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Experimental Investigation of LDPE and EVA on Asphalt Binder

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Abstract: This research study aims to investigate the impact of incorporating Ethylene Vinyl Acetate (EVA) and Low-Density Polyethylene (LDPE) on the properties of asphalt binder. The use of polymer-modified asphalt binders has gained significant attention in recent years due to their potential to improve the performance and durability of asphalt pavements. EVA and LDPE are two commonly used polymers that have shown promise in enhancing the rheological and mechanical properties of asphalt binders. The experimental investigation involved the preparation of asphalt binder samples with varying percentages of EVA and LDPE, ranging from 0% to 8% by weight. A series of laboratory tests were conducted to evaluate the effects of polymer modification on the fundamental properties of asphalt binder. These tests included penetration, softening point, ductility, viscosity, and dynamic shear rheometer (DSR) tests.The results of the study indicated that the addition of EVA and LDPE led to notable improvements in the rheological and mechanical properties of asphalt binder. Increased polymer content resulted in reduced penetration values, higher softening points, and improved resistance to rutting and deformation. Additionally, the modified binders exhibited enhanced viscosity and elastic behavior, as indicated by the DSR tests. The study also investigated the compatibility between EVA/LDPE and asphalt binder through microscopy and chemical analysis techniques.

The findings of this experimental investigation contribute to the understanding of the effects of EVA and LDPE on asphalt binder performance. The results highlight the potential of these polymers in enhancing the resistance to rutting and deformation of asphalt pavements. This research can serve as a basis for further studies on polymer modification of asphalt binders and aid in the development of improved asphalt pavement materials with enhanced durability and longevity.

I. INTRODUCTION

Asphalt, black or brown petroleum-like material that has a consistency varying from viscous liquid to glassy solid. It is obtained either as a residue from the distillation of petroleum or from natural deposits. Asphalt consists of compounds of hydrogen and carbon with minor proportions of nitrogen, sulfur, and oxygen. Natural asphalt which is believed to be formed during an early stage in the breakdown of organic marine deposits into petroleum, characteristically contains minerals, while residual petroleum asphalt does not.

Polyethylene is one of the primary sources of waste plastics and is recyclable from a variety of products, including reusable bags, containers, and trays, agricultural film, food packaging film, and geomembranes (all made of linear low density polyethylene, or LLDPE), toys, milk and shampoo bottles, pipes, and various home furnishings (all made of high density polyethylene, or HDPE).Compared with SBS, recovered PE (RPE), mostly LDPE, has excellent strength heat, oxidation, and ultraviolet and a lower cost.

Ethylene vinyl acetate (EVA) is the most common plastomer used for bitumen modification. EVA is a thermoplastic copolymer obtained by copolymerization of ethylene and vinyl acetate. Depending on the percentage of vinyl acetate, the properties of the copolymer changes, low vinyl acetate showing similar behavior to that of low density polyethylene(LDPE). EVA is characterized by its melt flow index (MFI) and vinyl acetate content. MFI measure din g/10 minutes is a viscosity test which is inversely related to molecular weight. Higher the MFI lower is the molecular weight and viscosity. Vinyl acetate, on the other hand provides amorphous and rubbery properties to the bitumen. The polyethylene segments which are crystalline in nature are bonded together with the vinyl acetate group, the later disrupting the crystalline nature of the system. Hence higher the vinyl acetate lower is the crystalline nature of the bitumen..

A. Problem Statement / Need of Study

Low-density polyethylene (LDPE) and ethylene–vinyl acetate (EVA) are two materials with low recyclability and slow degradation in the environment, which causes extreme pollution to the environment. In the pavement engineering field, natural resources depletion has always been a matter of controversy.

Thus, applying recycled LDPE and EVA to asphalt modification is an efficient approach to relieve environmental pollution and decreasing demand for natural resources. This research aims to determine the optimal preparation process of LDPE/EVA modified asphalt, and the effect of LDPE and EVA on the high-temperature rheological properties of asphalt was also investigated. Conventional physical properties tests of LDPE/EVA modified asphalt are conducted to determine the process parameters. In addition, Softening, Ductility, SEM Analysis And FTIR were utilized to evaluate the rheological properties at high-temperature range.. The test result indicated that shearing time in the preparation process was the foremost factor affecting the properties. LDPE/EVA modified asphalt exhibited optimal properties when prepared at 3500 rpm for 60 min at 180°C. Both LDPE and EVA have positive effects on high-temperature performance and the ability to resist permanent deformation of asphalt, and also increase the anti-temperature variety properties. It is because of that EVA could improve the compatibility between LDPE and asphalt significantly, which is beneficial for broad the application of waste plastic in pavement engineering. Generally, the results showed LDPE and EVA compound modified asphalt performing well, which is an eco-friendly material for pavement engineering.

B. Research Gap

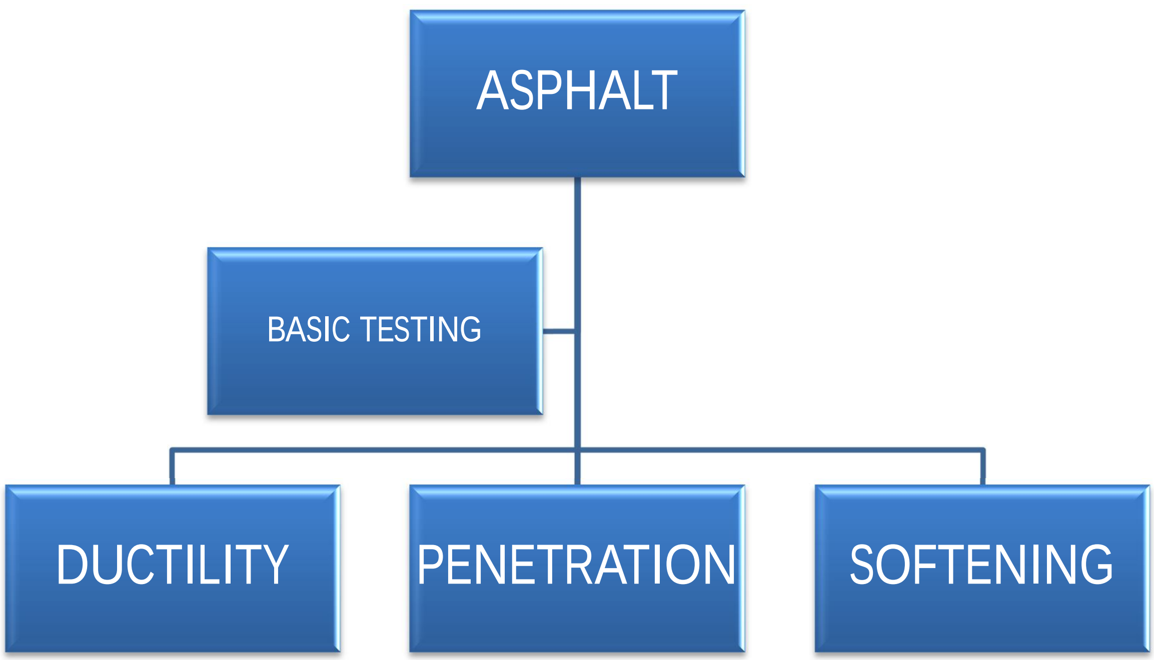
1) Although EVA is less efficient at improving the fatigue qualities at high temperatures, it is more effective at increasing the asphalt's resistance to rutting. Additionally, modified asphalt decreases its propensity to rigidify and become brittle at low temperatures.
2) Low density polyethylene modified asphalt can be chemically and physically treated to increase its anti-cracking properties.
3) Rapid increasing traffic volumes, heavier vehicle loadings as well as unexpected extreme weather during last decades are serious challenges to the consistency of pavement. In this sense, there are many distresses in bituminous roads at early stage that strongly shorten the service life, including rutting, thermal-cracking and fatigue

C. Objectives Of Study

1) To conduct conventional testing for asphalt binders like Penetration test, Ductility test, Softening point test, Viscosity test.
2) To conduct the characterization of polymer-modified asphalt binders with the help of SEM Analysis and FTIR Test.
3) To observe the rutting analysis of modified Asphalt binder.
4) Enhance the mechanical qualities of asphalt binder and to improve asphalt performance.
5) Increase the homogeneity and mixability of PE and EVA with asphalt binder

II. METHODLOGY

1) *Phase 1 : Conventional Testing of Asphalt Binder*



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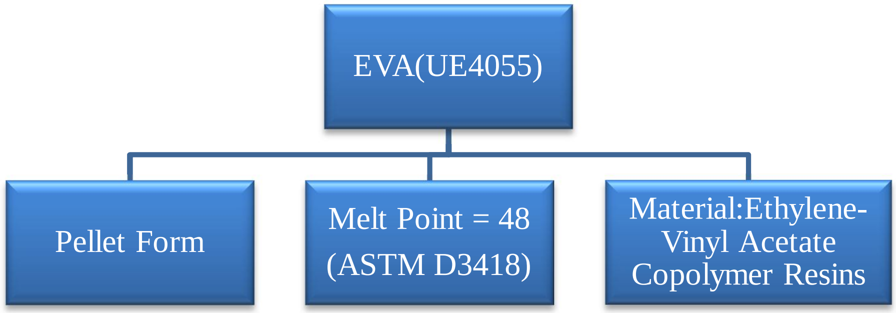
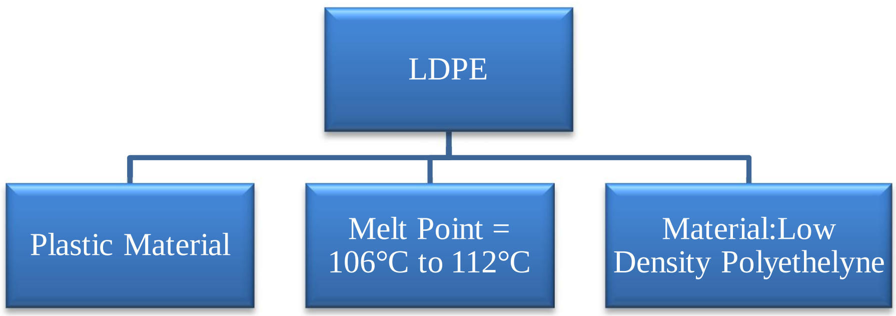
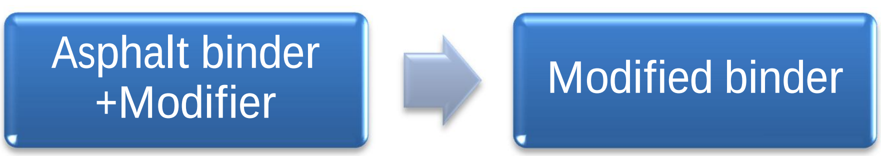
2) Phase 2 :Characteristics of Modifiers

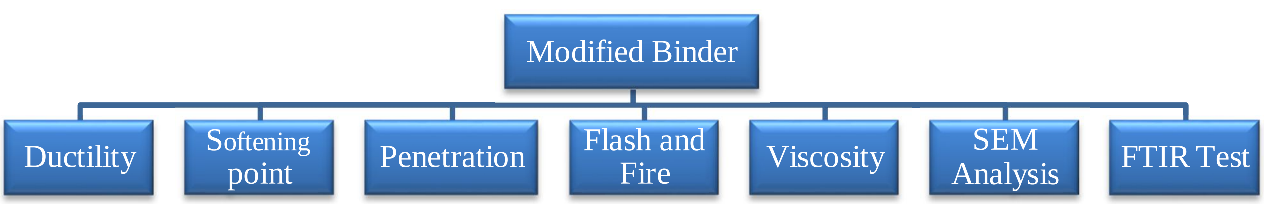




3) Phase 3: Mixing Process



4) Phase 4: Properties Of Modified Binder



III. RESULTS AND DISCUSSION

A. *Ductility Test of Bitumen*

1) Apparatus

a) Briquette mould: The material is brass. In order to hold the testing machine's fixed and moveable ends, circular holes known as clips are supplied at the ends. When properly put together, the mould creates a briquette specimen with the following dimensions:

- Total length 75.0 ± 0.5 mm
- Distance between clips 30.0 ± 0.3mm
- Width at mount of slip 20.0 ± 0.2mm
- Width at minimum cross-section (half way between clips) 10.0 ± 0.1mm

- Thickness throughout 10.0 ± 0.1mm

b) Water bath: A bath maintained at 27.0° 0.1°C below the designated test temperature, holding at least 10 liters of water, the specimen supported on a perforated shell, submerged to a depth of at least 10 cm, and less than 5 cm from the bath's bottom.

c) Testing device: Any device that is designed to keep the specimen constantly submerged in water while the two clips are being pushed apart horizontally at a constant speed of 50 2.5 mm per minute may be used to separate the bituminous material briquette.

d) Thermometer: Readable up to 0.2°C and with a range of 0-44°C.

