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Research Article

Influence of VG30 Grade Bitumen with and without reactive Ethylene Terpolymer (Elvaloy® 4170) in short term aging

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Abstract

Age solidifying of bitumen is induced by chemical and/or physical changes and is usually accompanied by hardening of the binder. In road applications, binder is exposed to aging at three different stages: storage, mixing, transport and laying, as well as during service life. India is a country having varied climate and excessive stress and strains on the road in a limited road space is there. The pavement deterioration is experienced due to high and low temperatures in some region. Further deterioration is due to increase in traffic density, axle loading and tyre pressure and an insufficient degree of maintenance. Moreover, exorbitant solidifying can likewise debilitate the grip between the bitumen and total, bringing about loss of materials at the surface layer what's more produce debilitating of the bitument mixture. In order achieve desired engineering properties, it is utmost important to modify the binders by adding additives for application of road bituminous mixes with higher performance. The chemistry of binder is very complex and is even more complex after the admixture of modifier. In the present study, physical properties of VG 30 grade bitumen with and without reactive ethylene terpolymer (Elvaloy® 4170) is found. The short-term aging of bitumen binder is simulated in the laboratory by conditioning a thin film oven test at a high temperature, for a short duration.

Keywords: *modifier, bitumen, aging, ethylene terpolymer.*

1. Introduction

Transport infrastructure is the lifeblood of modern society, but often struggles to meet demands and expectations on reliability, availability, maintainability, safety, environment, health and cost is there. India is a very vast country, having widely varying climate, terrain, construction materials and mixed traffic both in terms of loads and volume. Road performance is determined by properties of bitumen. Ageing or hardening of bituminous binder occurs during mixing and lay down process and during service life of pavement. Bitumen ageing is one of the principal factors causing negative change of physical structures and chemical compositions gradually with time due to heat, oxidation, ultra violet radiation and loss of volatile constituents resulting in the deterioration of its physical behaviors. Binder modification is a major breakthrough and the continuous research and is aiming to produce new binders with better rheological and mechanical characteristics which allow the manufacturing and application of road bituminous mixes with higher performance. The purpose of bitumen modification using polymers is to achieve desired engineering service properties. In this study, reactive ethylene ter polymer (Elvaloy® 4170) is used to modify the properties of asphalt binder (VG 30). An attempt is made to determine the characteristics of bitumen for compatibility criteria with and without additive reactive ethylene ter polymer (Elvaloy® 4170), which includes penetration test, softening point test, elastic recovery test and viscosity test. To determine the effect of heat (163°C) and air on short term aging, simulation lest is carried out in the laboratory using thin film oven test.

2. Some selected previous research work:

Rheology of asphalts modified with glycidyl-methacrylate functionalized polymers in this paper it states that asphalt is known to be a colloidal suspension in which asphaltenes are covered by a stabilizing phase of polar resins and form complex micelles that are dispersed in the oily maltenic phase. In order to enhance its mechanical properties (e.g., in road paving), asphalts are often loaded with polymeric materials, thereby obtaining blends that can have different physical or chemical structures, depending on the composition of the added polymer. Asphalts modified by the addition of reactive ethylene ter polymers were prepared and their dielectric and rheological properties were measured both before and after a cure at high temperature. Even if it is not possible to determine the exact nature of the chemical interactions between asphalt and polymer, master curves obtained from dynamic data clearly show that during the cure the material tends to the behavior of a cross-linked network (Giovanni Polacco, Jiri

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Stastna, Dario Biondi, Federico Antonelli, Zora Vlachovicova, Ludovit Zanzotto 2004).

Asphalt rubber versus other modified bitumen states that Asphalt rubber and rubberized asphalt samples were produced using various available, public recipes and their properties were compared to different laboratory and bitumen terminal / refinery produced linear and radial type of styrene-butadiene-styrene block copolymer (SBS), SBS-polyphosphoric acid (PPA), ethylene-vinyl-acetate (EVA) and Elvaloy modified bitumen. The aging characteristic of asphalt rubbers was found to be always better than the unsaturated polymer contained modified binders, however the confidence range of standards testing methods showed higher variability due to in homogeneity of the rubber modified binders. Asphalt rubber had the highest, while Elvaloy resulted the lowest viscosity at all tested temperatures. Elasticity of SBS modified bitumen's were found to be the best, while cold performance were significantly improved by rubber modified binders due to the presence of crumb rubber particles. It was found that an appropriately designed and manufactured asphalt rubber binder can replace SBS, SBS-PPA or EVA, Elvaloy modified bitumen. However it should be considered that the main objective is probably not this but to increase utilization of rubber modified bitumen versus common non-modified bitumen (Szabolcs Biro-Bence Fazekas *et al*, (2005)).

