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Polymer Modified Bitumen

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Abstract: *When the need of paved roads became a worldwide requirement, bitumen appeared very quickly as an ideal binder to build both the pavement structure and the wearing course. Increasing traffic volumes, vehicle loads and tyre pressures are causing accelerated degradation of our road pavements.. Bitumen occurs naturally, it is mostly obtained as a byproduct of oil production, and however, its thermoplastic characteristics cause difficulties with roads. For at least three decades, polymer modified bitumen's (PMBs) has been used in road technology with the intention of reducing road deterioration such as rutting, cracking and stripping These polymer modified bitumen are effective in reducing rutting and improving fatigue crack resistance. Modified bituminous materials can bring real benefits to highway maintenance and construction, in terms of better and longer lasting roads, and savings in total road life costing..*

Keywords: *polymer modified bitumen's, road pavements, Rubber, Crumb Rubber, asphalt concrete, Bitumen*

I. Introduction

When the need of paved roads became a worldwide requirement, bitumen appeared very quickly as an ideal binder to build both the pavement structure and the wearing course. Increasing traffic volumes, vehicle loads and tire pressures are causing accelerated degradation of our road pavements.At high temperatures, bitumen due to its viscous behavior can be mixed with aggregate to manufacture asphalt concrete, which remains sufficiently workable during placement and compaction. At ambient temperatures, bitumen behaves as a viscoelastic material providing both stability and flexibility Bitumen occurs naturally, it is mostly obtained as a byproduct of oil production, and however, its thermoplastic characteristics cause difficulties with roads. It has been demonstrated that the apparent glass transition temperature of bitumen is nearly zero degree Celsius. Bitumen is a viscoelastic material and may exhibit either elastic or viscous behavior, or a combination of these, depending on temperature and time over which bitumen is observe. At sufficiently low temperatures and high rates of strain, bitumen behaves essentially as an elastic solid.

1. Polymer'

'Polymer' is a derived word meaning "of many parts". Polymers can be thought of as long chemical strands that are made up of many smaller chemicals (monomers) that are joined together end-on-end. Polymers can therefore be made up of different numbers of the monomers and therefore they can have different 'chain lengths'. Only certain chain lengths may be suitable for a particular polymer type when used in bitumen. For example, the polymer 'polystyrene' is made up of many styrene molecules linked together one after the other. Two basic types of polymer are used in modifying bitumen for road applications: Bitumen occurs naturally, it is mostly obtained as a byproduct of oil production, and however, its thermoplastic characteristics cause difficulties with roads. It has been demonstrated that the apparent glass transition temperature of bitumen is nearly zero degree Celsius. Bitumen is a visco-elastic material and may exhibit either elastic or viscous behavior, or a combination of these, depending on temperature and time over which bitumen is observe. At sufficiently low temperatures and high rates of strain, bitumen behaves essentially as an elastic solid. Thus, asphalt concretes are susceptible to low temperature cracking that may lead to fracture. Further, in high summer temperatures asphalt undergoes flow or creep. The stability of asphalt paving surfaces requires that it does not flow or creep under heavy load.

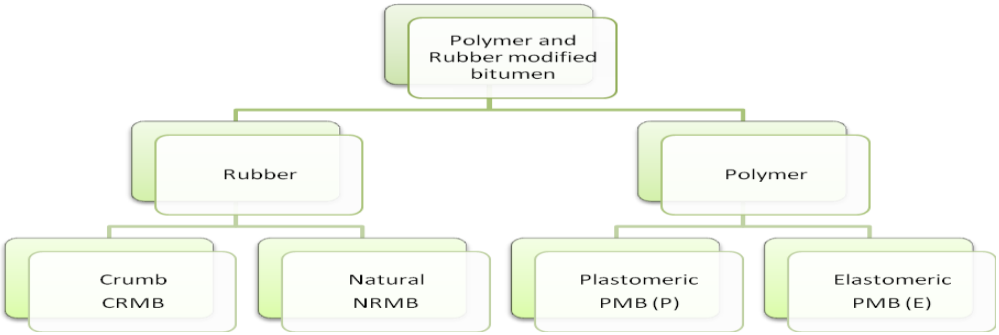
- Elastomers
- Plastomers

An elastomer is a polymer that has a flexible 'rubber' backbone and large side-chains in its structure. Styrene butadiene styrene (SBS) is an example of this type.

