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# WEO and WCO as a Rejuvenating Agent in Aged Bitumen

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## ABSTRACT

Bitumen is a useful and expensive material with high thermal sensitivity. Despite the limited resources, it has been applied in abundance (110 million tonnes annually in the world) in the high-way industry. Bitumen is a useful and expensive material with high thermal sensitivity .The ageing of the bitumen during storage, mixing, transport and laying on the road, as well as in service life, are the most important problems presented by the use of bitumen in pavements. This paper investigates the possibility of using Waste Cooking Oil (WCO) and Waste Engine Oil (WEO) which is a waste material that pollutes landfills and rivers, as an alternative natural rejuvenating agent for aged bitumen to a condition that resembles the original bitumen. With this target, the physical and chemical properties of the original bitumen, aged bitumen and rejuvenated bitumen were measured and compared by the bitumen binder tests – softening point, penetration, ductility, viscosity and specific gravity. In addition, the behaviour of the WCO and WEO rejuvenated bitumen is investigated and compared with virgin bitumen. The aged bitumen is rejuvenated by 2%, 3%,4% and 5% of waste cooking oil and waste engine oil by the total weight of bitumen.

**Keywords:** Aged bitumen, Rejuvenating agent, Waste cooking oil, Waste engine oil, Reclaimed Asphalt Pavement

## I. INTRODUCTION

Since past many years, paving of flexible roads is being done by the use of most known petroleum-based product which is bitumen. But after many years of service, binder material of road becomes aged and starts losing its properties. The ageing of the bitumen during storage, mixing, transport and laying on the road, as well as in service life, are the most important problems presented by the use of bitumen in pavements. The ageing problem of bitumen leads to pavement failure, such as surface ravelling and cracking, especially reflective cracking. Aging causes increase in stiffness of bitumen and also affects its physiochemical properties. Aged bitumen becomes more brittle and reduces the pavement strength and decrease the service life of road. These problems increase the expense of renovation and the preservation of bituminous pavements.

The properties of bitumen change as it age over time attributable to bulk storage, mixing, paving, transport and storage on site. Bitumen composition has its greatest influence on aging. Combination of oxidation and volatility are mainly cause physical and rheological properties change that induces to failure which is from hardening to embrittlement. Oxidation normally occurs simultaneously with loss of lower molecular weight volatiles. This loss rate is depending on the concentrations, temperature and environment. Because the loss rate is dependent on such conditions, volatility is important mainly in handling bitumen at elevated temperature. Consequently, the aging bitumen then leads to

deterioration and major distress of pavement such as fatigue, rutting and cracking.

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. Highway agencies, due to high demand, high expense, low life cycle, ageing, and lack of sufficient natural resources of bituminous material, have introduced the application of recycled asphalt pavement (RAP) material in hot mix asphalt (HMA) as an economic and environmentally sound solution. A successful use of rejuvenators should reverse the RAP binder aging process, restore the properties of asphalt binder for another service period and make the RAP asphalt effectively available to the mix.
A well designed reclaimed bitumen mixture can meet the properties of fresh bitumen. In order 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. Softening agent and rejuvenating agent. Softening agents are mostly used to lowering the viscosity of aged bitumen on other hand rejuvenating agent are added for regaining the physical and chemical properties of aged bitumen. So, rejuvenators used in this research paper are waste cooking oil and waste engine oil.

## II. LITERATURE REVIEW

**Ravi Datt Sharma, Amit Kumar Yadav, and Ashish Kumar (2017):** "Waste Cooking Oil as a Rejuvenating Agent in Aged Bitumen" (2017) .This research paper explains 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. The penetration value of aged bitumen increases with increasing percentage of waste cooking oil, softening point decreases with increase in percentage of waste cooking oil and the ductility of aged bitumen increases with increase in percentage of waste cooking oil This research proves that WCO can act as a best rejuvenating agent but only when used in appropriate proportion.

