EXPERIMENTAL STUDY ON THE APPLICATION OF POLYMER MODIFIED BITUMEN IN THE FLEXIBLE PAVEMENT

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ABSTRACT

The road transport facilities play a vital role in deciding a countries economy status. Developing countries like India mainly depends upon their road networks for transportation. To provide a road network which can perform for a longer period is the need of the hour. The main failure of a pavement is due to its permanent deformation, which is a result of the poor performance of the bitumen used as a binder. The Development of polymer modified bitumen composites gaining momentum due to its vast application in the field of flexible pavements, since it can produce pavements with longer life. A series of polymer modified bitumen samples were prepared using different varieties of polymer like PVP and PVA in different percentages of polymers starting from 3% to 7% and for WP its in the range of 1% to 5%. These polymer modified bitumen was characterized for its physical properties using some advanced analytical tools. Basic empirical tests were also carried out to check whether it obeys the basic properties of the binder. The polymer modified bitumen was also subjected to study its mix characteristics. The tests result concludes that there is a notable improvement in the properties of the bitumen when it is modified with polymers. A detailed discussion of the results obtained were also done in this project work. The study also concludes that the research on polymer modified bitumen paves a newer way in the area of flexible pavement construction.

Keywords: bitumen, PVA, PVP, WP, Polymer modified bitumen.

INTRODUCTION

The Development of polymer modified bitumen composites gain momentum due to its vast application in the field of flexible pavements. Bitumen is a visco-elastic material where temperature and rate of load application have a great influence on its behavior. Conventional bitumen is exposed to a wide range of loading and weather conditions; it is soft in a hot environment and brittle in cold

weather. Higher traffic volume produces high stress within pavement layer, which is one of the main causes for pavement distress. Fatigue cracking and permanent deformation is considered as most serious distresses associated with flexible pavements.

These distresses reduce the service life of the pavement and increase the maintenance cost. To reduce the pavement distresses there are different solutions such as adopting new mix design.

Considerable research in recent years is going on in the polymer modified bitumen to improve the performance of the bitumen in the flexible pavements. Modified bitumen provides the diversified properties needed to build better performing roads.

Nowadays, polymer technology is considered as a permanent part of the highway construction. On the other hand, using crumb rubber from scrap tiers, waste plastics, e waste and other waste related to polymers as asphalt modifier helps to solve serious environmental problems and to improve the pavement performance.

The main advantage of using polymer technology is to improve the adhesion properties between the binders and aggregate. The properties of modified bitumen depend on the modifier type with respect to modifier content and bitumen type. Three different types of polymers were used includes PVA, PVP and waste plastics. The modified bitumen prepared using these polymer shows positive results, which makes this modified bitumen to be used in pavement applications. A detailed study in this regard is discussed in detail in this project work.

Definition of Bitumen

The term bitumen is used by European and Eastern countries, whereas the term asphalt is used by Americans. The sources of bitumen can be classified into two categories. First bitumen is derivate from petroleum crude oil; second category includes the natural asphalt deposits.

Bitumen is a viscoelastic substance which behaves as an elastic solid at low temperatures or during rapid loading. At high temperatures or slow loading, it behaves a viscous liquid. This classical dichotomy creates a need to improve the performance of bitumen to minimize the stress cracking that occurs at low temperatures and plastic deformation at high temperatures.

Figure.1

The term bitumen consists of a wide variety of reddish brown to black materials of semisolid, viscous to brittle

character that can exist in nature with no mineral impurity or with mineral matter contents that exceed 50% by weight.

The American Society for Testing and Materials (ASTM) defines bitumen as a generic class of amorphous, dark coloured, cementitous substances, natural or manufacture composed principally of high molecular mass hydrocarbons, soluble in carbon disulphide.

Chemical Composition of Bitumen

Knowledge of bitumen chemistry has progressed rapidly as more sophisticated methods of analysis have been developed. There are a lot of techniques such as solvent Fractionation, thermal diffusion, sulphuric acid precipitation, adsorption and elution or by a combination of these procedures used for determining the composition of bitumen. The study of these fractions has been made by most available methods including infrared and ultraviolet spectrometry, x-ray analysis and electron-microscope techniques.