A plastomer is a polymer that will deform in a plastic or viscous manner at melt temperatures and becomes hard and stiff at low temperatures, i.e. the structure is reversibly broken down with the application of heat.

Two basics types of rubber are used in modifying bitumen for road application:

- Natural rubber (NRMB)
- crumb rubber (CRMB)



Natural Rubber:-

Rubberized asphalt, mainly surface course (wearing course) but also binder course (base course), has been used with a fair degree of success for over 40 years.

Crumb Rubber:-

Crumb rubber modified bitumen was used in numerous asphalt paving project in all 50 states of the Unites States from 1991 to 1995 due to a federal government mandate.

- PMB generally increase the life of road.
- PMB reduces the maintenance cost.
- PMB has higher binding strength than conventional bitumen.
- During the last decade increase in axle loads, heavy traffic, severe climatic conditions and construction failure led to a need to enhance the properties of best bitumen's.
- Polymer modification reduces temperature susceptibility of the bitumen. CRMB and Polymer Modified Bitumen (PMB) are comprised of almost identical materials, meet the same physical criteria, use the same aggregate blends, and are applied in the same manner. CRMB, with life cycle cost overtime, is more economical and will aid in alleviating the ecological nightmare of tire accumulation. Life cycle cost benefit - improved performance over time resulting in maintenance and repair cost reduction
- Cost savings incurred due to reduced thickness needed for binder
- Environmentally friendly - reduction of post-consumer waste materials that are otherwise harmful to dispose of and dangerous to store
- High performance in extreme weather temperatures
- Protection against alligatoring, fatigue cracking & rutting
- Speed of application – cuts down on construction-induced traffic
- Increased stoppage time due to rubber on rubber traction
- Noise reduction when driven on
- Protection against Urban Heat Island Effect

New Crumb Rubber Technology:-

Enterprising individuals are continuously developing new technologies to overcome the waste tire problem. Certainly, established government programs encourage growth in these industries. Some notable entries include tire chips as in septic leach ate fields, soil amendment, and playground safety material and noise absorption systems.

Sound Absorbing Material:-

Various civil engineering uses of scrap tires in highway applications have been explored extensively in the last decade. Using shreds in light fill in embankments can use large quantities of scrap tires. One use that has been only partially explored is the use of scrap tires in sound walls. Rubber has demonstrated very desirable sound absorbing characteristics.

II. Literature Survey

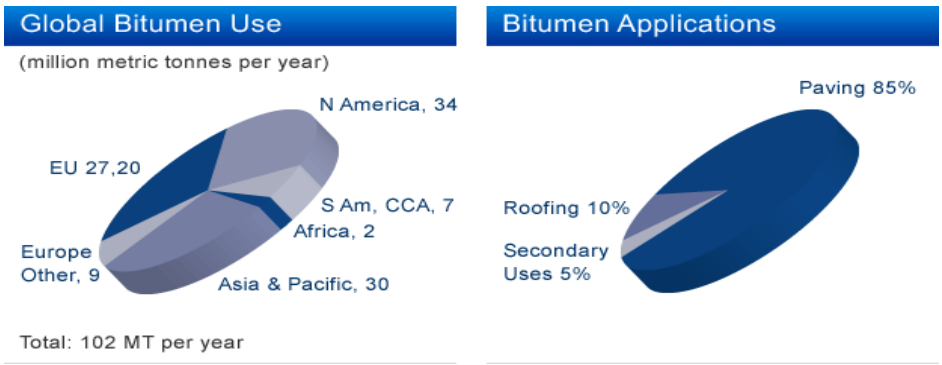
X.LU et al (June 26, 1998), They researched on rheological properties of SEBS, EVA and EBA polymer modified bitumen's. On the basis of the data and interpretations presented in their study they states that, polymer modification increases the elastic response and dynamic modulus of bitumen's and reduces their temperature susceptibility at intermediate (0-400C) and high (≥400C) temperatures. J.S. CHEN et al (February 21, 2002), They worked on evaluation and optimization of the engineering properties of polymer modified asphalt. In their study, SBS was shown to improve the rheological properties of the asphalt binder due to formation of a polymer network in the binder.

