Effects Of Functionalized Polyethylene And Styrene ButadIene Styrene Polymers On Performance Grade Of Local Asphalt Binder

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Abstract

Rutting is one of the major distresses in pavement. The objective of this paper is to develop an improved asphalt binder grading system for Iraq based on the principal of Superpave system, and increasing performance grade of product asphalt binder in Iraq using polymers without raising the viscosity of the binder. Two types of polymers are used, Plastomers, Functionalized Polyethylene (PE) which is developed by asphalt research group in Wisconsin University in the USA, and Elastomers, Styrene Butadiene Styrene (SBS) with and without cross linker. Mastercurve are drown for these modified binders, Rolling thin film aged, to show effects on rheological properties at high temperature for complex modulus (G^*) and phase angle (δ). It concluded that 3.5% of Functionalized Polyethylene polymer (PE) is more effective than 4% of Styrene Butadiene Styrene (SBS) to shift up performance grade of local asphalt binder two grades to be PG (76-16). Furthermore, the viscosity of binders increasing about 200% when using 4 % SBS, while no significant effect on viscosity when using 3.5 % of PE, therefore, there is no need to increase temperature of mixing and compaction which may be effect on polymers In addition $G^*/\sin\delta$ is increased by a ratios of 1.6 to 2.96 for 2%, 4% respectively of SBS-based modifier (RTFO aged) and 1.4 to 3 for 2%, 3.5% respectively of PE-based polymers modifier. It can be seen that PE reduce $G^*.\sin\delta$ about 10%, while SBS increase $G^*.\sin\delta$ about 30% and PE reduces the stiffness of asphalt binder about 15 % at low temperature which make PE more effective, there is no significant effects on m-value.

KEYWORDS: **Superpave; Performance Grading; Modified Binder; Master curve, PE, SBS.**

الخلاصة

تخدد التبليط هو احد انواع الفشل الرئيسية في العراق، ان الهدف من هذا البحث هو تحسين درجة اداء الاسفلت العراقي اعتمادا على نظام التبليط الفائق، وزيادة درجة الاداء للاسفلت المنتج في العراق باستخدام البوليمرات بدون زيادة لزوجة الاسفلت. تم استخدام نوعين من البوليمرات، لدن، البولي اثلين الفعال (PE) المطور من قبل مجموعة باحثين الأسفلت في جامعة وسكونسن في الولايات المتحدة الامريكية ومرن، الستايرين بيوتادين ستايرين (SBS) مع وبدون الكروس لنكر. مع رسم المنحني الرئيسي للاسفلت المعدل ذو التقادم الزمني القليل الذي يمثل خواص سيولة الاسفلت في درجات الحرارة العالية لمعامل القص المعقد (G^*) ولزاوية الطور(δ) . وجد ان 3.5% من PE اكثر فعالية من 4% من SBS لزيادة درجة اداء الاسفلت درجتين ليكون PG(16-76). استخدام SBS يؤدي الى زيادة لزوجة الاسفلت الى الضعف (200%) بينما ليس هناك تاثير ال PE على اللزوجة يذكر، لذلك ليس هناك حاجة لزيادة درجة حرارة الخلط والانضغاط والتي ممكن ان تؤثر على البوليمرات. $G^*/\sin\delta$ تزداد بمقدار 1.6 و 2.96 عند استخدام 2% و 4% من SBS على التوالي كأسفلت معدل ذو تقادم زمني قليل، وتزداد بمقدار 1.4 و 3 عند استخدام 2% و 3.5% من الاسفلت المعدل بال PE على التوالي. $G^*.\sin\delta$ تقل بمقدار 10% عند استخدام PE وتزداد بمقدار 30% عند استخدام SBS. مقدار متانة الاسفلت تقل بمقدار 15% عند استخدام PE في درجات الحرارة المنخفضة والذي يجعل استخدام ال PE اكثر فعالية، ليس هناك تاثير من استخدام البوليمر على ال قيمة M.

Introduction

Polymer-modified asphalt binders are frequently and effectively used in the paving industry to improve pavement performance and to increase pavement life. Polymer modification is reported to reduce pavement cracking due to thermal stresses and repetitive loads and, especially, decrease rutting due to plastic deformation.

Application of modified asphalt concrete is more expensive than traditional asphalt pavement. Therefore, it is important that the polymer-modified pavement is manufactured and constructed properly to assure that the improvement in pavement performance and pavement life is achieved.

The use of polymer modified asphalt cements in pavement construction is an important step in increasing the life and durability of asphalt roads Polymer-modified asphalt is typically manufactured by adding Plastomers, “Functionalized Polyethylene (PE) polymer”, Elastomers “Styrene Butadiene Styrene (SBS) with or without cross linker”

Modification of asphalt binders is usually performed to improve one or more of the basic asphalt properties that are related to one or more of the pavement distress modes, the basic properties that have been targeted include Rigidity, Elasticity, Brittleness, Storage stability and durability, resistance to accumulated damage (Bahia et al 1995).