2) Specimen Preparation

Bitumen's ductility test is conducted in two parts.

Sample Preparation: The bitumen sample is melted in this phase, and then it is poured into the briquette mould.

Testing of the Specimen: In this step, the ductility of the bitumen sample that was extracted from the mould is evaluated.

a) Heat the bitumen sample in a beaker to a temperature between 75 and 100 °C, which is higher than the material's approximate softening point. Allow the bitumen to melt completely before turning it into a liquid.

b) Glycerin and dextrin should be prepared in an equal combination. Mix it thoroughly. Then coat the interior of the sides of the briquette mould and the surface of the brass plate. As a result, the bitumen won't adhere to the mould.

c) With the aid of a screwdriver, fix the sides, clip over the base plate, and tighten the clip's screw.

d) The three briquette moulds should be prepared similarly.

e) Fill the briquette moulds to the top with the melted bitumen.

f) Allow the mould to cool for 30 to 40 minutes in the air at room temperature.

g) Put the entire assembly, including the brass plate and mould, in a water bath that is kept at 27 °C for approximately 30 minutes.

h) With the use of a hot, straight-edged putty knife or spatula, remove any extra bitumen from the surface, then level the top. The briquette that results has an exact 1 sq cm size.

3) Procedure

a) Reheat the water bath at 27 °C for 85–95 minutes while placing the brass plate and mould containing the specimen inside.

b) Unscrew the clamps, remove the sides of the briquette mould, and remove the briquette from the base plate.

c) With the aid of the rings of the clips, attach the bitumen sample assembly and base plate to the pins or hooks in the ductility machine. One clip of the mould is attached to the moving part of the ductility machine, and the other clip is attached to the stationary part.

d) With the use of a screwdriver, tighten the screw on the mould's clasp.

e) Verify that the ductility machine's pointer is set to zero. (Or write down the ductility machine's initial reading).

f) The moveable portion should travel at a speed of 50 mm per minute once the ductility machine is turned on and the gear is adjusted. (The machine's pull rate must be maintained at 50 mm per minute).

g) As a result, the two clips are slowly but steadily drawn apart until the briquette specimen ruptures.

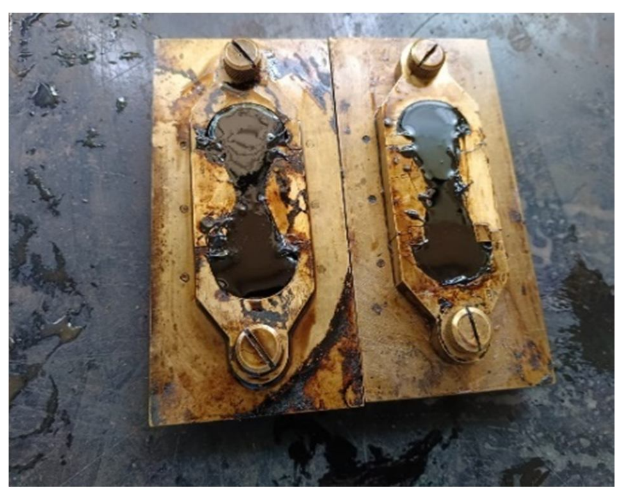


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Table No. 4.1 - Ductility Results of EVA Modified Asphalt

ASPHALT	DUCTILITY
Base Binder	95
VG10+Eva (2%)	84
VG10+Eva (3%)	82
VG10+Eva (4%)	76

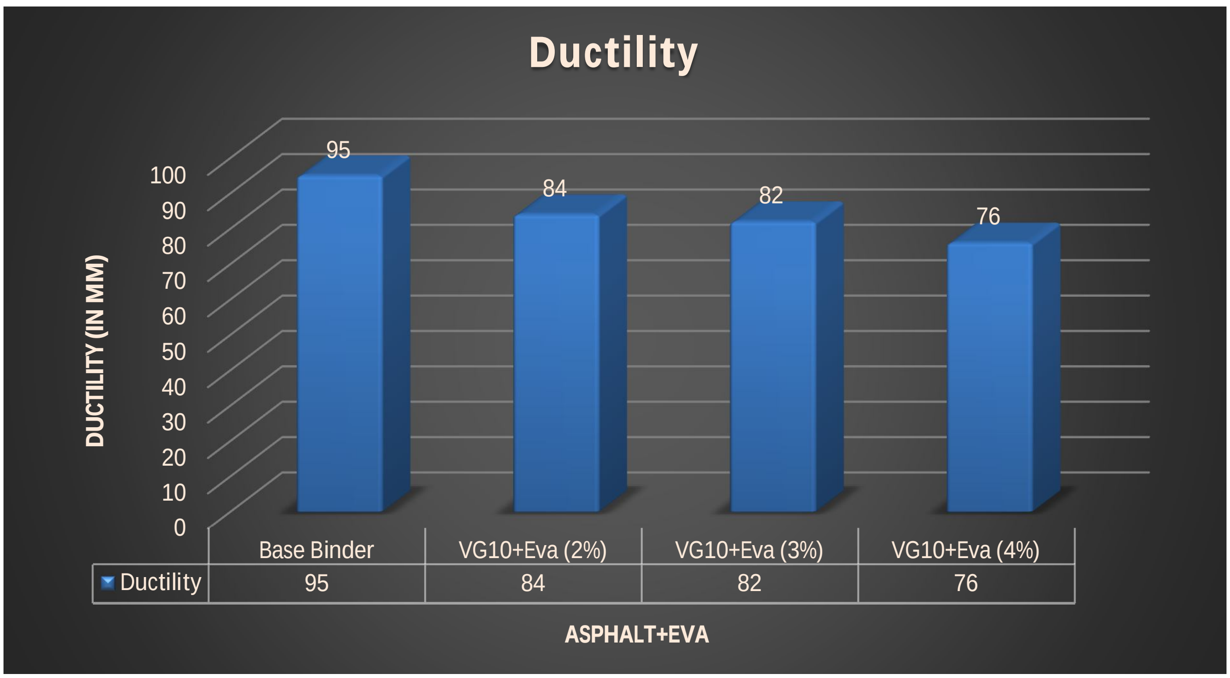

Fig. no. 4.1: Ductility Results of EVA Modified Asphalt

Table No. 4.2 - Ductility Results of EVA Modified Asphalt

ASPHALT	DUCTILITY
Base Binder	90
VG10+Eva (2%)	84
VG10+Eva (3%)	81
VG10+Eva (4%)	75

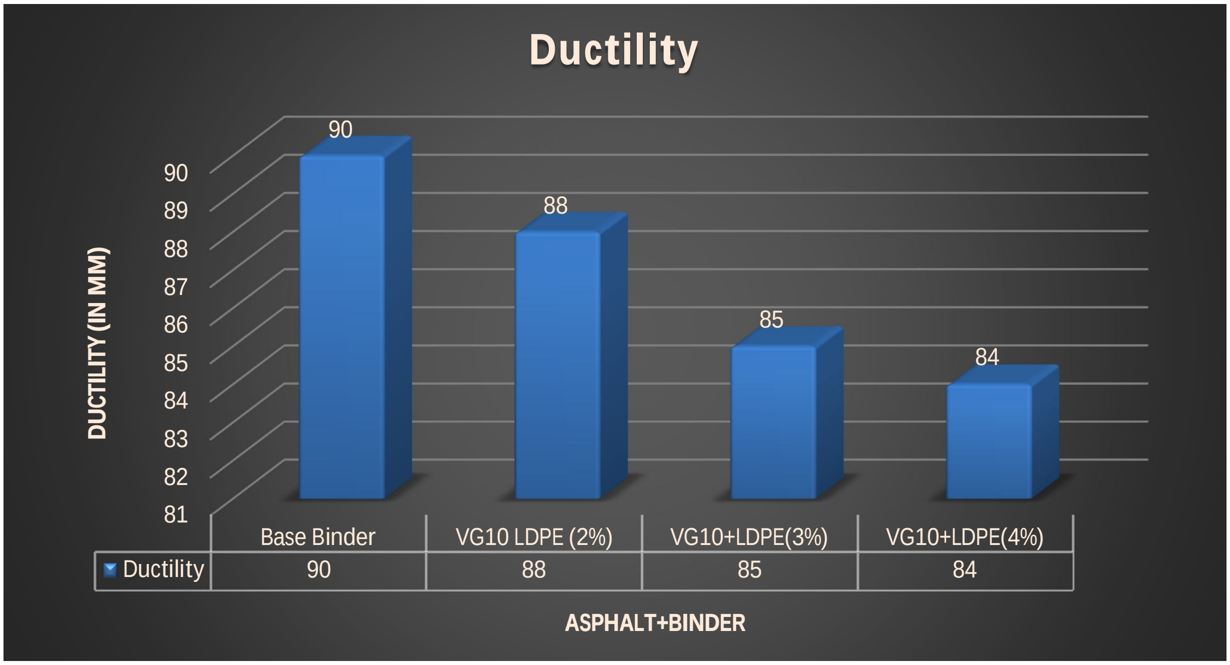

Fig. no. 4.2: Ductility Results of EVA Modified Asphalt

Table No. 4.3 - Ductility Results of EVA Modified Asphalt

ASPHALT	DUCTILITY
Base Binder	87
VG10+Eva (2%)	83
VG10+Eva (3%)	81
VG10+Eva (4%)	79

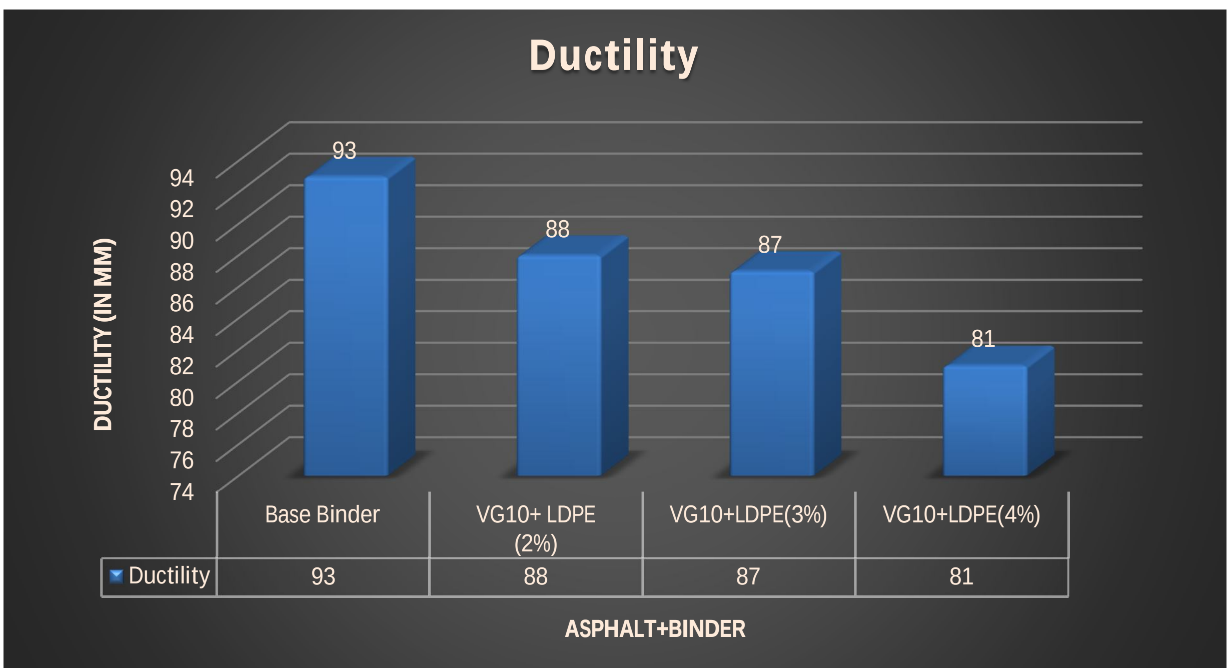

Fig. no. 4.3: Ductility Results of EVA Modified Asphalt

Table No. 4.4 - Ductility Results of EVA Modified Asphalt

ASPHALT	DUCTILITY
Base Binder	92
VG10+Eva (2%)	90
VG10+Eva (3%)	88
VG10+Eva (4%)	84