Bitumen is a mixture of hydrocarbons and compounds of a predominantly hydrocarbon character, varying both chemically and molecular size. These hydrocarbon components change from the no polar aliphatic wax compounds to highly polar condensed aromatics. Carbon and hydrogen compose approximately 90-95% of bitumen. The rest of the bitumen consists of heteroatom's such as nitrogen, oxygen and sulphur.

Uses of Bitumen

Bitumen, which has thermoplastic nature, water resistance and adhesion toward most other substances, is a primary engineering material. There are over one hundred different industrial applications or products in which bitumen is used. Almost every home, building or traffic area uses bitumen in different form. Bitumen has uses that range from the construction of the pavements of roads with an aggregate to waterproofing membrane in roofing and structural applications. Bitumen serves primarily as a binder in asphalt compacted mixtures which in turn are widely used in many types of road, street, runway and parking area applications. The other uses of bitumen are paints and coatings, paper, rubber products, electrical cables and other products of electrical industry.

Modification Methods

There are two types of modification. They are:-

1.Mixing the additives directly to the bituminous mixture to produce "modified mixture".

2.Mixing the additives to the bitumen to produce "modified bitumen".

In normal room temperature, the additives are generally solid. Despite they are starting to melt in 140^{O}C, to lower the mixing time mixing temperature is commonly chosen between 160^{O}C to 185^{O}C(Bulut, Palaoglu&Malkoc 2004). When hot mineral filler and aggregate come in contact with the additive, they relatively act as a wall between the bitumen and the additive, restraining the additive to modify the bitumen.

Considering mixing procedure has to be done with intensive care to produce homogeneous mixture and keeping in mind that, high shear mixtures could not be used for producing modified mixture, it may be reasonable to mix the additive to bitumen before adding the aggregates or mineral filler. In that case producing PMBs are likely to be cost effective than producing modified mixture except special conditions. This is the main reason this thesis is based on PMBs rather than modified mixtures.

Purpose of Modification

Nowadays a lot of different materials are being sold in the market in the name of bituminous additives or modifiers. The main purpose of using all the additives or modifiers in the bitumen is to enhance the properties of the bituminous mixtures. The main properties that are improved due to the modification of the bitumen are:-

- **Viscoelastic property of the bitumen modified positively**

When bitumen is modifies using the modifier the energy water spent to enter between bitumen film and aggregate increases and consequently the stripping resistance increases.

- **Increased fatigue resistance**

Due to the addition of the modifier polymer to the bitumen, the bitumens elasticity get increased and hence there will be decrease in the permanent deformation due to wheel load.

- **Temperature susceptibility increases**

The modification of bitumen using polymer improves the temperature susceptibility of bitumen by increasing binder stiffness at high service temperature and reducing stiffness at low service temperatures.

- **Stability increases**

The addition of polymer to the bitumen increases the elastic nature of the bitumen. Hence they provide very high resistance to permanent deformation.

- **Decrease in total cost of pavement**

The usage of modifiers may cause an increase in initial construction costs, but in time it should decrease the overall costs

of the pavement by significantly lowering the maintenance cost.

Polymers

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 therefore be made up of different numbers of the monomers and therefore they can have different 'chain length'. Only certain chain length 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.

The physical and chemical properties of a polymer will depend on the nature of the individual molecular units the number of them in each polymer chain and their combination with other molecular types. Consequently, the different polymers behave in different ways and generally the different PMBs have to tried out in bitumen applications before they can be considered suitable.

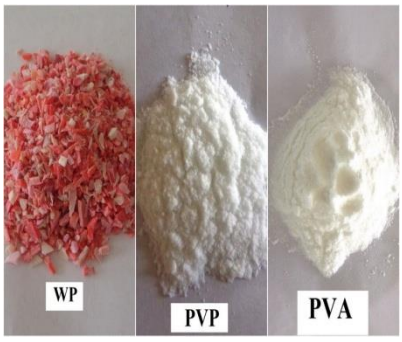


Figure.2

Polymers used for producing PMB

Despite the large number of polymeric products, there are relatively few types which are suitable for bitumen modification. When used as bitumen modifiers, selected polymers alone or blended with bitumen should be compatible with bitumen, be capable of being processed by conventional mixing and laying equipment and maintain their premium properties during mixing, storage and application in service.