Objective

The objective of this paper is to analyze and select polymer-modified binders that may improve pavement performance without presenting extensive difficulties in mixing, when compared to traditional asphalt binders by considering influence of polymer types and concentration on the high temperature performance of polymer modified asphalt.

Rheological Properaties Of Local Asphalt Binder

Table 1 shows result of rheological properties measured for the Daurah asphalt binder. The testing included the rotational viscometer (RV), dynamic shear rheometer (DSR) and bending beam rheometer (BBR) for binders after different aging conditions, following the Superpave performance grading requirements, which are tested in Wisconsin University.

Polymers

Polymer means multiple "mer" unites, which can be linked together to form the polymers Link is formed by breaking the double carbon/carbon bond and allowing it to link with others to form. The physical structure of the polymers chain has a large effect on the mechanical properties of plastics. The number of monomers in each chain defines the degree of polymerization. The source of synthetic polymers many are produced from processing crude oil. They are commonly referred to as plastics. Properties depend on the polymer chain lengths, extent of cross-linking, radial compounds, and the production process.

Daurah asphalt is used as base binder and two types of polymers are used in this study, Elastomers “Styrene Butadiene Styrene (SBS) with or without cross linker” and Plastomers, new type of polymer developed by highway research group in Wisconsin University called “Functionalized Polyethylene (PE)”.

Polymers Concetration

Initially, 2% polymer concentrations are selected for each polymer, and 0.123 % of cross linker is mixed with 2% of SBS polymer. Based upon results, further polymer concentrations are determined, 4% of SBS and 3.5% of PE, for raising performance grade of Daurah asphalt binder two grades.

Preparation Of Polymer-Asphalt Mixes

To obtain SBS combination the initial mixing rate is about 250 rpm. Typically, the binder climbed the shaft of the mixer, and a spatula is used to prevent it from climbing into the mixer motor. The mixing rate is kept low enough to prevent the binder from climbing past the spatula. As the temperature of the binder raise, the mixing rate could be increased gradually. The mixing rate is increased every 10 minutes until the maximum rate of 1,000 rpm is reached for 4 to 4.5 hours and maintained the temperature of the sample at 180°C, which is necessary to obtain a uniform mixture, therefore, need to put heavy gas to prevent oxidation of binder. The polymers are added into the asphalt gradually for 0.5 hour. The temperature of the mixture is dropped immediately when the polymer are added, therefore, need to raise the temperature to 180°C. Mixing is completed when the modified asphalt no longer climbed the mixer shaft. a small spatula is dipped in the mix and smeared on clean, white paper. If the polymer grains are visible, the mixing process is incomplete. When the grains disappeared, the process is considered complete.

For obtaining modifying asphalt binder with Functionalized Polyethylene (PE) polymer is easier than asphalt modifying with SBS because the temperature of mixing is 145°C for 1.5 hour, therefore, there is no problem with oxidation.

Modification Of Asphalt Binder

The rheological properties listed in Table (1) of Daurah asphalt binder does not meet climate, traffic, and pavement structure requirements in Iraqi, therefore, it is very necessary to shift up the performance grade of local asphalt binder by adding modifier as one of the attractive approach to improve the asphalt binder properties that are related to one or more of the pavement distress modes. The basic properties that have been targeted include rigidity (total resistance to deformation which can be measured by complex modulus like G* under dynamic loading or by creep stiffness, S(t),under quasi-static loading), Elasticity (recovery of deformation using stored energy applied, it can be measured either by phase angle(δ) or by logarithmic creep rate (m)),brittleness (failure at low strains is the best definition of brittleness),storage stability and durability (oxidative aging, physical hardening and volatilization are key durability properties, resistance to accumulated damage (rutting and fatigue damage) (Bahia, 2009). The superpave binder specification contains criteria based on simply assumption test to match critical pavement performance, Anderson et al. 1994; Bahia et al. 1999 reported the most important assumption for neat and modification binders and concluded that stability of modified asphalt. It is noticed that effect of different polymers on failure properties is depend largely on the type of interaction between the asphalt and polymer, the molecular nature of the polymer additive, and the way of dispersion in the asphalt.