**Mohamed Rehan Karim Hallizza Asli, Esmaeil Ahmadinia (2013):** "Investigation on physical properties of waste cooking oil – Rejuvenated bitumen binder" (2013). This paper investigates the novelty of using waste cooking oil (WCO), which is frequently found as a polluting waste material in landfills and rivers from the food industry, to rejuvenate the bituminous binder. The physical properties of the original bitumen, aged bitumen and rejuvenated bitumen were measured and compared by the conventional bitumen binder tests including softening point, penetration and Brookfield viscosity, and statistical analyses were used to assess the results. In general, the results showed that the aged bitumen was rejuvenated by the WCO due to a change in its physical properties, which resemble the physical properties of original bitumen (80/100). The optimum percentage of waste cooking oil for the rejuvenated aged bitumen group of 50/60, 40/50, and 30/40 was recognised by adding 1%, 3–4%, and 4–5% WCO, respectively.

**Hallizza Asli, Esmaeil Ahmadinia, Majid Zargar, Mohamed Rehan Karim (2012):** "Investigation on physical properties of waste cooking oil – Rejuvenated bitumen binder" (2012). This paper investigates the possibility of using waste cooking oil (WCO), which is a waste material that pollutes landfills and rivers, as an alternative natural rejuvenating agent for aged bitumen to a condition

that resembles the original bitumen. With this target, the physical and chemical properties of the original bitumen, aged bitumen and rejuvenated bitumen were measured and compared by the bitumen binder tests – softening point, penetration, Brookfield viscosity, dynamic shear rheometer and Fourier transform infrared spectroscopy. In addition, the behaviour of the WCO rejuvenated bitumen is investigated and compared with fresh bitumen. In general, the results showed that using 3–4% of WCO the aged bitumen group 40/50 was rejuvenated to a condition that closely resembled the physical, rheological properties of the original bitumen (80/100), however, there was a difference in the tendency to ageing between the WCO rejuvenated bitumen and the fresh bitumen during mixing, transport and laying on the road.

## III. MATERIALS AND METHODOLOGY

### A. Materials

There are four different samples of bitumen used in the study. They are:

1. Sample 1-Fresh Bitumen
2. Sample 2-Aged Bitumen
3. Sample 3-Aged Bitumen blended with Waste Engine Oil.
4. Sample 4-Aged Bitumen blended with Waste Cooking Oil.

### B. Experimental Procedure

Initially, untreated bitumen (virgin 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 the 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 Waste cooking oil and waste engine oil is blended in the aged bitumen in the proportion of 2%, 3%, 4%, 5% by weight of bitumen. This Waste Cooking Oil (WCO) mixed aged bitumen is considered as sample 3 and Waste Engine Oil (WEO) blended sample is considered as sample 4. Penetration test, Softening test, Ductility test, specific gravity test and Viscosity test were conducted on the four samples. Further analysis was done by comparing the test results obtained by blending WCO and WEO in aged bitumen with those obtained for fresh bitumen.

### C. IS Tests Used For Study

The following IS tests were performed in the study. They are:

1. Standard Penetration test (IS:1203-1978)
2. Ductility test (IS:1208-1978)
3. Viscosity test (IS:217-1969)
4. Specific Gravity test (IS:1203-1978)
5. Softening Point test (IS:334-1982)\

## IV. RESULTS AND DISCUSSIONS

### A. Test Results

#### 1 Analysis of Sample 1 and Sample 2

300 gm of virgin bitumen and aged bitumen samples are taken, heated at 100-150 degree Celsius and melted into its viscous form and all the physical tests were performed. Results for sample 1 and sample 2 were observed and are presented in table 1.

**Table 1.** Test Results Of Fresh Bitumen And Aged Bitumen

| Bitumen tests | Sample 1 | Sample 2 |
|---|---|---|
| Penetration value(1/10 th of mm) | 92 | 46 |
| Softening point(in degree Celsius) | 47 | 58 |
| Ductility(in cm) | 87 | 74 |
| Specific Gravity | 1.105 | .5 |
| Viscosity(in sec) | 38 | 11.3 |