X.LU et al (December 2003), They performed experimental study on influence of polymer modification on low temperature behavior of bituminous binders and mixtures which gives information of low-temperature properties of bituminous binders and mixtures were greatly dependant on base bitumen, and in most cases, polymer modification did not show significant benefits as compared to the corresponding base bitumen.
N.P.KRUT'KO et al (March10,2008), They researched on thermal oxidation resistant of bitumen modified with Styrene-Butadiene-Styrene and Ethylene-Vinyl-Acetate copolymers, He was concluded that interaction of the carbonyl group of Ethylene-Vinyl-Acetate copolymer with components of bitumen asphaltenes enhances the heat resistance of the polymer bitumen compound.

III. Methodology

A) Bitumen:

Bitumen is an oil based substance. It is a semi-solid hydrocarbon product produced by removing the lighter fractions (such as liquid petroleum gas, petrol and diesel) from heavy crude oil during the refining process. As such, it is correctly known as refined bitumen. In North America, bitumen is commonly known as "asphalt cement" or "asphalt". While elsewhere, "asphalt" is the term used for a mixture of small stones, sand, filler and bitumen, which is used as a road paving material. The asphalt mixture contains approximately 5% bitumen. At ambient temperatures bitumen is a stable, semi-solid substance.
Uses:



Bitumen Uses in Different Countries with Applications
Source: The Bitumen Industry - A Global Perspective, 2008

Bitumen does occur naturally, but for all intent and purposes it is petroleum on which the world relies for its supplies of bitumen today. The bitumen content of crude can vary between 15% and 80%, but more normal range is 25% to 40%.
In fact three broad classifications for crude oil are-

- Bitumen based
- Paraffin based
- Bitumen and paraffin based

Types Of Bitumen
There are six major classifications of petroleum bitumen produced by the refining and manufacturing process.
Paving Grade Bitumen:

Paving grade bitumen (or asphalt cement in the USA) is the most widely used bitumen and is refined and blended to meet road engineering and industrial specifications that take into account different climatic conditions. Paving grade bitumen may also be considered as the parent bitumen from which the other forms are produced.

Cutback Bitumen:
Consist of bitumen that has been diluted in solvent (cutter or flux) to make it more fluid for application. The fluidity of cutback bitumen's (or cutbacks as they are known) depends on the degree of hardness of the bitumen and the proportion of diluent.
Bitumen Emulsions: Bitumen emulsions are dispersions of bitumen in water. Hot bitumen, water and emulsifier are processed in a high speed colloid mill that disperses the bitumen in the water in the form of small droplets. These droplets or particles of bitumen are normally in the 5-10 micrometer size range but may be even smaller. The emulsifier assists in forming and maintaining the dispersion of fine droplets of bitumen. Bitumen emulsions
Modified Bitumens: Modified bitumens are formulated with additives to improve their service performance by changing such properties as their durability, resistance to ageing, elasticity and/or plasticity. The most important modifiers are polymers.

Polymer Modified Binders: Polymer modified binders (PMB) are a major advancement in bituminous binder technology as these materials better satisfy the demands of increasing traffic volumes and loads on our road networks. As well as natural rubbers, polymers such as styrene butadiene styrene (SBS), polybutadiene (PBD) and ethylene vinyl acetate (EVA) are commonly used to modify bitumen.
Multigrade Bitumen: Multigrade bitumen is a chemically modified bitumen that has the properties of a hard paving grade bitumen at high service temperatures coupled with the properties of a soft paving grade bitumen at low temperatures (i.e. it has properties that span multiple grades).
Industrial Bitumens: Industrial bitumens (or oxidized bitumens) are made by blowing air through hot paving grade bitumen. The so-called blowing process results in harder bitumen that softens at a higher temperature than that at which paving grade bitumen softens. Industrial bitumens also have more rubber-like properties and their viscosities are much less affected by changes in temperature than is the case with paving grade bitumen.