Result And Analysis

The superpave performance grading (PG) system is developed to evaluate binder properties at specific temperature with specific testing system. One of the main objectives of Strategic Highway Research Program (SHRP) was to develop test methods for characterization of asphalts that are equally applicable to unmodified or modified asphalt cements, collectively called asphalt binders (Anderson et al. 1994). A modifier can be selected to improve one or more of the main performance related properties of asphalts. Table 1 shows SHRP parameters obtained from superpave tests under various temperature for different types of modified binders at different concentration, it can be seen although PE modifier shifting up performance grade with same jump of SBS modifier but not significant effects on viscosity, therefore, there is no need to increase temperature of mixing and compaction which may be effect on polymers, Furthermore, 3.5 % of PE is used for shifting up the performance two grade while 4% of SBS is needed to achieve PG(76-16). Figure 1 depicts a bar chart of the ratios of the SHRP parameters for asphalt after modification with different concentration of the based polymer. The Figure indicates that there is a favorable trend in changes of all the performance parameter, G*/sinδ is increased by a ratios of 1.6 to 2.96 for SBS-based modifier (RTFO aged) and 1.4 to 3 for PE-based polymers modifier. It can be seen that PE would be reduced G*.sinδ about 10%, while increase 30% if SBS is added. PE reduces the stiffness of asphalt binder about 15 percent at low temperature which makes PE more effective, while there is no significant effects on m-value could be seen.

Master Curve Fof Modified Binders

Rheological properties can be represented either by the variation of G* and δ as a function of frequency at a constant temperature (commonly referred to as master curve) or by the variation of G* and δ with temperature at a selected frequency or loading time, commonly called isochronal curve (Bahia, 2009). To show the effect of modifiers type on G* and δ, master curves are drown in Figure 2 using dynamic shear rheometer for rolling thin film oven aged binder at 64^{o}C. It can be seen that G* increases while δ decreases. This indicates that an increase in rigidity and elasticity, which results better resistance to permanent deformation.

Conclusions

Two types of polymers are used in this study Plastomers “Functionalized Polyethylene (PE) polymer”, Elastomers “Styrene Butadiene Styrene (SBS) with or without cross linker”.

Table 1 shows SHRP parameters “performance grade” for Daurah asphalt binder which not much the requirements of climate and traffic for Iraq, therefore, it is very necessary to add polymer to the local asphalt binder.

It is noticed that 3.5% of Functionalized Polyethylene (PE) polymer is more effective than 4% of Styrene Butadiene Styrene (SBS) to shift up performance grade of local asphalt binder two grades PG (76-16). The viscosity of binders increasing about 200% when using 4 % SBS while no significant effect on viscosity when using 3.5% of PE, therefore, there is no need to increase temperature of mixing and compaction which may be effect on polymers. G*/sinδ is increased by a ratios of 1.6 to 2.96 for 2%, 4% respectively of SBS-based modifier RTFO aged and 1.4 to 3 for 2%, 3.5% respectively of PE-based polymers modifier. It can be seen that PE reduce G*.sinδ about 10%, while SBS increase G*.sinδ about 30% and PE reduces the stiffness of asphalt binder about 15 % at low temperature which make PE more effective. Furthermore, there is no significant effect on m-value. Master curve shows that using 2% of SBS, G* is increased by 12% than G* of asphalt binder modified with 2% of PE at 19.35 Hz frequency, and there is no significant change in δ.

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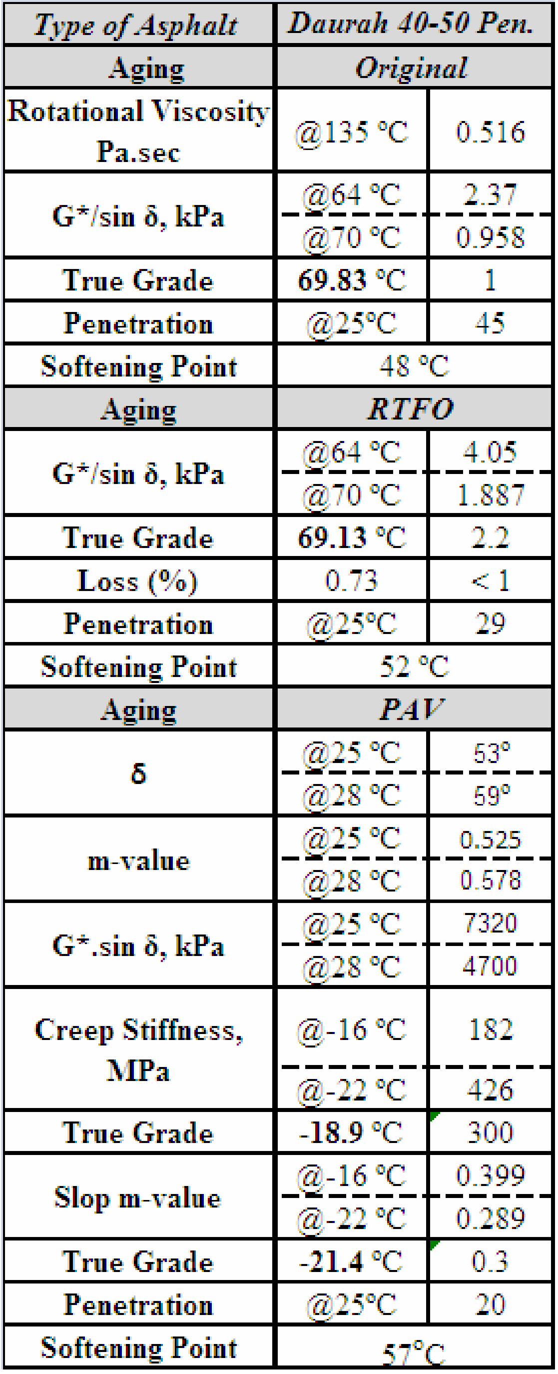
Table (1) Rheological Properties of Daurah Asphalt Binder