### B. Comparison of Test Result by Graph

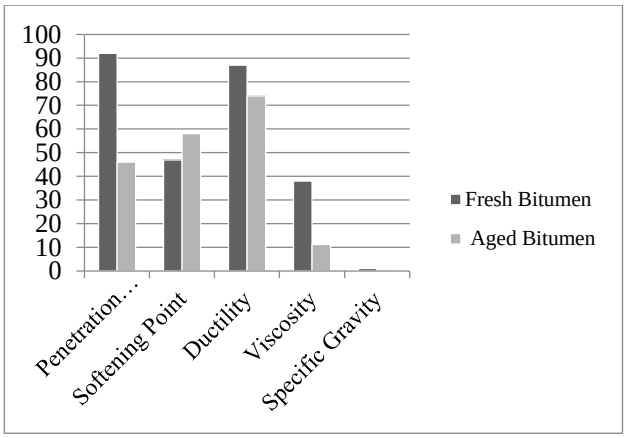



**Figure 1.** Comparison Of Sample 1 And Sample 2

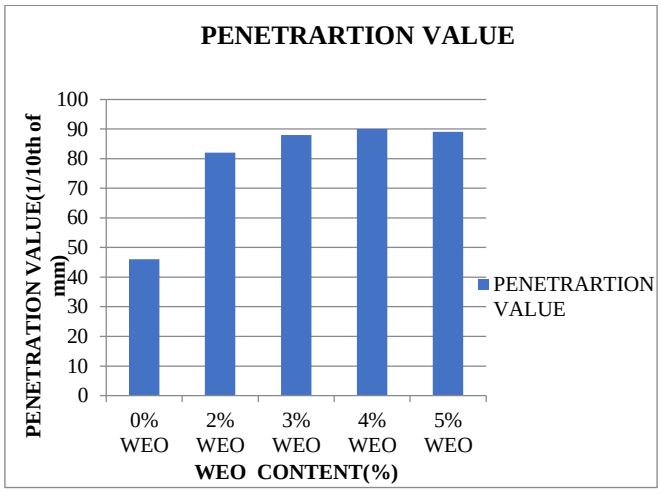



**Figure 2.** Penetration Value Versus Different Percentages Of Weo

By comparison it is proved that there is lot of variation in the properties of bitumen after aging. Penetration value of 80/100 grade of bitumen is reduced from 92 to 46 after aging. Softening point is increased from 47$^0$C to 58$^0$C because of aging. Ductility value also affected because of aging. The value has been reduced from 87 cm to 74 cm. The viscosity value falls from 38 seconds to 11.3 seconds. Specific gravity value has been changed from 1.105 to 0.5

### 3. Analysis of Sample 3

#### 1. Penetration Test

The penetration values of aged bitumen blended with various percentage of waste engine oil is obtained after testing in the penetrometer apparatus and is shown in fig 2. Aged bitumen is blended with 2%, 3%, 4%, 5% of waste engine oil by weight of bitumen.

As we can see that the penetration value of virgin bitumen reduces after aging. In contrast the value of penetration value increased with the addition of waste engine oil content into the aged bitumen especially for bitumen with 4% of WEO. The higher penetration value indicates less temperature susceptibility and more rubbery elastic behaviour . From the test results it is observed that the penetration value of aged bitumen after blending with 4% WEO resembles closer to the penetration value of fresh bitumen which is 92.

#### 2. Softening Point Test

The softening point of aged bitumen by adding various percentage of waste engine oil by weight of bitumen were determined and the results are presented in Figure 3.

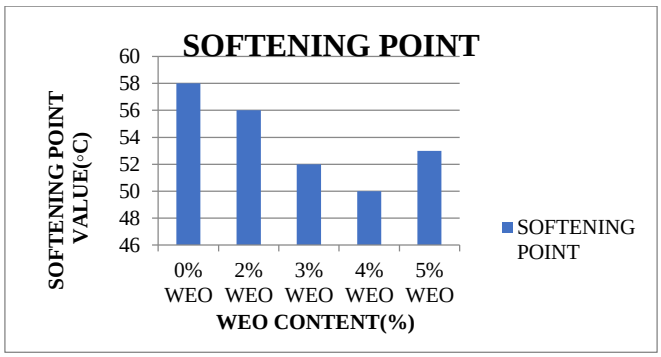



**Figure 3.** Softening Point Versus Different Percentages Of Weo

As illustrated in the figure 3, with the increasing ageing times, the softening point temperature increases due to the oxidation reaction. In the aged bitumen, increasing the asphaltene content with high molecular weight can produce harder bitumen, while the chemical group changes during the mixture of waste engine oil can rejuvenate the aged bitumen. There is a gradual decrease in the softening point of bitumen by adding waste engine oil to aged bitumen. However an appreciable change can be noted by adding 4% of waste engine oil to aged bitumen. From the test results it is observed that the softening point value of aged bitumen after blending with 4% WEO resembles more close to the softening point value of fresh bitumen.