B) Polymer
Types of Polymer
Synthetic Polymers

These are polymers that have been manufactured in a chemical process to combine particular molecules in a way that would not occur naturally. And although various synthetic polymers have been capable of being produced since the early part of this century it is the more recently developed polymers that are now being used to modify bitumen and produce the "new" bituminous binders.

Natural Rubber:

Rubberized asphalt, mainly surface course (wearing course) but also binder course (base course), has been used with a fair degree of success for over 40 years. Rubber is a natural polymer and its action in a bituminous mix is similar to that of the synthetic TR's. Quite a lot of the original trial work including rubber in bituminous mixes was conducted in Leicestershire in conjunction with the TRRL and the rubber companies..

3.1.5 Ethylene Vinyl Acetate (EVA):

Ethylene Vinyl Acetate Particles

There are many types of EVA polymers available. EVA polymers can contain different ratios of ethylene to vinyl acetate and can have different molecule weights, i.e. different polymer lengths. Typical vinyl acetate levels are 18% and 33%.
The following main parameters control the properties of EVA:
VA content: The more the VA content increases, the higher the proportion of rubbery regions (i.e. an increase in flexibility) and the lower the proportion of crystalline regions (i.e. a decrease in stiffness).
They are highly flexible products, compatible with many other polymers and additives, and are easy to process. Due to its chemical structure, the EVA range:

- are highly flexible
- Delivers high cohesive strength and compatibility
- ensures excellent adhesion to a wide range of substrates
- are highly resistant to rupture

See below the structure of random Ethylene Vinyl Acetate copolymers obtained by high pressure radical polymerization.

3.1.6 Crumb Rubber (CR):

Bitumen-rubber is manufactured by adding graded crumbed rubber, obtained from grinding vehicle tyres, to hot bitumen which contains a quantity of heavy extender oil. Following the addition of the rubber, a digestion period is required for the rubber to swell and partially dissolve in the bitumen/extender oil blend. The rubber never completely dissolves in the bitumen and the product is thus classed as a non-homogenous binder. Special manufacturing equipment is required to manufacture this highly viscous material.

Sources of crumb rubber:

Crumb rubber can be obtained from truck tyres or automobile tyres or both. Truck tyres contain 80 percent more rubber hydrocarbons than automobile tyres and also contain significantly higher amount of natural rubber. Whole truck tyre contains 18 percent natural rubber compared to 9 percent in an automobile tyre and 2 percent in tyre trades. The amount of natural rubber has shown to affect the properties of CRMB significantly. \

Method of producing crumb rubber:

Crumb rubber is produce from discarded tyres by two methods: (a) Grinding at ambient temperatures and (b) Grinding cryogenically cooled tyre rubber. In the latter process, the tyre rubber is chilled by liquid nitrogen.

1. Experimental Procedure:

For determining the properties and behavior of conventional as well as polymer modified bitumen we had taken following tests according to IS: 1201-1978.

a) Tests on physical properties

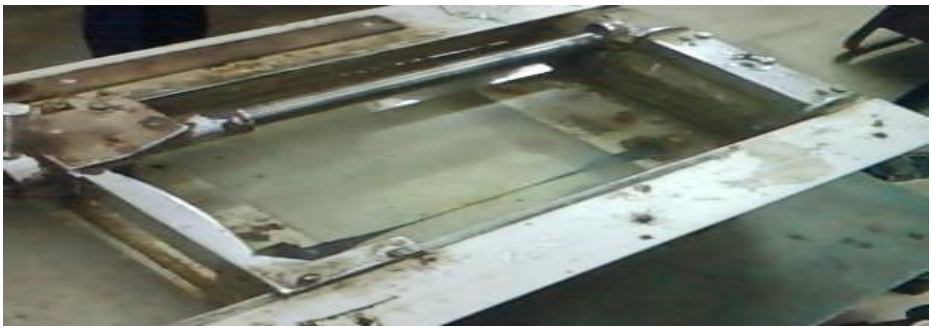
1. Ductility.
2. Softening point.
3. Viscosity.
4. Penetration.