Polymer-Modified Bitumen using Ethylene Terpolymers highlights that polymer modified bitumen (PMB) is used in various construction applications, especially in motorways. The aim of this study is to improve features of 60/70 penetration grade, modified bitumen used on highways. Increasing the sensitivity to temperature and oxidation resistance are very important points for the modified bitumen. This condition was provided by reacting the carboxylic acid groups in asphaltene with the reactive ethylene terpolymer to form ester. Reactive ethylene terpolymer (RETP) and ethylene terpolymer (ETP) manufactured by DuPont USA were used as additives in this study. Infrared Spectrophotometer (IR) graphics and optical pictures of the modified bitumen have been examined. It has been observed that the softening point has increased on the other hand, the penetration and ductility values have decreased according to the test results (S. Keyf, O. Ismail & B. D. Çorbacioğlu *et al*, (2007)).

The modification of bitumen with reactive ethylene terpolymer, styrene butadiene styrene and variable amounts of ethylene vinyl acetate states that 50/70 penetration graded TUPRAS bitumen was modified. Reactive elastomeric terpolymer (Elvaloy RET) from DuPont, ethylene vinyl acetate (EVA) and styrene butadiene styrene (SBS) polymers were used in the bitumen modification. Set hours of the tests were applied to samples taken from the obtained modified bitumen mixture, and 1 % reactive ethylene terpolymer, 1 % SBS and 0.5, 1, 1, 5, 2, and 2.5 % EVA (w/w) were added to the raw bitumen. Penetration, penetration index, softening point, ductility and % elastic recovery tests were performed with the modified bitumen and raw bitumen. The samples of raw bitumen and modified bitumen with 2 % RET, 1 % SBS and 1 % EVA were investigated by means of IR spectroscopy (FT-IR) and thermo gravimetrical analysis/differential thermal analysis (TG/DTA). The raw bitumen was modified with RET, SBS and EVA, and it was determined that the penetration and ductility values were decreased while the penetration index, softening point and % elastic recovery were increased. The most important characteristics (such as softening point, penetration and % elastic recovery) of the new polymer-modified bitumen (NPMB) containing 2.5 % EVA, 1 % RET and 1 % SBS were compared with eight different types of polymer-modified bitumens in Turkey (TPMB). NPMB provided all the required parameters (softening point, penetration and % elastic recovery) for two different types of TPMBs (TPMB 70-16, TPMB 70-22) (S.Keyf *et al*, (2013)).

Rheological Properties of Oxidized Bitumen with Polymer Additive concludes that rheological properties of bitumen of grade BND-90/130 obtained from crude oil of Westrern Siberia (Russia) by the direct oxidation method and polymer binder, obtained by adding in pure bitumen the polymer Elvaloy 4170 are investigated. Binders in initial state and after short term aging at high and average temperatures were tested on Dynamic Shear Rheometer (DSR) and at low temperature after double aging-on the Bending Beam Rheometer (BBR). The obtained results showed that in all cases of testing operational properties of polymer-bitumen binder is significantly better than pure bitumen (Teltayev Bagdat, Izmailova, Galiya and Amirbayev Yerik et al, (2014)).

3 Experimental Programme

3.1 Materials

In this study the following materials are taken into consideration for carrying out experiments:

3.1.1 Bitumen

Viscosity Grade –30 bitumen supplied by the Tiki Tar Industries, Halol Vadodara district is used to construct extra heavy duty bitumen pavements in warmer climate to have greater mix of design, better road performance and load carrying capacity.

3.1.2 Modifier

Commercially available Elvaloy® 4170, the most chemically reactive grade of elastomeric terpolymer was chosen in the experiment for modifying asphalt. It had a density of 0.94 g/cm³, and melting point of 72°C. Its chemical structure provides both elastomeric and chemical stability to asphalt allowing no polymer separation and therefore it is called a stable and homogenous mixture PMB. In this study Elvaloy® 4170 is added to un-aged bitumen in dosages of 1.5%, 1.8% and 2% only by weight of bitumen. It has the properties to improve long term resilience and climate resistance, better resistance to rutting, reduced cracking and fatigue.

Table 1: Physical properties of un-aged bitumen

Binder type	Penetration at 25°C (mm)	Softening point (°C)	Elastic recovery at 15 °C, (%)	Dynamic Viscosity in Poise @135°C	Specific gravity
VG-30	52	50	20	2.6	1.39
1.5%Elvaloy® (RET)	48	58	65	7.9	1.020
1.8%Elvaloy® (RET)	41	65	73	8.6	1.022
2%Elvaloy® (RET)	38	71	75	8.8	1.026

Table 2: Physical properties after TFOT ageing

Binder type	Penetration at 25°C(mm)	Softening point, (°C)	Elastic recovery at 15°C, (%)	%Loss of weight after TFOT
VG-30	48	51	16	0.05
1.5%Elvaloy® (RET)	40	60	63	0.06
1.8%Elvaloy® (RET)	35	67	69.5	0.05
2%Elvaloy® (RET)	31	74	70	0.04