Globally, approximately 75% of modified binders can be classified as elastomeric, 15% as plastometric with the remaining 10% being either rubber or miscellaneously modified(Airey2003). Plastomers modify bitumen by forming a tough, rigid, three dimensional network to resist deformation, while elastomers have a characteristic high elastic response and therefore resist permanent deformation by stretching and recovering their initial shape. Plastomers such as polypropylene, polyethylene, and PVC tend to improve the asphalt mixture stability and reduce deformation under load at high service temperatures (Patrick 2003; Wong et al.2004).Elastomers such as styrene-butadiene styrene, styrene isoprene, and polybutadiene tend to increase the elasticity of asphaltic mixtures and hence

improve their low temperature properties Lu and Isacsson 1998, 1999.

Properties of Polyvinyl Alcohol:

Polyvinyl alcohol has excellent film forming, emulsifying and adhesive properties. It is also resistant to oil, grease and solvents. It is odorless and nontoxic. It has high tensile strength and flexibility, as well as high oxygen and aroma barrier properties. The water, which acts as a plasticizer, will then reduce its tensile strength, but increase its elongation and tear strength. PVA is fully degradable and dissolves quickly. PVA has a melting point of 230°C and 180–190°C (356-374°F) for the fully hydrolysed and partially hydrolysed grades, respectively. It decomposes rapidly above 200°C as it can undergo pyrolysis at high temperatures.

Properties of Polyvinyl Pyrrolidone:

Polyvinyl Pyrrolidone is a water soluble polymer and it will acts as a good binder hence it is used in variety of industries. However it possess greater adhesive property and will give good flexibility when it is mixed with binders. Its glass transition temperature is 110-180^0c and its melting point is 150 to 180^0c. PVP is soluble in water and other polar solvents. When dry it is a light flaky powder, which readily absorbs up to 40% of its weight in atmospheric water. In solution, it has excellent wetting properties and readily forms films. This makes it good as a coating or an additive to coatings.

Properties of waste plastic polymer:

Plastics, a versatile material and a friend to common man become a problem to the environment after its use. Today, in India nearly 4 million tones of plastics are used and it is hoped to reach 12 million tonnes by 2010. Their visibility has been perceived as a serious problem and made plastics a target in the management of solid waste. Plastics are non-biodegradable. They also have very long lifetime. However, the end-of-life plastics can be recycled into a second life application but after every thermal treatment, degradation of plastics takes place to a certain extent. Hence this is the new conservative technology on utilizing plastic waste for bituminous pavements.

Polyethylene carry bags were cut into pieces using a shredding machine. It was sieved and the plastic pieces passing through 4.75mm sieve and retaining at 2.36mm sieve were collected. These plastic pieces were added slowly to the hot bitumen of temperature around 170-180^0C. The mixture was stirred well using mechanical stirrer for about 20-30 minutes. Polymer-bitumen mixtures of different compositions were prepared and used for carrying out various tests.

POLYMERS WITH BITUMEN

Many types of polymers are typically used in bitumen modification in different forms such as plastics. Mixing polymers into bitumen has important consequences on the engineering Properties of bituminous materials. The extent of modification and the improvements in the performance characteristics depend on bitumen nature, polymer chemical nature, it dosage and chemical compatibility, molecular weight, particle size, as well as blending process conditions such as type of mixing/dispersing device, time and temperature play important role in determining the modified bitumen properties.

Bitumen modification by polymers improves its mechanical properties, increases the viscosity, allows an expansion of temperature range of service and improves the deformational stability and durability of bitumen.

Methodology

Penetration Test

The penetration test is conducted as per ASTM D 1321for paving bitumen. Thus the basic principle of the penetration test is the measurement of the penetration(in units of $1/10^{th}$ of a mm) of a standard needle in a bitumen sample maintained at 25^{o}C during 5 seconds, the total weight of the needle assembly being 100 grams.