The ductility of bituminous material is measured by the distance in centimeters to which it will elongate before breaking.

In a flexible pavement construction where bituminous binder are used, it is significant importance that the binder from ductile thin films around and aggregates. The ductility is expressed as the distance in cm to which a standard briquette of bitumen can be stretche the before the thread, breaks. The test is conducted at 27^{o} to 5^{O}c and at the rate of pull of 50 ±2.5 mm/min.

Apparatus: Mould for ductility test, Water bath, Testing machine, Thermometer

.Molds for Ductility Test



Ductility Test Machine

Application Of Test:

The ductility value get seriously affected if any of the following factors are varied. pouring temperature cross section of briquette, improve level of briquette placement, test temperature, rate of pulling. A certain minimum ductility is necessary for a bitumen binder.

Softening Point:

The temperature at which the substance attains a particular degree of softening under specified condition of test. Softening point was used to determine the temperature at which a phase change occurs in the binder

Apparatus: Ring and ball apparatus, Ball guide, Thermometer, Beaker, Stirrer

Assembly for Softening Point Test

Viscosity:

The property of fluid by which it resist flow due to internal friction, and one of the method by which it is measured, is by determining the time taken by 50cc of the material to flow from a cup through a specified orifice under standard conditions of test and at a specified temperature.

Apparatus: Tar viscometer: Cup, valve, water bath, sleeve, stirrer, curved shield, receiver, and thermometers.

Assembly for Viscosity Test

Penetration:

The penetration of a bituminous material is the distance in tenths of a mm that a standard needle while penetrate vertically in to a sample of the material under standard conditions of temperature, load and time. Bituminous material are available in various types and grades.

Apparatus: Container, needle, water bath, transfer dish, penetration apparatus, thermometer, time device.

Mould Of Penetration Test

Assembly of Apparatus for Penetration Test

Application of Test:

The penetration is most commonly adopted test on bitumen to grade the material in terms of its 100. Depending upon the climatic condition and type of construction, bitumen and different penetration grades are used 80/100. Bitumen it denotes that the penetration value ranges between 80 and 100.The penetration values of various

The project had been conducted on the basis of following steps.

1. Set of above test on plain bitumen.
2. Set of above test on bitumen + 2% EVA.
3. Set of above test on bitumen + 4% EVA.

Like wise up to 10 % EVA

4. Set of above test on bitumen + 2% CR.
5. Set of above test on bitumen + 4% CR.

Like wise up to 10 % CR.

IV. Result

For study we have used 60/70 grade bitumen obtained from shell corp. India Ltd. This bitumen is used as base bitumen and then it is further modified with EVA and CR at different percentage. When the bitumen is tested for the viscosity, penetration, softening point and ductility without adding polymer it shows the following results.

Viscosity (sec)	Penetration (dmm)	Softening point (ºC)	Ductility (cm)
7	65	40	>120

Result of Plain BitumenThese test are conducted at specific temperature i.e. pouring temperature was 120º C for the penetration, softening point and ductility while viscosity test was conducted at 120ºC. After cooling in air and water for the duration as specified in IS code the above results are obtained. The main purpose of these tests is to study the change in physical properties of the bitumen after adding the polymers. Thus after testing the plain bitumen we had add 2% EVA in the plain bitumen and above four tests are conducted on it.

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Bitumen + EVA

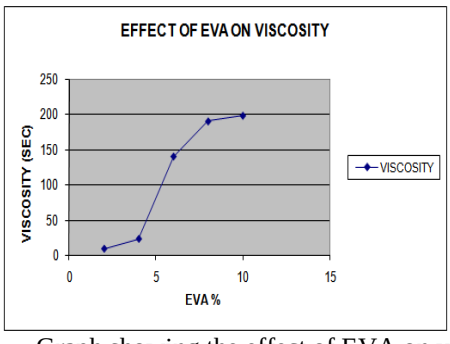
Mixing of EVA in Bitumen

Likewise these test are conducted on the plain bitumen+4%, 6%, 8%, 10% EVA. The pouring and the testing temperature were kept as that of the temperature when the tests were conducted for the plain bitumen. The results are as follows:

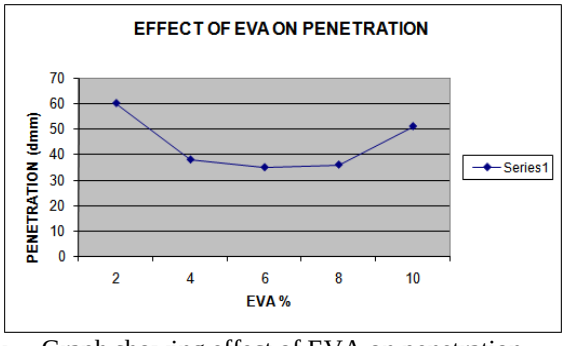
Test	Viscosity	Penetration (dmm)	Softening point (ºC)	Ductility (cm)
2%	9sec	60	54	60
4%	23sec	38	68	24
6%	2min 20 sec	35	78	12
8%	3min 10 sec	36	80	9
10%	3min 18 sec	51	82	8.4

Results of Plain Bitumen+ EVA

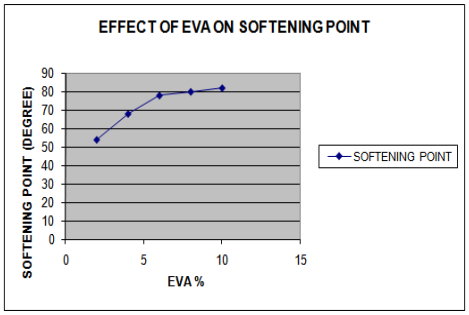
The EVA was obtained from National Chemicals of old Nagpur. The effect of EVA polymer modification on the properties of the plain bitumen can be seen in table 2, as a decrease in penetration and ductility values and an increase in viscosity and softening points with increasing polymer content. The increase in softening point temperature is favorable since bitumen with higher softening point may be less susceptible to permanent deformation (rutting).



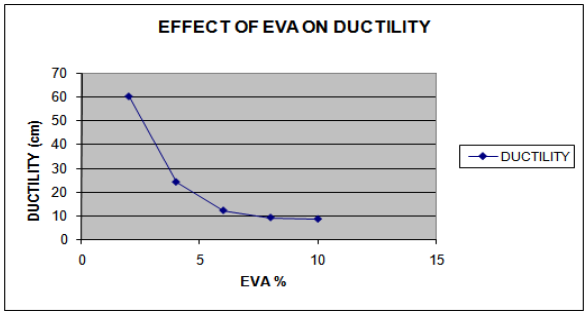
Graph showing the effect of EVA on viscosity.



Graph showing effect of EVA on penetration.



Graph showing the effect of EVA



Graph showing the effect of EVA on ductility on softening point.

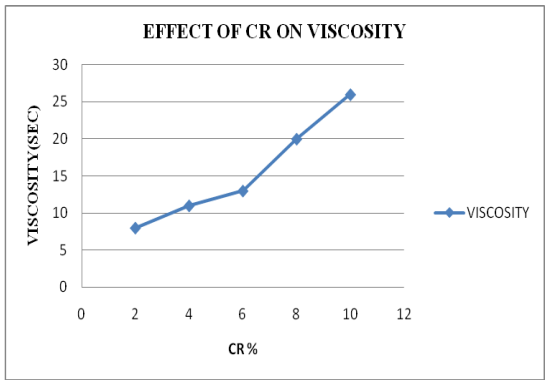
The graph shows that the ductility of bitumen decreases as the EVA polymercontent increases and it is not allowable to increase the % of EVA more than 4%. The CR was used as second modifying polymer in our study which was obtained from local maruti motor show room. The bitumen was modified with CR with different percentage same as done for the EVA.

