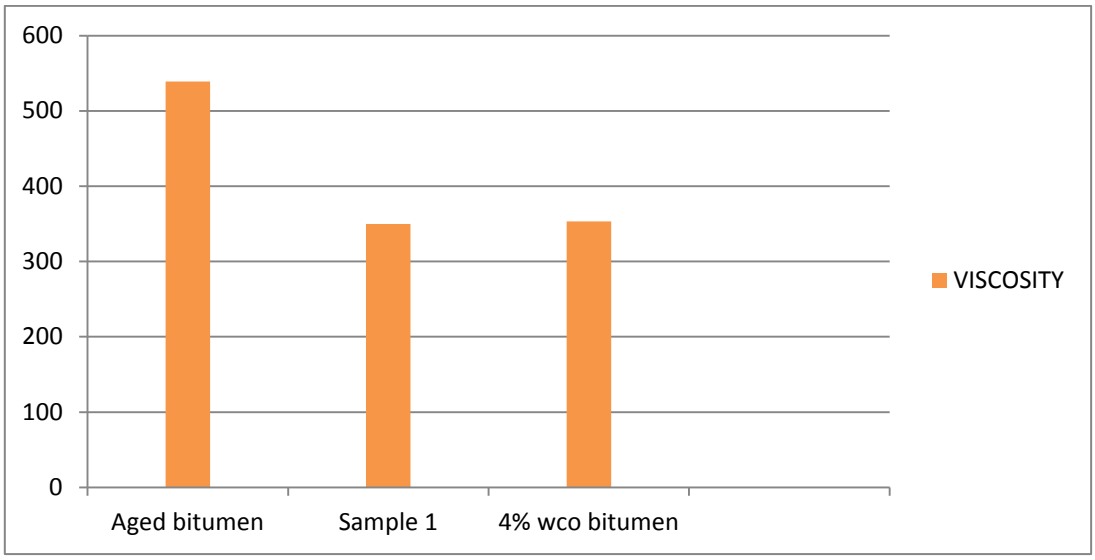



**Figure 5.8** Graph for comparison of WCO bitumen,Sample1 and Aged bitumen

This comparison reflects that when 4% of waste cooking oil is added into aged bitumen then, the obtained viscosity becomes equals to the standard viscosity of 60-70 grade of bitumen.

# CHAPTER-6
# CONCLUSION AND FUTURE SCOPE

As mentioned earlier, the main target of this research work is to observe the effect of WCO in aged bitumen. So from various physical and chemical tests, Researcher gets various results-

### 6.1 For Aged Bitumen

1) Due to gradual aging, bitumen loses its properties.

2) As the result of aging, bitumen hardens.

3) Due to aging the softening point increases.

4) Due to aging Ductility decreases.

5)Due to aging viscosity decreases

### 6.2 For Waste Cooking Oil

1) This research proves that Acid Value depends upo.n the frying action.

2) This research proves that waste cooking oil can act as a rejuvenator in bitumen mix.

### 6.3 Aged Bitumen Blended with Waste Cooking Oil

1. This research proves that 3-4%WCO content can rejuvenate the 30-40 penetration grade of aged bitumen to meet the properties of bitumen of 60-70 grade.

2. This research proves that penetration value of aged bitumen increases with increasing percentage of waste cooking oil.

3. This research proves that the softening point decreases with increase in percentage of waste cooking oil.

4. This research proves that the ductility of aged bitumen increases with increase in percentage of waste cooking oil

5. This research proves that WCO can act as a best rejuvenating agent but only when used in appropriate proportion.

### 6.4 Future Scope

In this paper aged bitumen collected was not directly extracted from the RAP material. So by extracting bitumen directly from RAP material this experiment can be done. Further testing on bituminous mix of WCO blended aged bitumen can be examined.

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