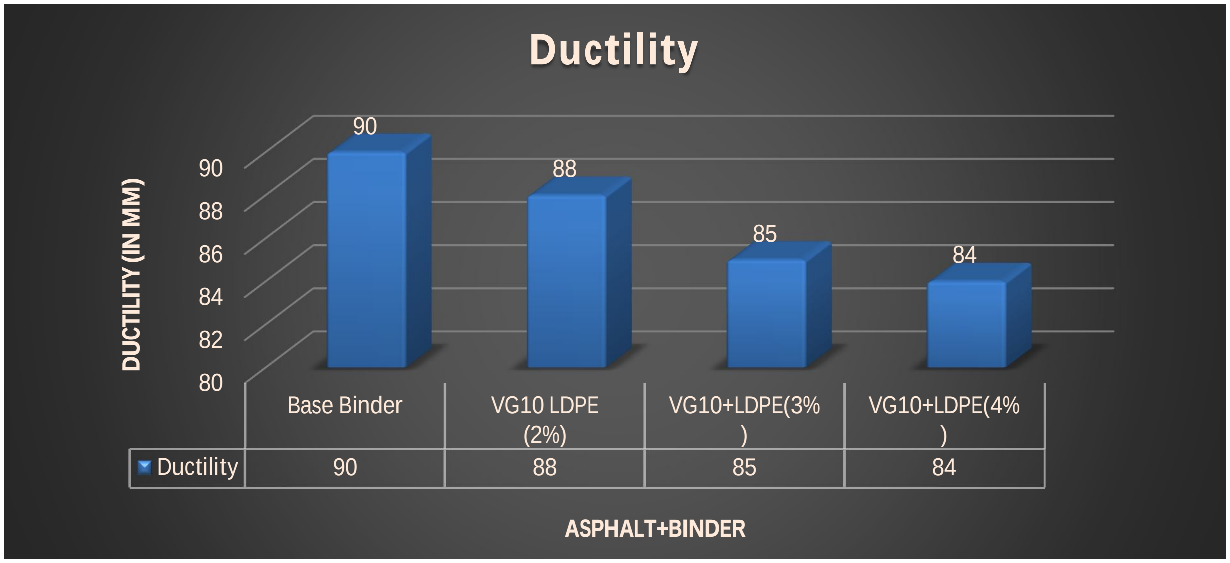

Fig. no. 4.4: Ductility Results of EVA Modified Asphalt

Table No. 5.1 - Ductility Results of LDPE Modified Asphalt

ASPHALT	DUCTILITY
Base Binder	91
VG10+ LDPE (2%)	87
VG10+LDPE(3%)	79
VG10+LDPE(4%)	76

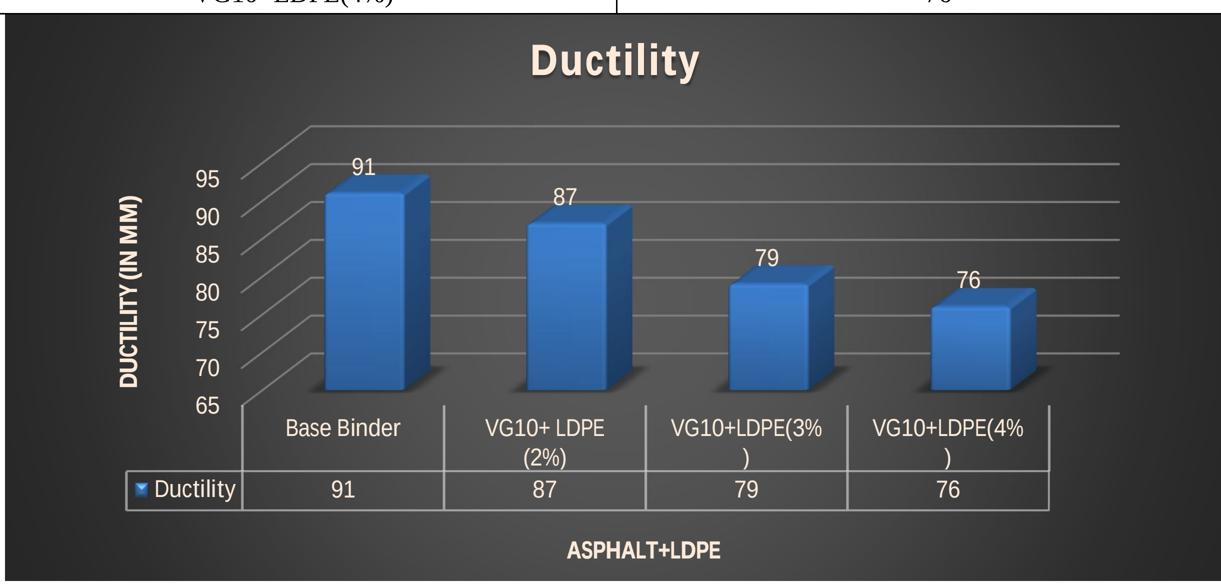

Fig. no. 5.1: Ductility Results of LDPE Modified Asphalt

Table No. 5.2 - Ductility Results of LDPE Modified Asphalt

ASPHALT	DUCTILITY
Base Binder	90
VG10+ LDPE (2%)	87
VG10+LDPE(3%)	84
VG10+LDPE(4%)	75

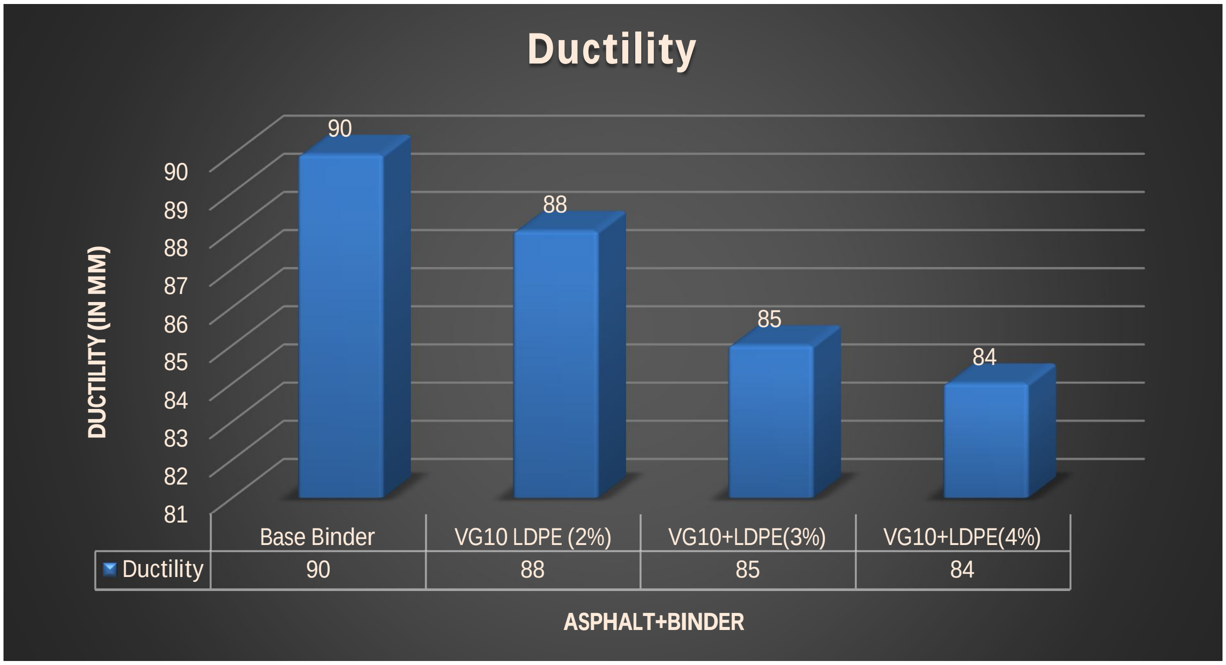

Fig. no. 5.2: Ductility Results of LDPE Modified Asphalt

Table No. 5.3 - Ductility Results of LDPE Modified Asphalt

ASPHALT	DUCTILITY
Base Binder	93
VG10+ LDPE (2%)	88
VG10+LDPE(3%)	87
VG10+LDPE(4%)	81

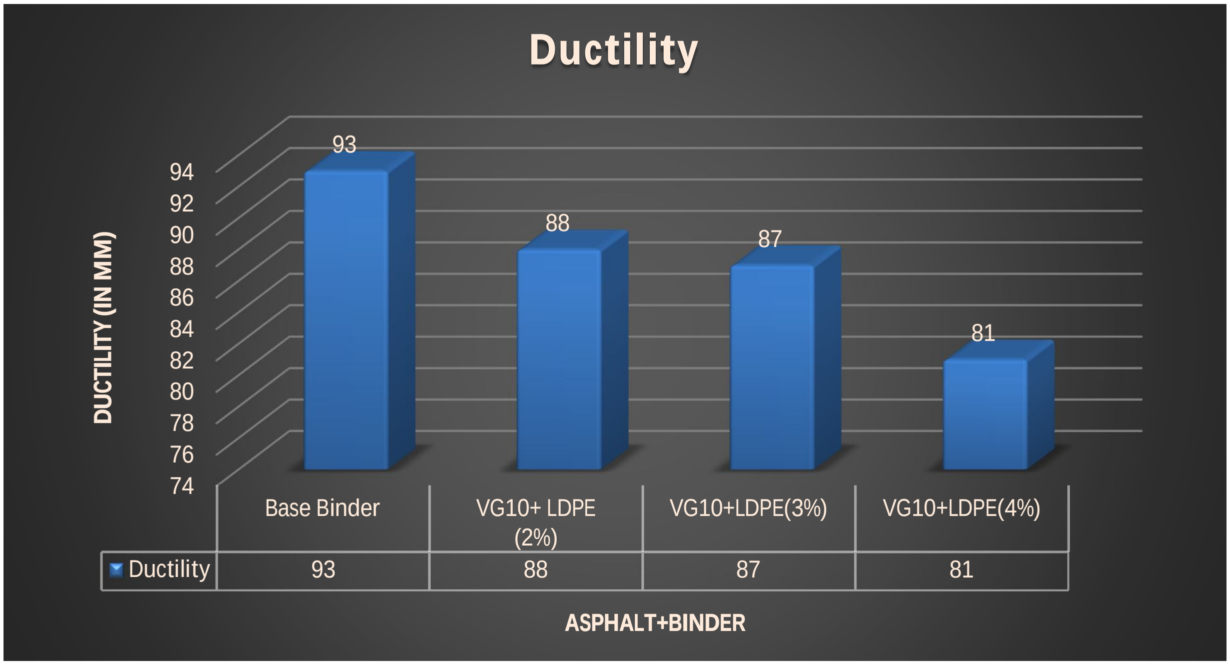

Fig. no. 5.3: Ductility Results of LDPE Modified Asphalt

Table No. 5.4 - Ductility Results of LDPE Modified Asphalt

ASPHALT	DUCTILITY
Base Binder	93
VG10+ LDPE (2%)	88
VG10+LDPE(3%)	87
VG10+LDPE(4%)	81

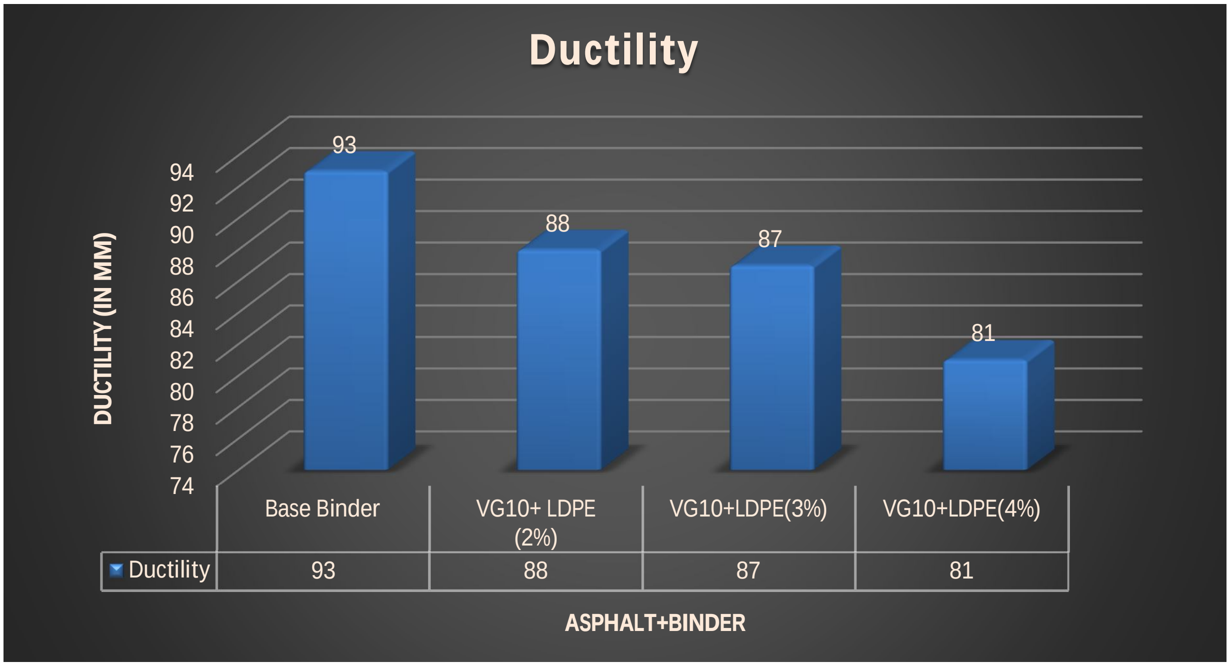

Fig. no. 5.4: Ductility Results of LDPE Modified Asphalt

B. Softening Point Test

1) Apparatus Required

Thermometer – To measure up to 120°c and an accuracy of 0.5°c.
Steel ball 2 numbers – 7.5mm diameter & weight – 3.5 grams
Brass ring 2 numbers – Depth is 6.4mm & inner diameter for top – 17.5 mm & inner diameter for bottom –15.9mm
Ball frame / Ball guide 2 numbers – to resist the steel ball movement & hold it in position. The ball guide& the ring can fit each other and should be placed in the middle of the metal plate frame.
Heat resistant beaker – Capacity of 600ml (85mm inner dia & 120mm Depth)
The metal frame consists of 3 plate – The top plate has a hole to insert the thermometer. The middle platehas 2 slots to place the ring. The distance between the middle & bottom plate is 25 mm.
Hot Plate – It is connected to the energy regulator, which can control the rate of heat production.
Stirrer – Distribute the uniform temperature in the beaker.
Disttiled Water