3.2 Preparation of modified binders

To 1.5 liter capacity metal container around 500 g of the bitumen was warmed to liquid condition. The blending was performed in the research center utilizing a broiler fitted with a mechanical stirrer and pivoted at 1550 rpm for blending the bitumen and modifiers. For readiness of mixes VG30 bitumen was warmed to a temperature of 180 °c. To it Elvaloy® 4170 (reactive ethylene terpolymer) white pellets (1.5, 1.8 and 2%) were added to the bitumen for blending for 80-90 min to make a homogenous mixture

3.3 Testing

3.3.1 Brookfield Viscometer (ASTM D4402)

It was used for determining the kinematic viscosities of the samples at 135°C for 5 min. at 20 rpm. The rotational viscosity was determined by measuring the torque required to maintain a constant rotational speed of 20 rpm of a cylindrical spindle submerged in bitumen maintained at the test temperature through thermosel.

3.3.2 Short term aging test

Ageing of the binders was performed by thin film oven test (TFOT, ASTM D1754). Samples of VG30 with and without additive Elvaloy® 4170 (reactive ethylene terpolymer) are placed on a rotating disc for 5 hr at 163ºC. The loss of volatile fractions contributes to the difference in weights between original and aged sample. The maximum loss in weight should be 1 per cent as per IRC: SP: 53:2002.

4. Test Results and Discussion

4.1 Before ageing

4.2 Physical properties of VG-30 bitumen before aging (table 1)

4.2.1 Penetration test result

Penetration measures the bitumen consistency. There is a significant decrease in penetration values for modified blends as the percentage is increased using Elvaloy® 4170 (reactive ethylene terpolymer), indicating the improvement of bitumen becoming harder and more consistent. This is good in one sense since it might improve the rutting resistance of the mix.

4.2.2 Softening point result

The increase in softening point is an indicator of stiffening effect with the addition of reactive Elvaloy (®RET) in suitable dosages with VG 30 bitumen is favorable; this phenomenon indicates that the resistance of the binder to the effect of heat is increased and it will reduce its tendency to soften in hot weather. Thus, with the addition of the modified binder will be less susceptible to temperature changes. Hence at heavy traffic areas VG 30 modified by reactive ETP is more favorable.

4.2.3 Elastic recovery results

The ability of the modified binder to recover after stretching is related to the modification agent Elvaloy® 4170 (reactive ethylene terpolymer) used. Table 1 shows that increase in percentage of Elvaloy® 4170 (reactive ethylene terpolymer) contributes to higher value of elastic recovery owing to improved homogeneity indicates more flexibility to the binder and will increase the life of pavement at low temperature.

4.2.4 Specific gravity test

The results demonstrate that the particular gravity quality diminishes essentially by changing the chemistry of bitumen by addition of reactive ETP in suitable doses. The diminishment signifies the decrease in aromatic type mineral impurities with reduction in density thereby maintains stiffer bitumen in hotter temperatures. It substantially reduces rutting and increases stability.

4.2.5 Viscosity Test

Viscosity is synonymous with internal friction and is a measure of the resistance to flow. The thickness is an

essential designing parameter which shows increments on presentation of Elvaloy® 4170 (reactive ethylene terpolymer) and this helps effortlessly pump the material into the HMA plant for blending and can be put to the site for road work.

4.2 After aging

4.3 Physical properties after aging (table 2)

4.4.1 Penetration test

The material gets to be stiffer after dissipation of unpredictable, material maturing solidifies and accordingly entrance worth reductions and the quality abatements as the rate of modifier.

4.4.2 Softening point test

There is an increment in softening point noted with expanding modifier content.

4.4.3 Elastic recovery test

The result got demonstrates an expanding example which shows the material as more adaptable to binder.

4.4.4 Loss in weight

The loss of unstable parts helps the distinction in weights between un-matured and matured specimen. The most extreme misfortune in weight is inside as far as possible as set down in codal procurement i.e. short of what 1%.

Conclusions

The systematic experimentations carried out in the laboratory to authentify the effect of short term aging using TFOT test on VG 30 bitumen with and without DuPont™ Elvaloy® ETP in dosages of 1.5%, 1.8% and 2.0 % reveals that as DuPont™ Elvaloy® ETP is a reactive polymer involves improving the performance when melt-blended and properly reacted with bitumen, shows permanently improving resilience of modified asphalt binder. It shows properties changing in the wake of recreating the base bitumen for enhancing the stiffness of bitumen and the loss of unpredictable weight loss due to helps the distinction in weights between un-aged and aged bitumen. The elastic recovery increases with increase in percentage of reactive ethylene ter polymer at 2.0%. It can be utilized as a part of high temperature and substantial activity zones and states the climatic conditions in which it ought to be utilized usefully. It has got opportunities for highway segment building organizations.

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