CR Particles

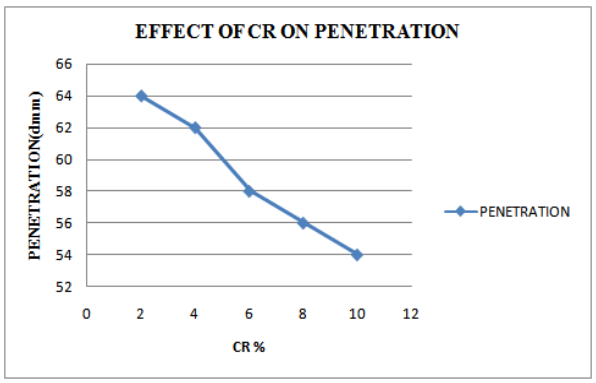
The test results were as follows:-

Test	Viscosity	Penetration (dmm)	Softening point(ºC)	Ductility (cm)
2%	8sec	64	47	97
4%	11sec	62	49	76
6%	13 sec	58	52	72
8%	20 sec	56	54	71
10%	26 sec	54	56	71

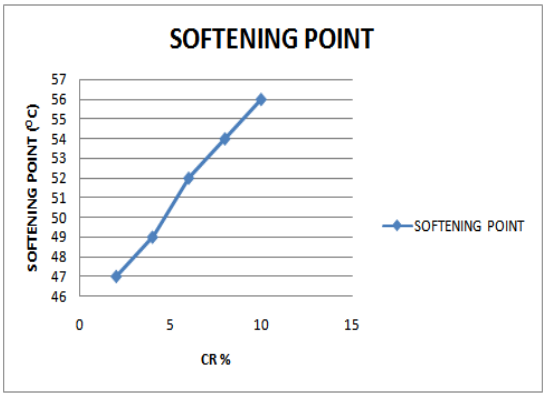
Result of Plain Bitumen + EVA



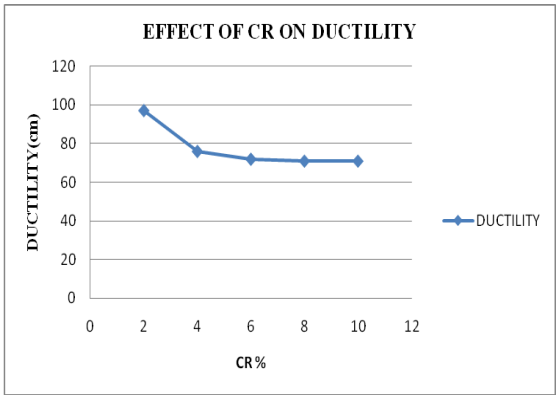
Graph showing effect of CR on viscosity



Graph showing effect of CR on penetration



Graph showing effect of CR on softening point



Graph showing effect of CR on ductility

Results of Penetration, Softening Point and Elastic Recovery tests have been presented in Table 3. Based on obtained results, it could be concluded that, CR had considerable effect on stiffness and elastic properties of studied bitumen. Absorption of maltene phase by CR increases the asphaltene part of bitumen. Furthermore, the stiffness of CR particles is more than bitumen. Hence, increasing the CR content leads to increased stiffness.

V. Conclusion

- The study shows that the physical properties of the plain bitumen are increased by modification of EVA polymer and crumb rubber.
- Pavements made with modified bitumen are more resistant to fatigue, thermal cracking, rutting and temperature susceptibility than neat bitumen.
- As the EVA polymer and crumb rubber increases the penetration of the modified bitumen decreases.
- As the penetration value decreases the bitumen becomes harder, due to this the quality of bitumen improves.
- The viscosity of the modified bitumen increases with the increase in EVA polymer and crumb rubber.
- Increased viscosity indicates the stiffening effect of EVA and crumb rubber modification.
- The softening point of bitumen increases with increase in percentage of EVA polymer and crumb rubber.
- Polymer modification using EVA improves the physical properties of bitumen in the temperature region where the material is used as a surface coating.
- EVA modification causes increasing softening point and decreasing penetration.
- The modified bitumen also has high elasticity.
- The study presented the application of CR modifier in bitumen modification of flexible pavement.
- The results of viscosity, penetration, softening point, ductility shows that the CR can be used as modifier in hot mix bitumen to improve resistance to rutting and produce pavement with better durability.
- The road users would be insure of safer and smoother roads.

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