2) Procedure

a) Fill the beaker with the distilled water, making sure that the water level reaches the metal frame'smiddle plate.
b) Now use the ball guide to fix and tighten the ring. It needs to go in the slot on the middle palate that issupplied for it.
c) Place the steel ball over the ball guide after cooling it to 5 °C. Place the metal frame into the beakerright now.
d) Through the top plate's central hole, insert the thermometer.
e) Fixing the stirrer now entails turning on the hot plate. Inside the beaker, the temperature rises steadilyat a rate of 5 °C each minute. Make sure the beaker is heated evenly.
f) At a certain temperature, the bitumen will melt, and the steel ball will drop to the bottom plate alongwith it.
g) Take note of the temperatures of the two balls as they descend to the bottom plate.

Table No. 6.1 – Softening Point Results of EVA Modified Asphalt

ASPHALT	SOFTENING POINT(In °C)
Base Binder	43
VG10+Eva (2%)	45
VG10+Eva (3%)	45
VG10+Eva (4%)	49

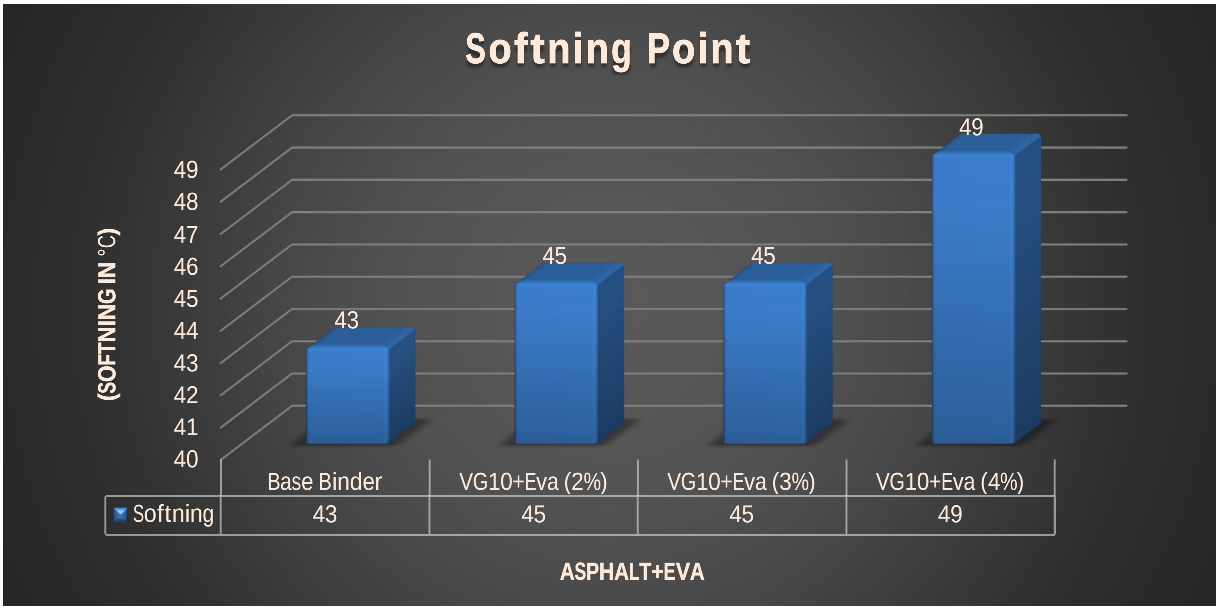

Fig. no. 6.1 : Softening Point Results of EVA Modified Asphalt

Table No. 6.2 – Softening Point Results of EVA Modified Asphalt

ASPHALT	SOFTENING POINT(In °C)
Base Binder	38
VG10+Eva (2%)	40
VG10+Eva (3%)	44
VG10+Eva (4%)	48

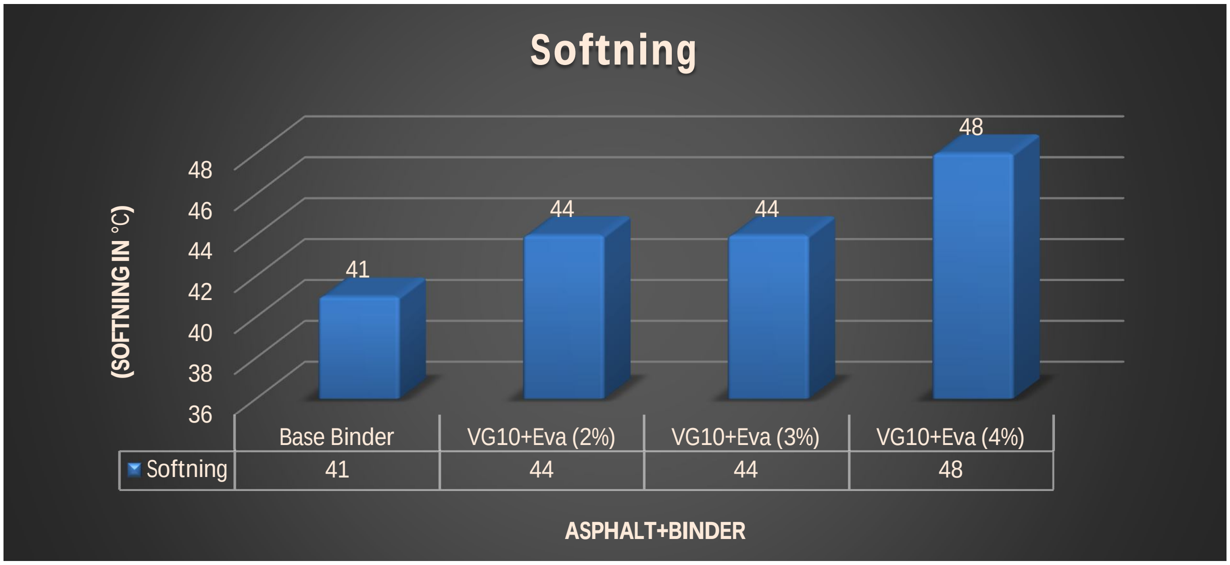

Fig. no. 6.2: Softening Point Results of EVA Modified Asphalt

Table No. 6.3– Softening Point Results of EVA Modified Asphalt

ASPHALT	SOFTENING POINT(In °C)
Base Binder	41
VG10+Eva (2%)	44
VG10+Eva (3%)	44
VG10+Eva (4%)	48

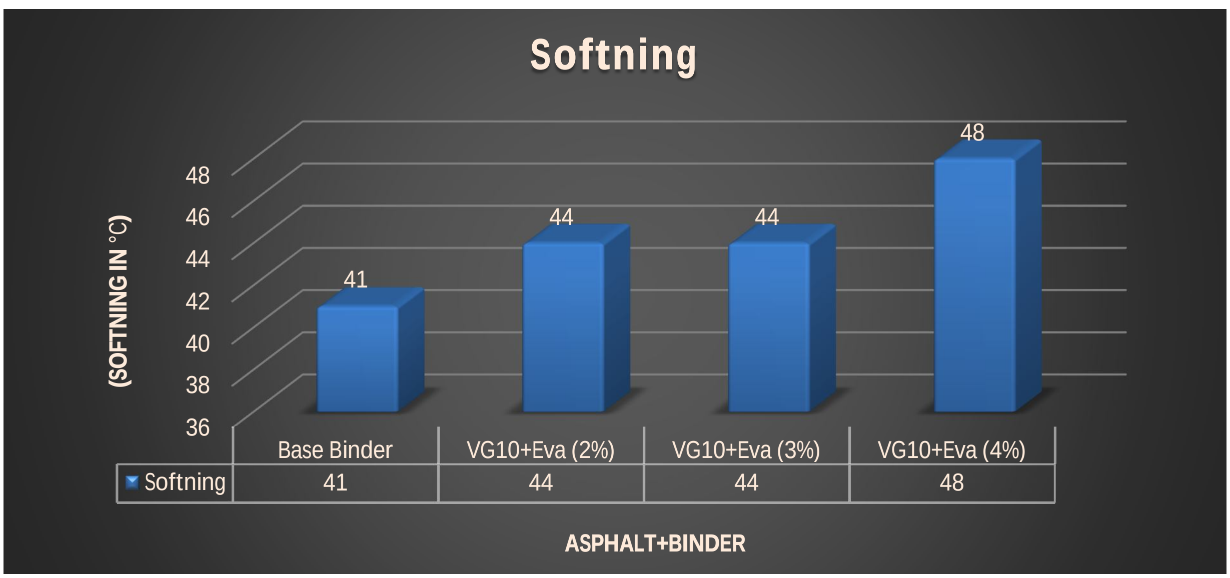

Fig. no. 6.3 : Softening Point Results of EVA Modified Asphalt

Table No. 6.4 – Softening Point Results of EVA Modified Asphalt

ASPHALT	SOFTENING POINT(In °C)
Base Binder	41
VG10+Eva (2%)	44
VG10+Eva (3%)	44
VG10+Eva (4%)	48