### 3 Ductility Test

The ductility of bitumen reduces due to aging. Ductility test was performed on aged bitumen by adding 2, 3, 4, 5% of waste engine oil by weight of bitumen.

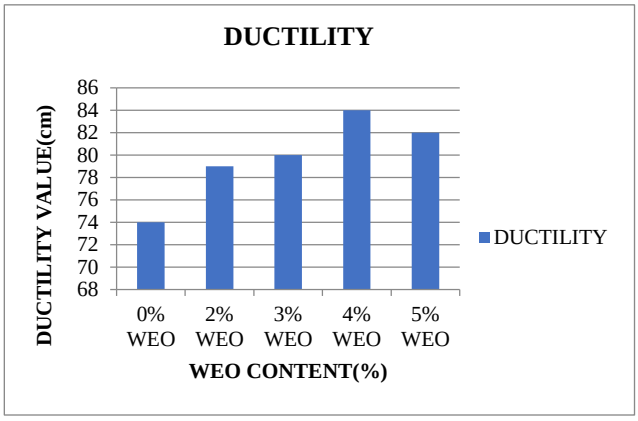



**Figure 4.** Ductility Versus Different Percentages Of Weo

It is clear that after the addition of waste engine oil the ductility of aged bitumen has increased. By adding 4 % of WEO the ductility of aged bitumen resembles close to that of virgin bitumen. So it proves that by little addition of WEO to aged bitumen the adhesive property of aged bitumen is increased and the value is coming closer to that of virgin bitumen whose ductility value is 82 cm.

### 4 Specific Gravity Test

The specific gravity values of aged bitumen blended with various percentage of waste engine oil is obtained after testing and is shown in fig 5. Aged bitumen is blended with 2%, 3%, 4%, 5% of waste engine oil by weight of bitumen.

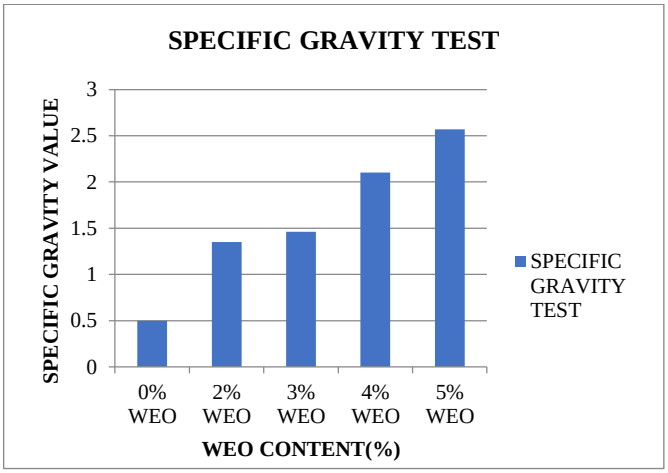
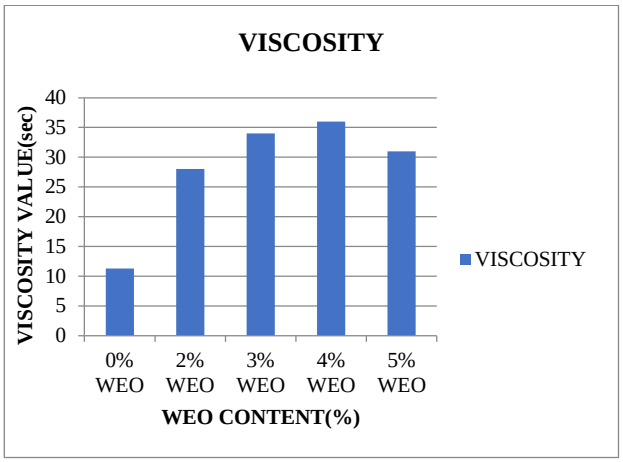