Softening point test

The test is conducted as per ASTM 3461. Bitumen does not suddenly change from solid to liquid state, but as the temperature increases, it gradually. becomes soften until it flows readily and it is determined by Ring and Ball apparatus.

Ductility test

The ductility test is standardized by the ASTM D 11307. The test is conducted at $27^{O}\pm0.5^{O}$C and a rate of pull of 50±2.5 mm per minute. The ductility is expressed as the distance in centimeters to which a standard briquette of bitumen can be stretched before the thread breaks.

Stripping Analysis

The stripping study was carried out to study the nature of the binding capacity of the PMB over the aggregate. As per the IRC coding a minimum of 5% stripping is allowed for flexible pavements. The study on the PMB with aggregate mix shows that there is no stripping even after 48hrs at 40^{0}c. The peeling out of the bitumen from the aggregate is called as the stripping value.

AGGREGATE TEST

1.Impact test

Aggregate impact value

= 25.41%

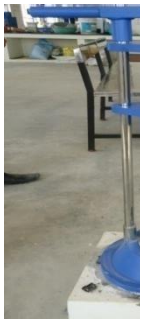
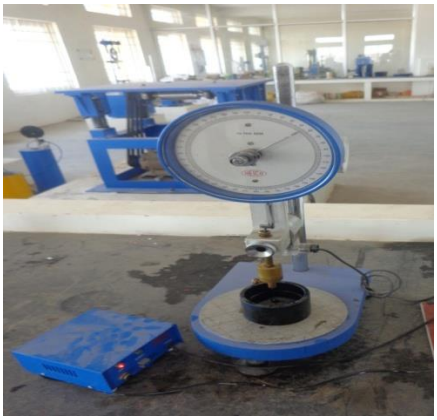


figure **2.Aggregate crushing value**

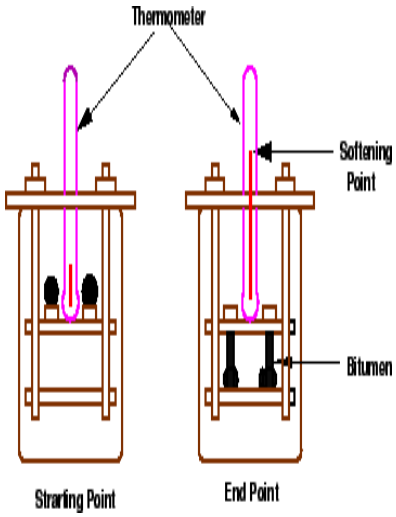
PMB TYPES	PENETRATION VALUES (mm)		
	3%	**5%**	**7%**
PLAIN	67		
PVA	67	64	60
PVP	65	63	60
WP	**1%**	**3%**	**5%**
	60	57	55

3.Penetration Test



Penetration values for PMB Samples

The modified or unmodified bitumen samples were heated until they have a liquid phase and were poured in the penetration cans, and then they were cooled to room temperature for 1-1.5 hours. Subsequent to the cooling process the samples were put in the 25ºC water bath for 1-1.5 hours. They were removed out of the water bath and put in a container filled with 25ºC water. A weight of 100 grams for 5 seconds was applied to the sample by the penetration device.(figure 8.2) and the mechanism of penetration is given in Figure 8.2.1.The penetration value on the indicator was noted



4.Softening Point Test

A container was filled 9cm high with 5^{o}C pure water. Bottom of the ring contains the bitumen sample placed 2.5 cm higher than the bottom of the container. In this time marble is placed on the ring. The temperature of the water bath, hold constant on 5^{o}C for 15 minutes. Then the heater set to increase the temperature of the water bath by 5^{o}C per 3 minutes. The temperature when the marble hit the bottom of the container has been noted as softening point.

PMB TYPES	**SOFTENING POINT (^{O}C)**		
	3%	**5%**	**7%**
PLAIN	41		
PVA	49	48	47
PVP	45	46	40
	1%	**3%**	**5%**
WP	47	49	52