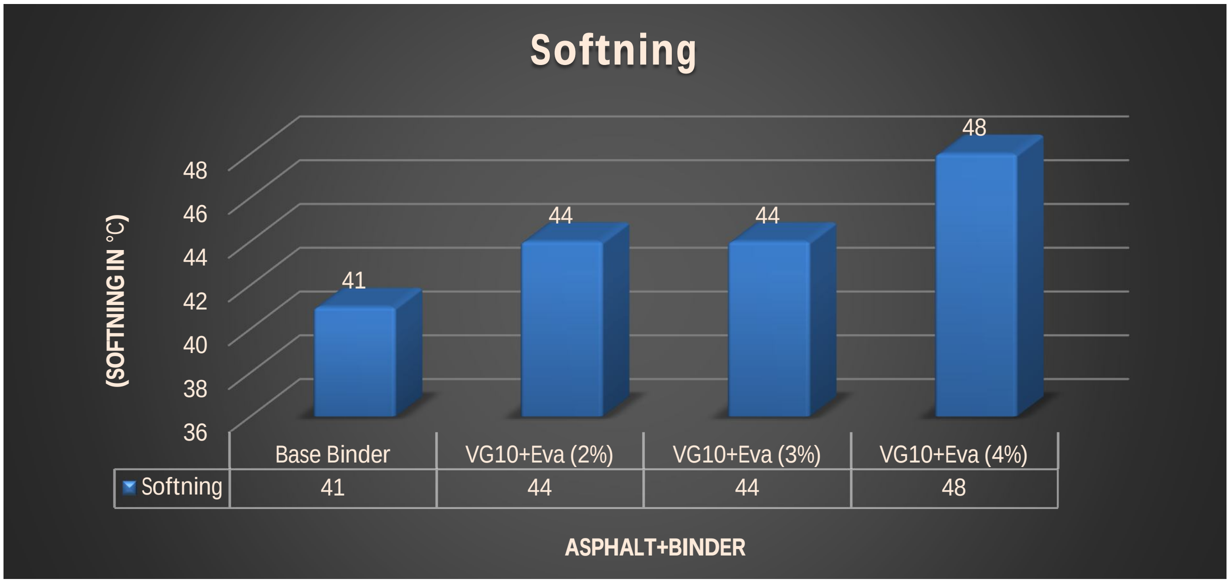

Fig. no. 6.4 : Softening Point Results of EVA Modified Asphalt

Table No. 7.1 – Softening Point Results of LDPE Modified Asphalt

ASPHALT	SOFTENING POINT(In °C)
Base Binder	43
VG10+ LDPE (2%)	44
VG10+LDPE(3%)	46
VG10+LDPE(4%)	49

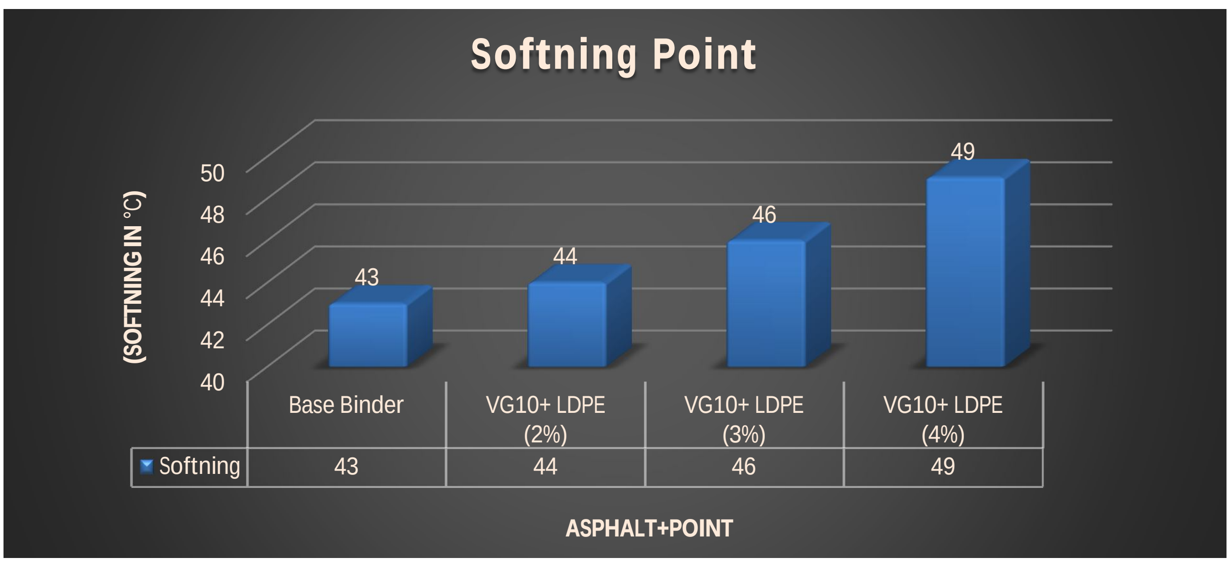

Fig. no. 7.1 : Softening Point Results of LDPE Modified Asphalt

Table No. 4.5 – Softening Point Results of LDPE Modified Asphalt

ASPHALT	SOFTENING POINT(In °C)
Base Binder	40
VG10+ LDPE (2%)	42
VG10+LDPE(3%)	46
VG10+LDPE(4%)	51

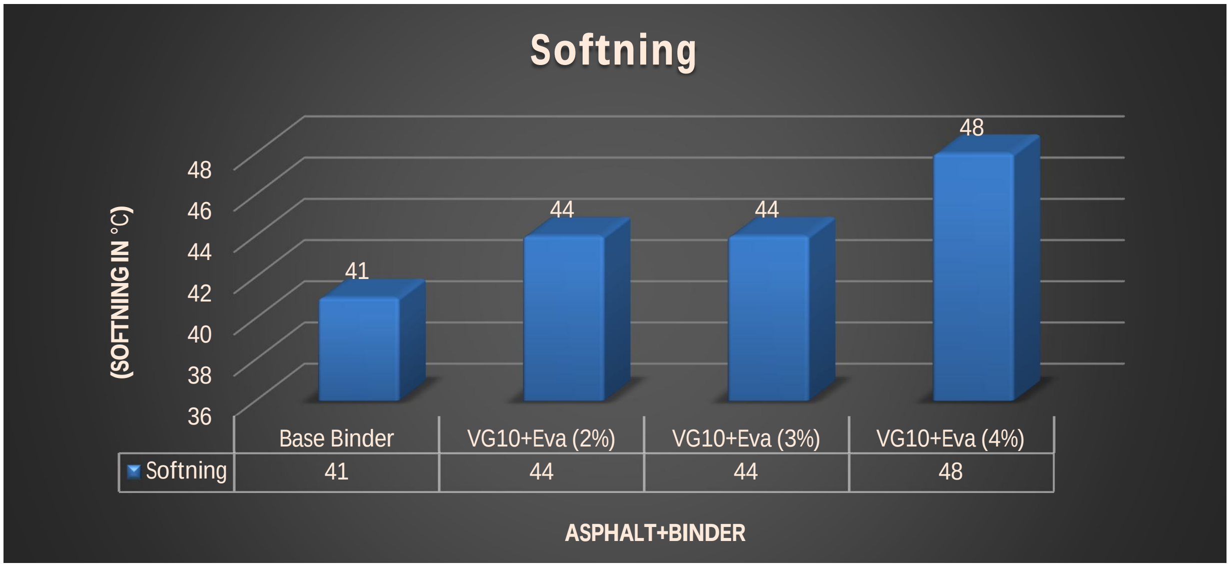

Fig. no. 7.2 : Softening Point Results of LDPE Modified Asphalt

Table No. 4.6 – Softening Point Results of LDPE Modified Asphalt

ASPHALT	SOFTENING POINT(In °C)
Base Binder	39
VG10+ LDPE (2%)	41
VG10+LDPE(3%)	43
VG10+LDPE(4%)	49

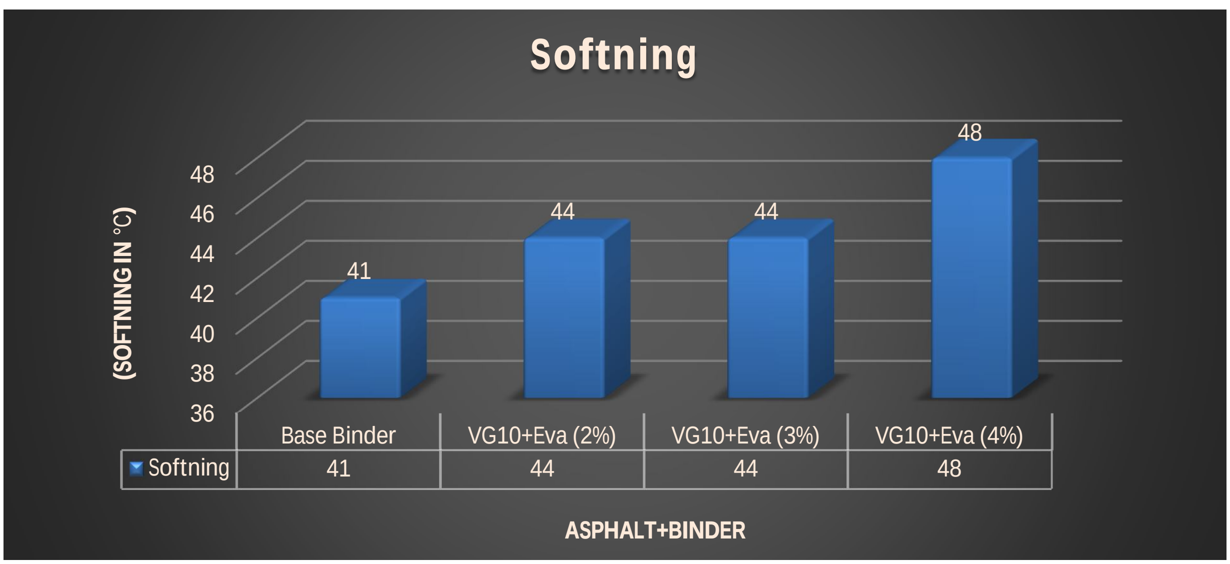

Fig. no. 7.3 : Softening Point Results of LDPE Modified Asphalt

Table No. 7.4 – Softening Point Results of LDPE Modified Asphalt

ASPHALT	SOFTENING POINT(In °C)
Base Binder	38
VG10+ LDPE (2%)	40
VG10+LDPE(3%)	44
VG10+LDPE(4%)	48

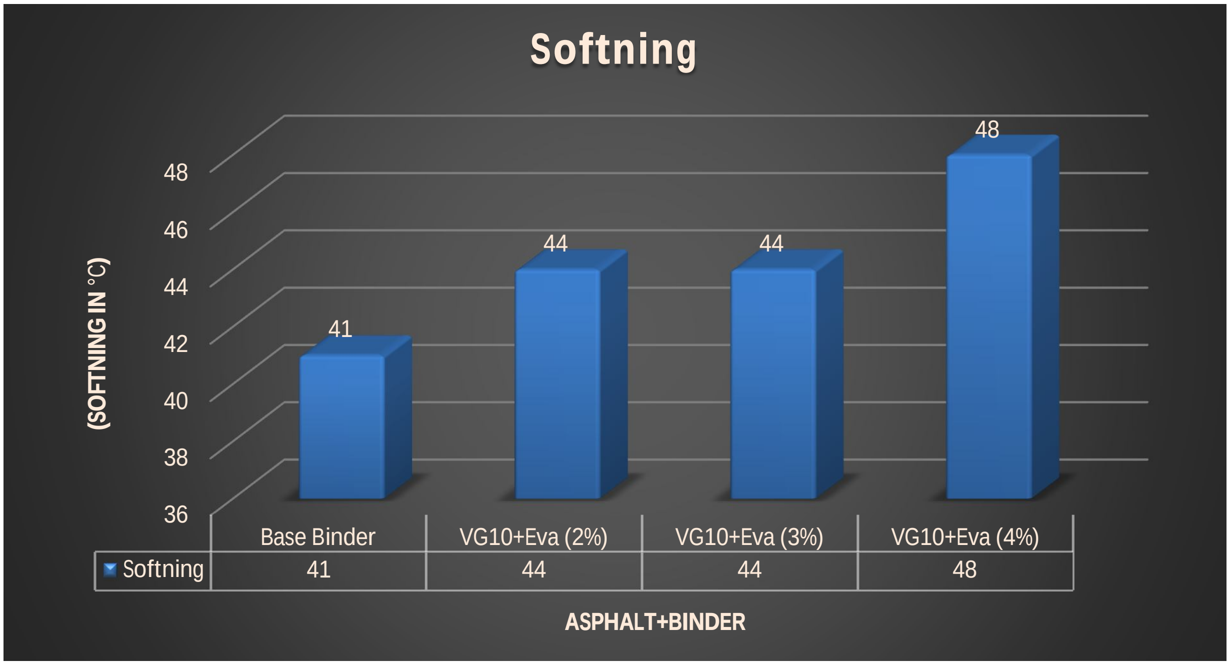

Fig. no. 7.4 : Softening Point Results of LDPE Modified Asphalt

C. Penetration Test on Bitumen

1) Apparatus Required

Penetrometer – Contains a knob to release the weight carrier, a graduated scale (1 in 10mm), and a 100gpenetration carrier. a spirit level at the bottom to keep the surface level.
Penetration needle – Stainless Steel needle (SS316)
Sample container – 55mm dia & 35mm Depth
Water bath – It should contain 10 litres of water & maintain at 25°C.
Stopwatch – 1/10 seconds or Automatic penetrometer timer
Transfer tray – To immerse the sample container into the water.
Thermometer – 0 to 44°C

2) Procedure

a) Once the bitumen has reached the necessary melting temperature, pour it into the container and let itcool naturally for up to an hour.
b) Now turn on the water bath, set the temperature to 25°C, and fill the transfer tray with water.
c) The sample container should then be submerged in the transfer tray and placed there for up to twohours in the water bath.
d) Place the container now on top of the penetrometer's base. The steel needle must then be cleaned withbenzene and attached to the weight carrier.
e) The needle should first make contact with the bitumen's top surface before beginning the penetration.It can be done using the penetrometer's adjustment screw.