**Figure 5.** Specific Gravity Versus Different Percentages Of Weo

The specific gravity value of bitumen reduces due to aging caused by the oxidation of bitumen. Specific gravity determines the strength of bitumen. By the addition of various percentage of waste engine oil to aged bitumen the specific gravity value of bitumen is increased. This proves that waste engine oil can increase the strength of aged bitumen and it can be again used for road construction works. From the test results it is observed that the specific gravity value of aged bitumen after blending with 5% WEO resembles closer to the specific gravity value of fresh bitumen.

### 5 Viscosity Test

The viscosities of aged bitumen by adding various percentage of waste engine oil by weight of bitumen are presented in Figure 6.




**Figyer 6.** Viscosity Versus Different Percentages Of Weo

Figure 6 displays the viscosity of the 80/100 aged bitumen penetration group with various percentages of waste engine oil. As the graph shows, the age bitumen has a highest viscosity value, while the addition of 4% waste engine oil into the aged bitumen achieves almost the same viscosity as the original bitumen. The viscosity value of aged bitumen is 38 seconds.

## 4 Analysis of Sample 4

### 6 Penetration Test

The aged bitumen binder is rejuvenated with waste cooking oil (WCO) at, 2%, 3%, 4% and 5% by weight of bitumen. The effects of mixing waste cooking oil into aged bitumen on the penetration value are clearly illustrated in Figure 7

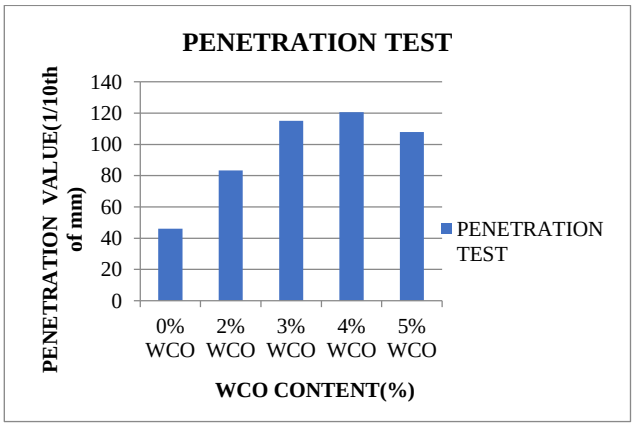



**Figure 7.** Penetration Test Versus Different Percentages Of Wco

It was observed that the penetration value increases as the amount of added waste cooking oil into aged bitumen increases up to 4 % and by adding 5 % of WCO to aged bitumen there is a slight decrease in the penetration value. Increasing the penetration value for various degrees of ageing is caused by changes to the bitumen by the chemical groups (asphaltenes and maltenes), due to the addition of waste cooking oil, that lead to having a softer binder. However, when it reached an optimum percentage of waste cooking oil, the lower penetration value resembled that of the original bitumen. As displayed in Fig.7, adding approximately 2% of waste cooking oil does rejuvenate the aged bitumen to a similar level as the original bitumen. Similarly, with the addition of 4% waste cooking oil to the aged bitumen, the approximate penetration value of original bitumen is attained.

### 7 Softening Point Test

The relationship between softening point value and 80/100 group aged bitumen are presented in figure 8.

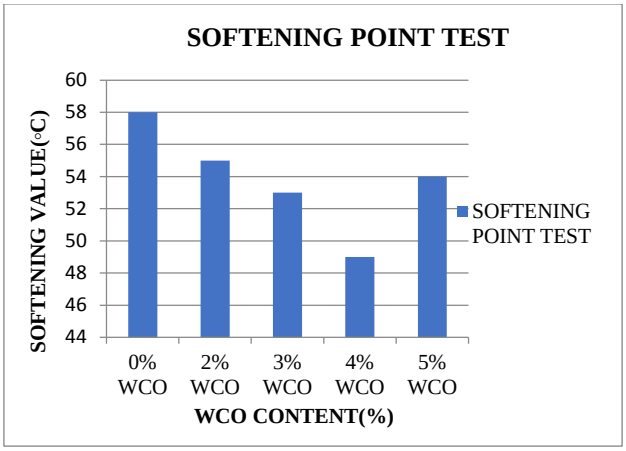



**Figure 8.** Softening Point Versus Different Percentages Of Wco

As illustrated in the figure 8, the softening point value decreased with the addition of waste cooking oil content into the aged bitumen. In the aged