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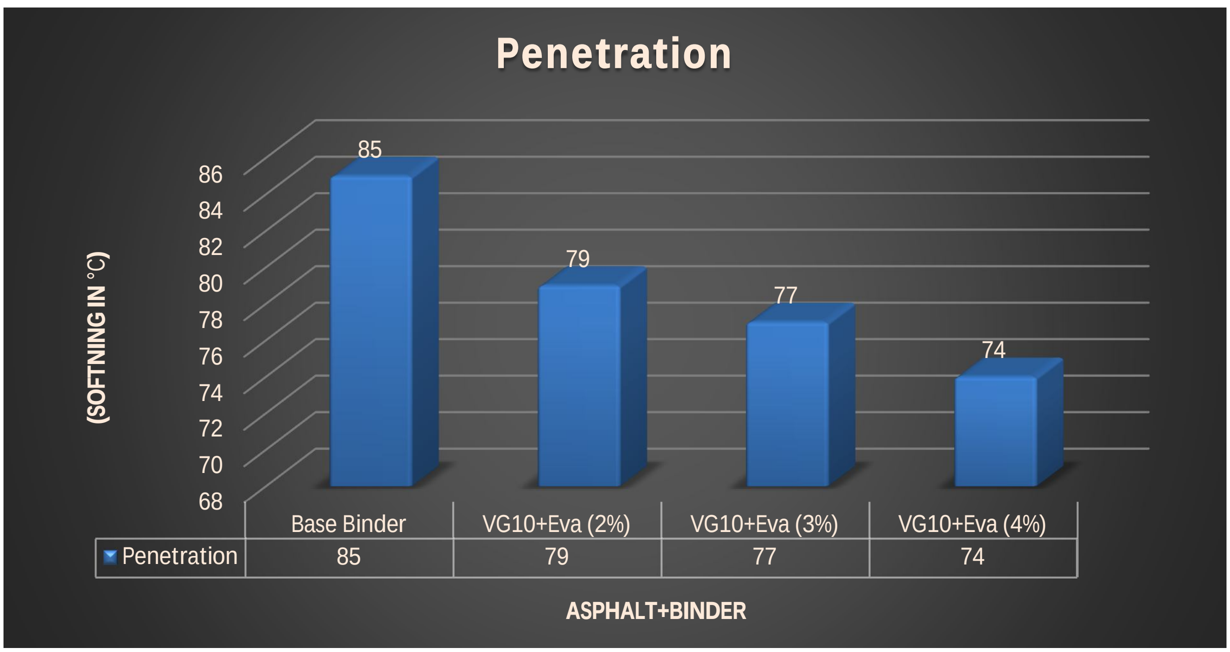
f) Take the G1 reading on the graded scale as your initial reading.
g) 5 seconds after turning on the automated timer Currently, the needle gently penetrates the bitumenand automatically stops after 5 seconds.
h) Take the graded scale's final reading, now.

Table No. 8.1 – Penetration test Results of LDPE Modified Asphalt

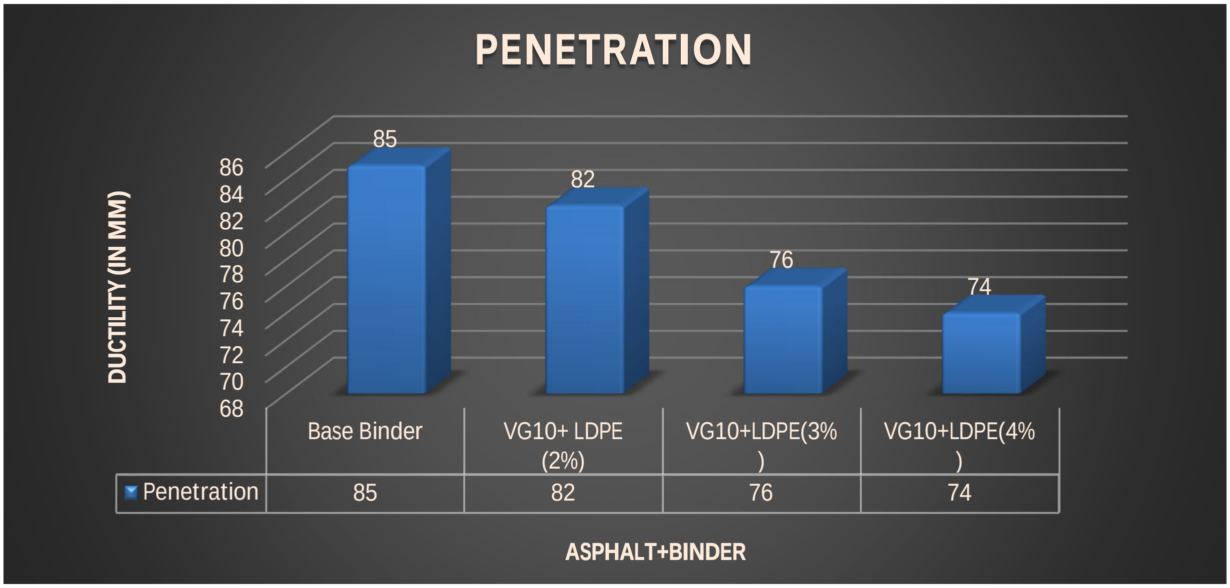
ASPHALT	PENETRATION (mm)
Base Binder	85
VG10+ eva(2%)	79
VG10+eva(3%)	77
VG10+eva(4%)	74



Graph No. 8.1: Penetration Results of Eva Modified Asphalt

Table No.8.2– Penetration test Results of Sasobit Modified Asphalt

ASPHALT	PENETRATION (mm)
Base Binder	85
VG10+ LDPE (2%)	82
VG10+LDPE(3%)	76
VG10+LDPE(4%)	74



Graph No.8.2: Penetration Results of LDPE Modified Asphalt

D. Ftir Test

By measuring the infrared light absorption, the Fourier Transform Infrared (FTIR) technique can be used to determine the molecular make-up of a substance. Here is a general description of the FTIR technique and the equipment needed for bitumen analysis:

1) Apparatus

a) *FTIR Spectrometer:* The main tool for the analysis is this one. A light source, an interferometer, a sample chamber, and a detector make up the device.
b) *Sample Cells:* These are the holding containers for the bitumen sample while it is being tested. They should be made of a material that transmits infrared light, like polyethylene or quartz.
c) *Software:* The software used for instrument management, data acquisition, and spectral analysis is often included with FTIR spectrometers.
d) *Reference Materials:* These are known-composition samples that are used for calibration and verification.
e) *Solvents:* Bitumen samples may occasionally need to be dissolved in a suitable solvent to produce a consistent film for analysis.

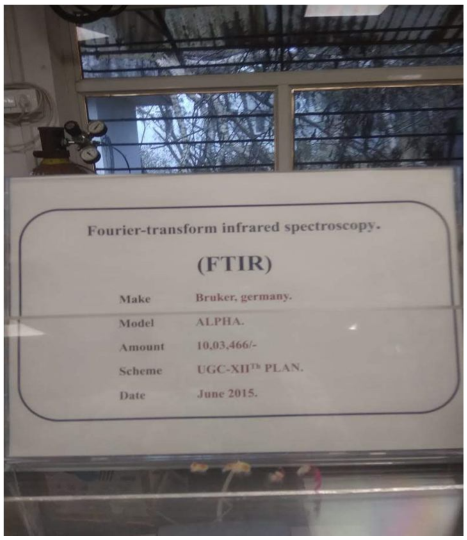
2) Procedure

a) *Sample Preparation:* It might be necessary to melt the bitumen sample at the proper temperature before examination if it is solid. In contrast, if the sample is a solution, it can be applied right away. In some circumstances, it can be necessary to produce a thin film of the sample by applying a little amount to a suitable substrate.
b) *Instrument Setup:* Ensure that the FTIR spectrometer is properly set up and calibrated according to the manufacturer's instructions. This includes aligning the optics, setting the appropriate parameters (such as resolution and scan range), and verifying the instrument performance using reference materials
c) *Baseline Correction:* Before measuring the sample, it is essential to establish a baseline by scanning an empty sample cell or the solvent used (if applicable). This accounts for any background interference in the system.
d) *Sample Measurement:* Place the bitumen sample in the sample cell or apply a thin film to the substrate. Carefully insert the sample cell into the spectrometer's sample compartment. The sample cell should be tightly sealed to prevent any air gaps or moisture interference.
e) *Spectral Acquisition:* Apply the software that came with the FTIR spectrometer to start the spectrum acquisition. An interferogram is typically created by scanning a range of infrared wavelengths and collecting the resulting data.
f) *Data Processing:* A spectrum of absorbance versus wavelength or wavenumber is produced from the collected interferogram after it has undergone the Fourier transformation. The bitumen sample's molecular makeup is depicted in the resulting spectrum.

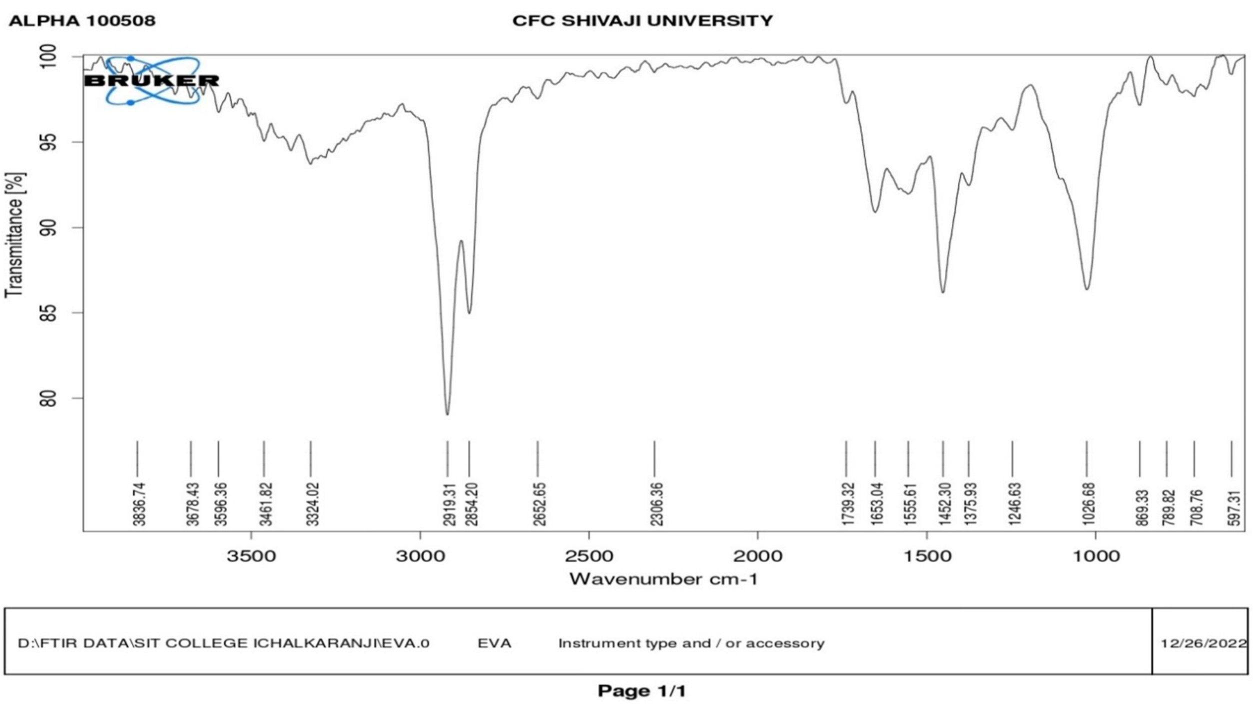
g) *Data Analysis:* Determine the characteristic peaks and absorption bands that correspond to particular functional groups or molecular vibrations found in the bitumen by studying the resulting spectra. Identification and quantification can be aided by comparison with reference spectra or databases.

h) *Interpretation:* Interpret the spectral features and relate them to the properties or constituents of the bitumen, such as the presence of specific compounds, chemical bonds, or structural information.

It is significant to remember that depending on the equipment model and the type of bitumen sample, the specifics of the operation may change. For accurate and dependable findings, always refer to the instrument's user handbook and abide by the suggested procedures.

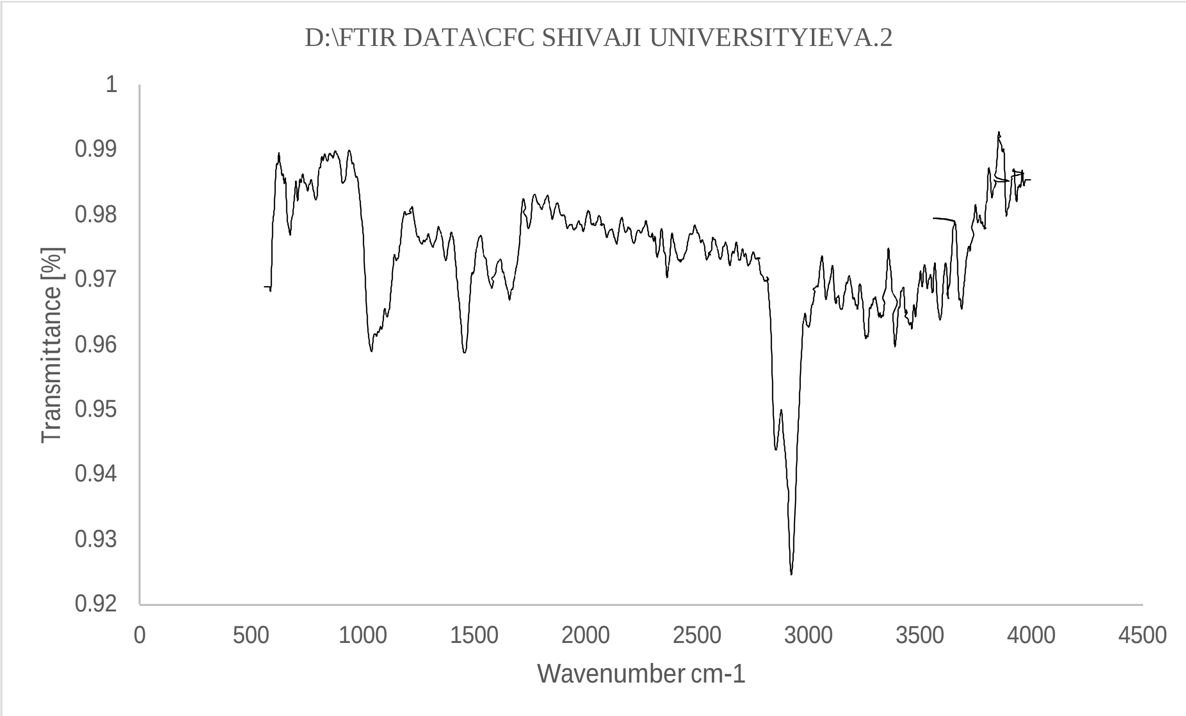


IV. FTIR RESULTS OF EVA MODIFIED ASPHALT



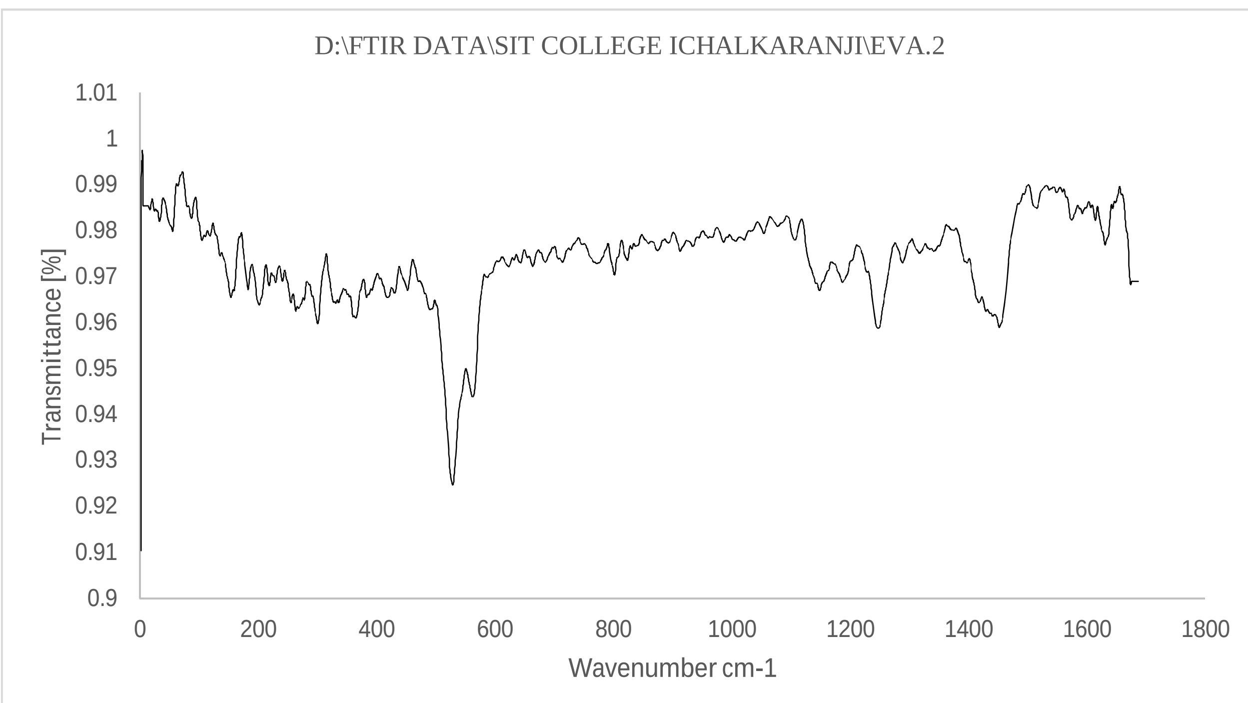
Graph. no. 9. 1: FTIR Results of EVA Modified Asphalt

A. FTIR Results of EVA Modified Asphalt



Graph. no. 9. 2: FTIR Results of EVA Modified Asphalt

B. FTIR Results of EVA Modified Asphalt



Graph. no. 9. 3: FTIR Results of EVA Modified Asphalt

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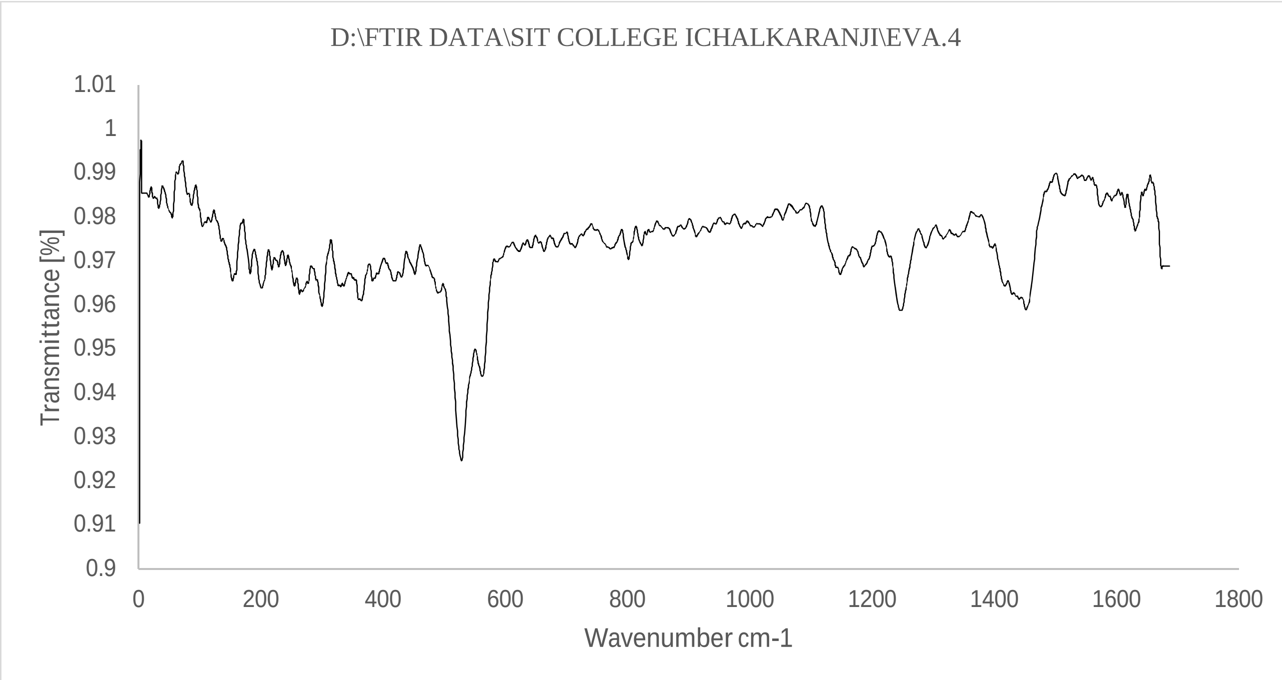
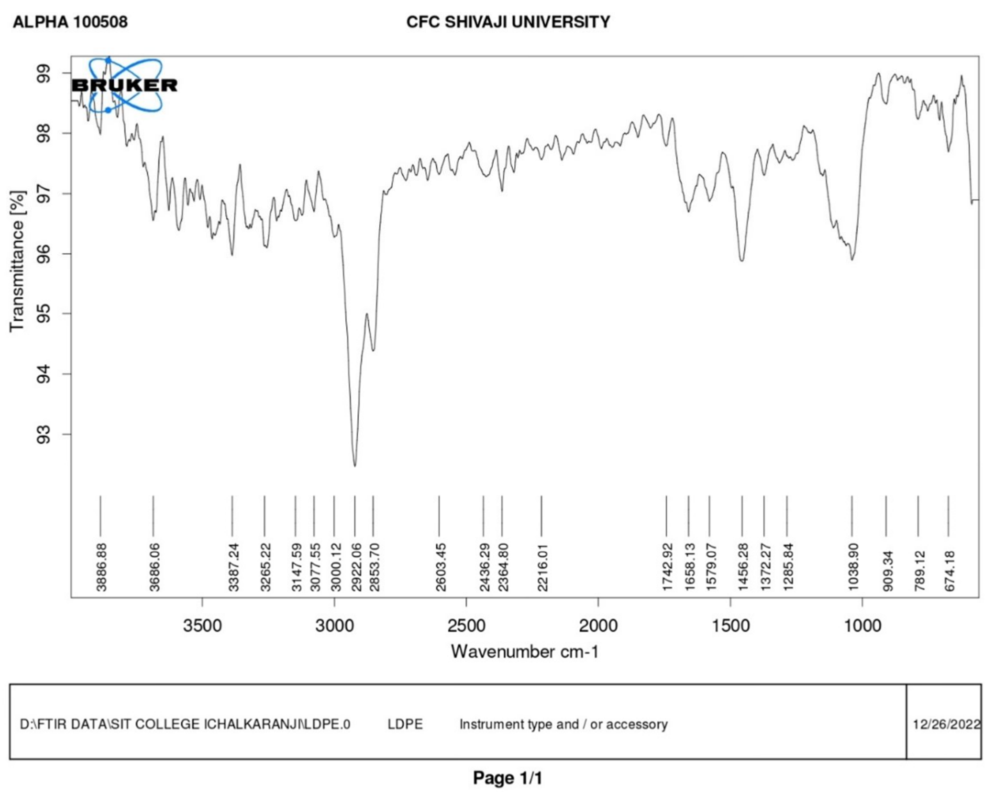
C. FTIR Results of EVA Modified Asphalt