bitumen, the increase of asphalt content with high molecular weight can produce harder bitumen with lower temperature susceptibility and an increase in the softening point while the mixture of waste cooking oil can rejuvenate the aged bitumen. As can be seen in table 9, when approximately 4% of waste cooking oil is added into aged bitumen penetration group 80/100, it resembles the original bitumen value. The softening point of virgin bitumen is 47$^0$C

## 8 Ductility Test

The ductility of bitumen reduces due to aging. Ductility test was performed on aged bitumen by adding 2, 3, 4, 5% of waste cooking oil by weight of bitumen.

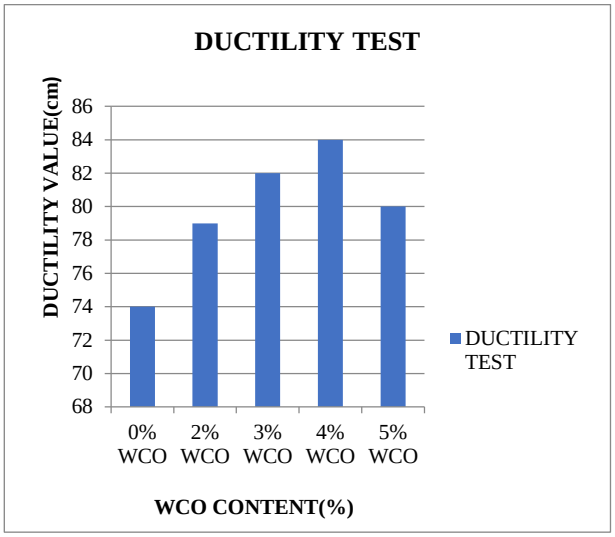
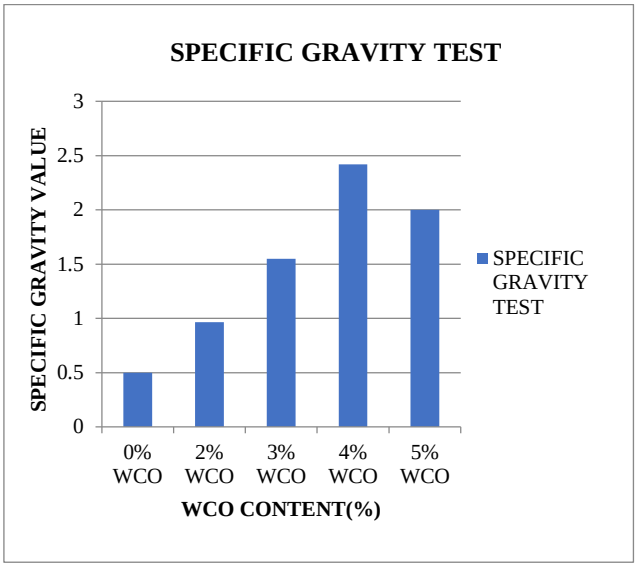



**Figure 9.** Ductility Versus Different Percentages Of Wco

The ductility of bitumen reduces due to aging. Waste cooking oil is added to aged bitumen at 2, 3, 4, 5% by weight of aged bitumen. We can see that after the addition of waste cooking oil the ductility of aged bitumen has increased. By adding 4 % of WCO the ductility of aged bitumen resembles close to that of virgin bitumen. So it proves that by little addition of WCO to aged bitumen the adhesive property of aged bitumen is increased and the value is coming closer to that of virgin bitumen which is 87 cm. But there is a slight decrease in the ductility value after the addition of 5% of WCO.

## 9 Specific Gravity Test

The specific gravity values of aged bitumen blended with various percentage of waste cooking oil is obtained after testing and is shown in fig10. Aged bitumen is blended with 2%, 3%, 4%, 5% of waste cooking oil by weight of bitumen.