Graph. no. 9. 4: FTIR Results of EVA Modified Asphalt

D. FTIR Results of LDPE Modified Asphalt



Graph.no. 10. 1: FTIR Results of LDPE Modified Asphalt

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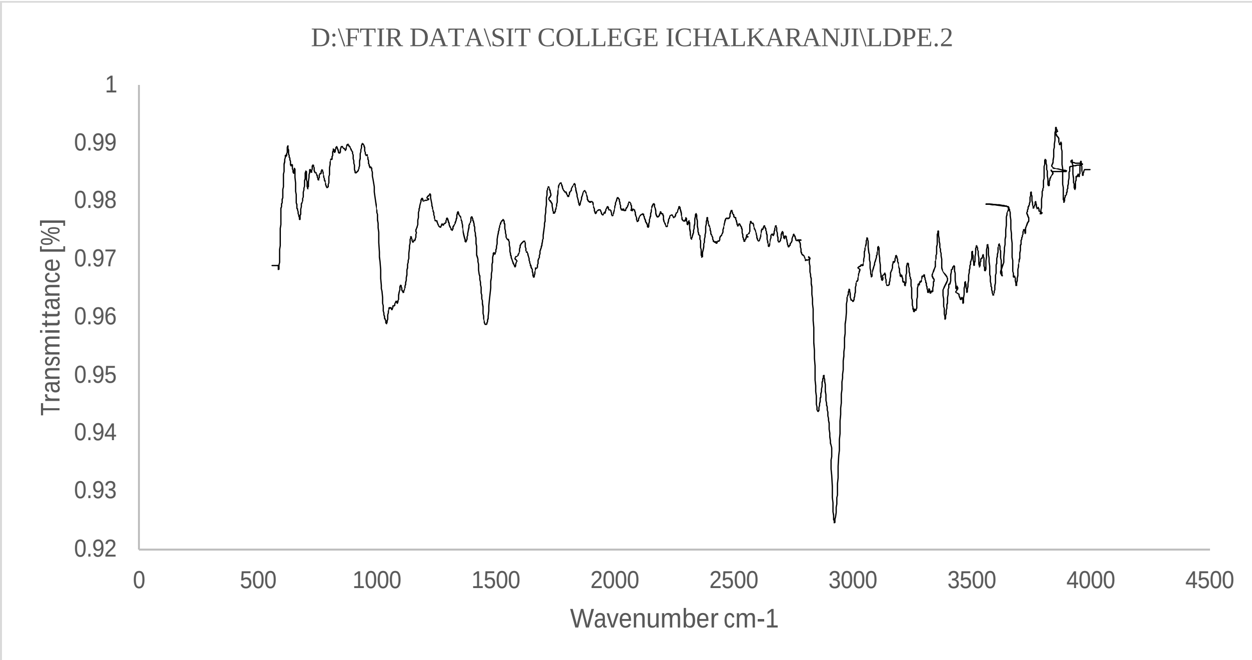
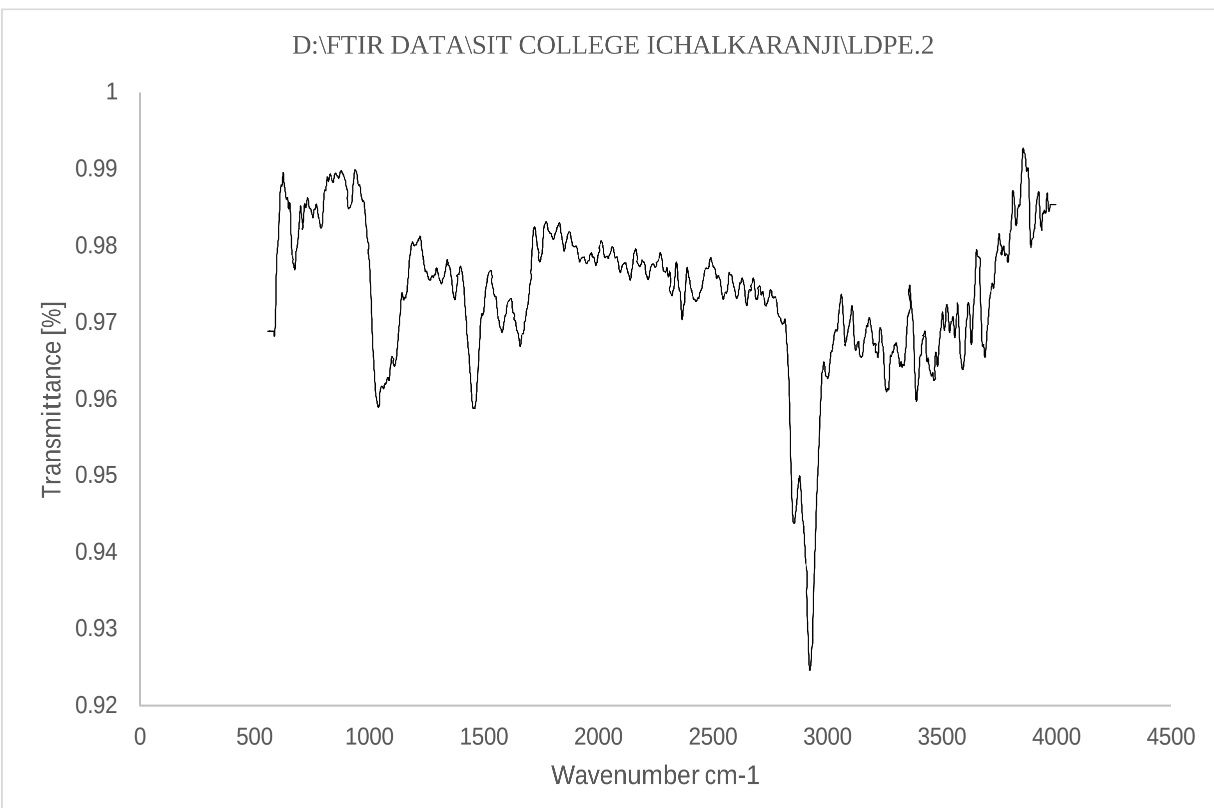
E. FTIR Results of LDPE Modified Asphalt



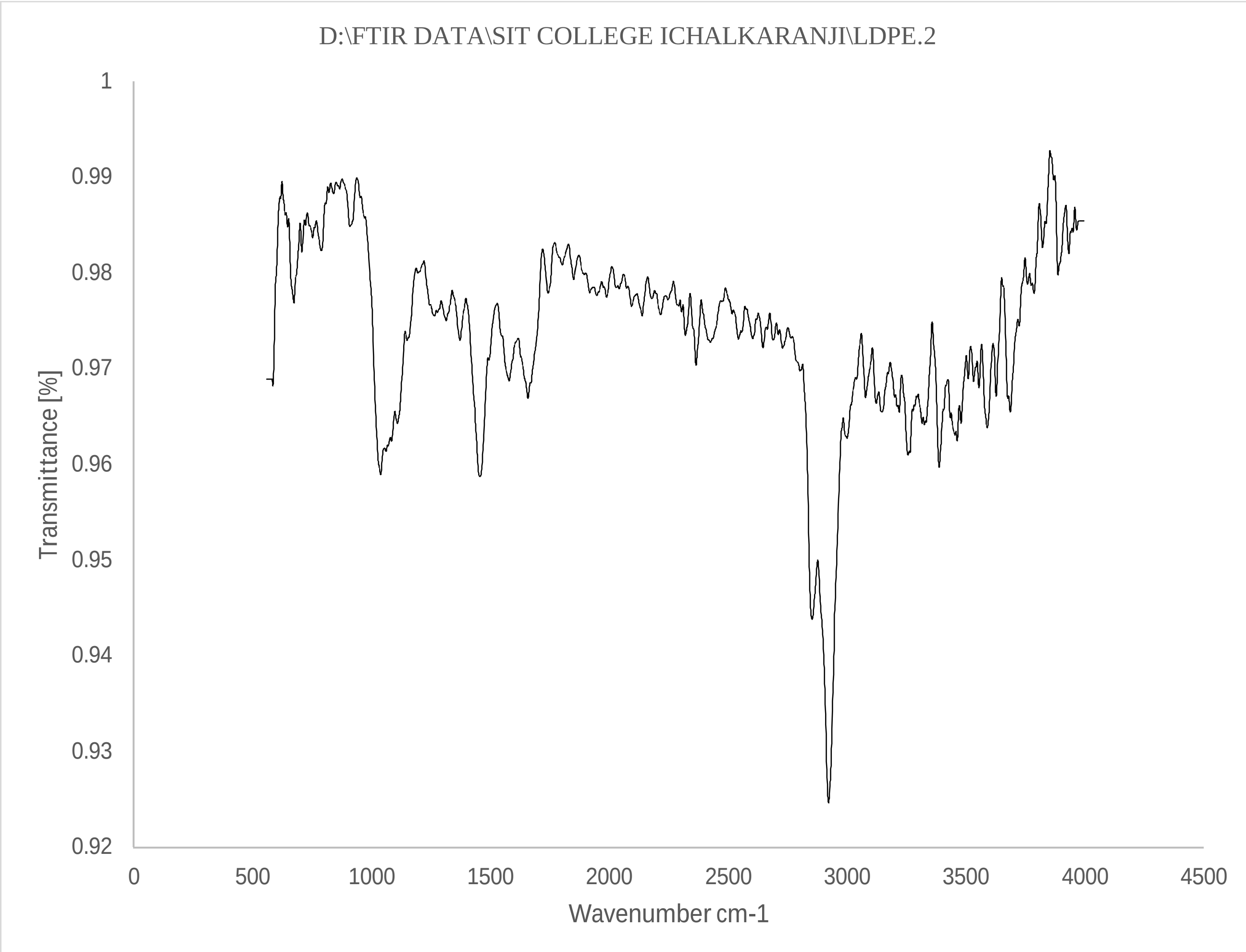
Graph.no. 10. 2: FTIR Results of LDPE Modified Asphalt

F. FTIR Results of LDPE Modified Asphalt



Graph.no. 10. 3: FTIR Results of LDPE Modified Asphalt

G. FTIR Results of LDPE Modified Asphalt



Graph.no. 10. 4: FTIR Results of LDPE Modified Asphalt

V. CONCLUSION

The experimental investigation of LDPE (Low-Density Polyethylene) and EVA (Ethylene-Vinyl Acetate) on asphalt binder has provided valuable insights into their effects on the properties and performance of the binder.

The addition of LDPE and EVA to asphalt binder has been found to enhance various aspects of its performance. The inclusion of these polymers has led to improvements in the binder's rheological properties, such as increased viscosity and reduced susceptibility to temperature-related deformation. This indicates that LDPE and EVA can effectively modify the binder to better withstand the stresses and strains experienced on the road.

Moreover, the modified asphalt binder with LDPE and EVA has exhibited improved resistance to aging and oxidative degradation. The polymers act as protective agents, reducing the rate of binder aging and increasing its durability. This is crucial for the long-term performance of asphalt pavements, as it helps to maintain the integrity of the binder and extend the lifespan of the road surface.

Urthermore, LDPE and EVA have shown potential in enhancing the adhesive properties of the asphalt binder. The modified binder has demonstrated improved adhesion to aggregates, resulting in better bond strength and reduced moisture susceptibility. This is particularly beneficial in preventing moisture-related distresses, such as rutting and stripping, which can compromise the structural integrity of the pavement.

Overall, the experimental investigation has established that the incorporation of LDPE and EVA into asphalt binder has significant positive effects on its performance characteristics. The findings suggest that these polymers can be considered as effective modifiers for enhancing the quality and durability of asphalt pavements.

However, further research and testing are needed to optimize the polymer content, blending methods, and long-term performance of the modified binder, in order to fully understand and harness their benefits in practical road construction applications.

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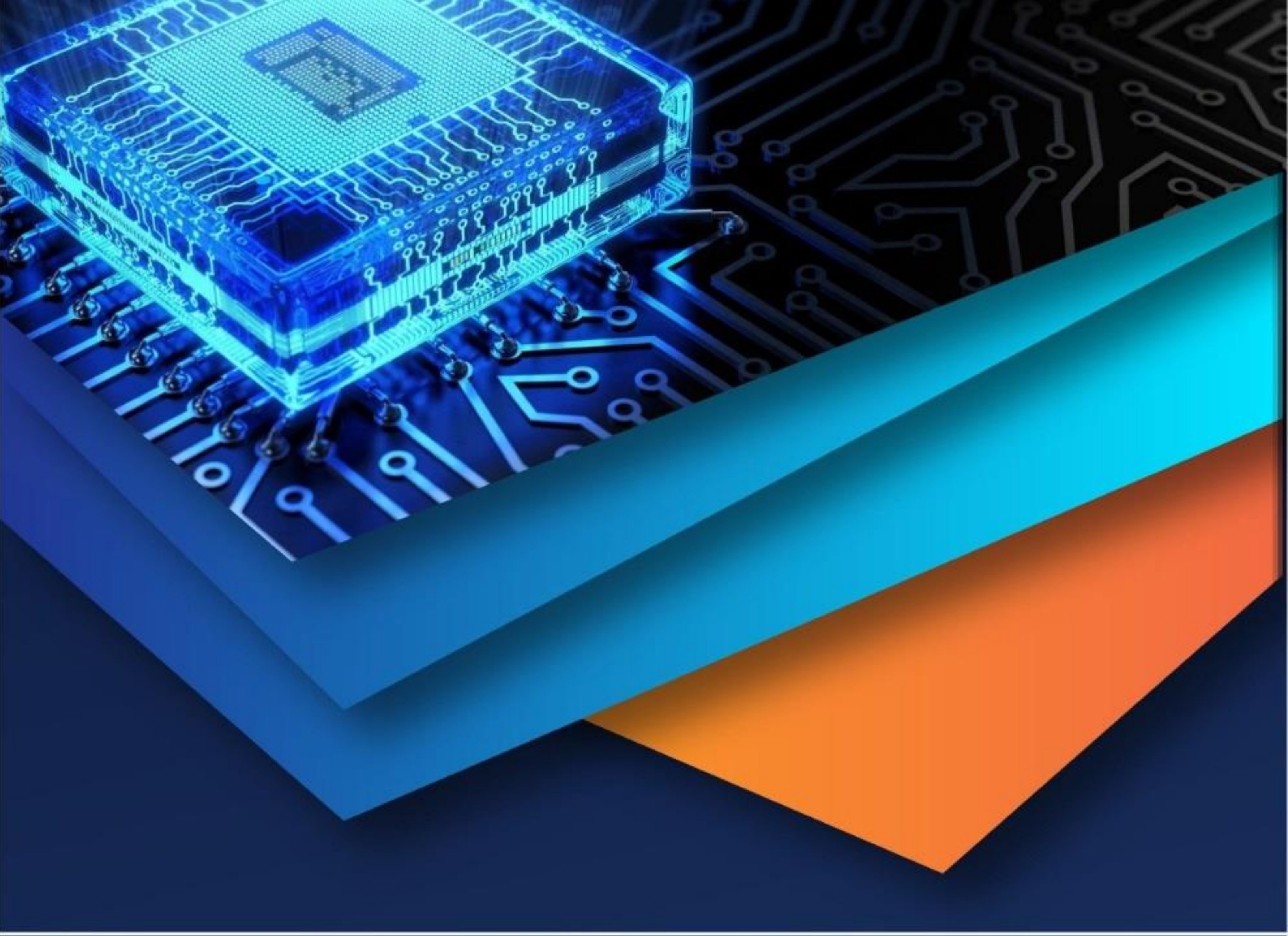

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