**Figuer 10.** Specific Gravity Versus Different Percentages Of Wco

There is a change in the value of specific gravity value of bitumen by blending waste cooking oil to aged bitumen. The specific gravity value is increasing by the addition of 4% cooking oil after that there is a reduction in the specific gravity value by the addition of 5% of waste cooking oil. From the test results it is observed that the specific gravity value of aged bitumen after blending with 5% WEO resembles more close to the specific gravity value of fresh bitumen.

## 10 Viscosity Test

The viscosities of aged bitumen by adding various percentage of waste engine oil by weight of bitumen are presented in figure 11.

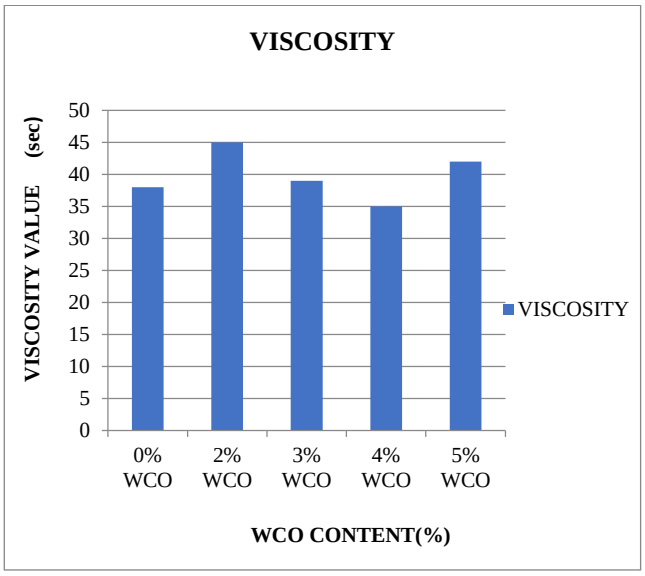



**Figure 11.** viscosity Versus Different Percentages Of Wco

As in the figure 11, clearly shows a decrease in viscosity due to the addition of waste cooking oil contents into different aged bitumen. The graphs show that the addition of 4% waste cooking oil into aged bitumen, could achieve almost the same viscosity of the original bitumen. With the same temperatures as well, it was found that balance percentage of waste cooking oil could rejuvenate aged bitumen. Similarly, when 5% of waste cooking oil was blended into it, the rejuvenated bitumen managed to achieve the aged bitumen. From the test results it is observed that the viscosity value of aged bitumen after blending with 4% WEO resembles closer to the viscosity value of fresh bitumen whose value is 38 seconds.

## V. CONCLUSIONS

We investigates the possibility of using Waste Cooking Oil (WCO) and Waste Engine Oil(WEO) which is a waste material that pollutes landfills and rivers, as an alternative natural rejuvenating agent for aged bitumen to a condition that resembles the original bitumen. With this target, the physical and chemical properties of the original bitumen, aged bitumen and rejuvenated bitumen were measured and compared by the bitumen binder tests – softening point, penetration, ductility, viscosity and specific gravity. In addition, the behaviour of the WCO and WEO rejuvenated bitumen is investigated and compared with virgin bitumen. The aged bitumen was rejuvenated by 2%,3%,4% and 5% of waste cooking oil and waste engine oil by the total weight of bitumen for Aged Bitumen due to gradual aging, bitumen loses its properties. As the result of aging, bitumen hardens, softening point increases, Ductility decreases, viscosity decreases.

This research proves that 4% WCO and WEO content is the optimum. This research proves that penetration value of aged bitumen increases with increasing percentage of waste cooking oil and waste engine oil, Softening point decreases with increase in percentage of waste cooking oil and waste engine oil, ductility of aged bitumen increases with increase in percentage of waste cooking oil. Specific gravity determines the strength of bitumen. By adding various percentages of WEO and WCO to aged bitumen the specific gravity value of aged bitumen is increased thereby increasing the strength of aged bitumen. The use of waste cooking oil and Waste Engine Oil as rejuvenating agent into the aged bitumen showed a very promising result.This research proves that WCO and WEO can act as a best rejuvenating agent but only when used in appropriate proportion.

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