Type of Asphalt	*Daurah 40-50 Pen.*	
Aging	*Original*	
Rotational Viscosity Pa.sec	@135 °C	0.516
G*/sin δ, kPa	@64 °C	2.37
	@70 °C	0.958
True Grade	**69.83 °C**	1
Penetration	@25°C	45
Softening Point	48 °C	
Aging	***RTFO***	
G*/sin δ, kPa	@64 °C	4.05
	@70 °C	1.887
True Grade	**69.13 °C**	2.2
Loss (%)	0.73	< 1
Penetration	@25°C	29
Softening Point	52 °C	
Aging	***PAV***	
δ	@25 °C	53°
	@28 °C	59°
m-value	@25 °C	0.525
	@28 °C	0.578
G*.sin δ, kPa	@25 °C	7320
	@28 °C	4700
Creep Stiffness, MPa	@-16 °C	182
	@-22 °C	426
True Grade	**-18.9 °C**	300
Slop m-value	@-16 °C	0.399
	@-22 °C	0.289
True Grade	**-21.4 °C**	0.3
Penetration	@25°C	20
Softening Point	57°C	

Table 2 Effect of Modification Binder on SHRP Parameters

Type of Asphalt	*Daurah 64-16 NEAT*		*Daurah 70-16 2%SBS*		*Daurah 76-16 4%SBS*		*Daurah 70-16 2%SBS+CRLINK*		*Daurah 70-16 2%PE*		*Daurah 76-16 3.5%PE*	
Aging	*Original*		*Original*		*Original*		*Original*		*Original*		*Original*	
R.V@135 °C Pa.sec	0.516		0.84		1.56		1.04		0.547		0.563	
G*/sin δ, kPa	@64 °C	2.37	@70 °C	1.4	@76 °C	1.15	@70 °C	1.88	@70 °C	1.983	@76 °C	2.2
	@70 °C	0.958	@76 °C	0.696	@82 °C	0.621	@76 °C	0.991	@76 °C	1.054	@82°C	1.725
Aging	*RTFO*		*RTFO*		*RTFO*		*RTFO*		*RTFO*		*RTFO*	
G*/sin δ, kPa	@64 °C	4.05	@70 °C	3.03	@76°C	2.35	@70 °C	2.79	@70 °C	2.646	@76 °C	2.391
	@70 °C	1.887	@76 °C	1.47	@82 °C	1.23	@76 °C	1.51	@76 °C	1.329	@82°C	1.329
Loss (%)	< 1		< 1		< 1		< 1		< 1		< 1	
Aging	*PAV*		*PAV*		*PAV*		*PAV*		*PAV*		*PAV*	
δ	@25 °C	53°	@25 °C	52°	@28 °C	52°	@25 °C	54°	@25 °C	55°	@25 °C	52°
	@28 °C	59°	@28 °C	56°	@31 °C	55°	@28 °C	62°	@28 °C	59°	@28 °C	56°
G*.sin δ, kPa	@25 °C	7320	@25 °C	7540	@28°C	6060	@25 °C	7445	@25 °C	7363	@25 °C	6993
	@28 °C	4700	@28 °C	4760	@31 °C	4140	@28 °C	2790	@28 °C	4560	@28 °C	4444
Creep Stiffness , MPa	@-16 °C	182	@-16 °C	206	@-16 °C	215	@-16 °C	225	@-16 °C	181	@-16 °C	158
	@-22 °C	426	@-22 °C	454	@-22 °C	471	@-22 °C	480	@-22 °C	419	@-22 °C	380
Slop m-value	@-16 °C	0.399	@-16 °C	0.363	@-16 °C	0.329	@-16 °C	0.372	@-16 °C	0.396	@-16 °C	0.372
	@-22 °C	0.289	@-22 °C	0.269	@-22 °C	0.278	@-22 °C	0.281	@-22 °C	0.289	@-22 °C	0.266

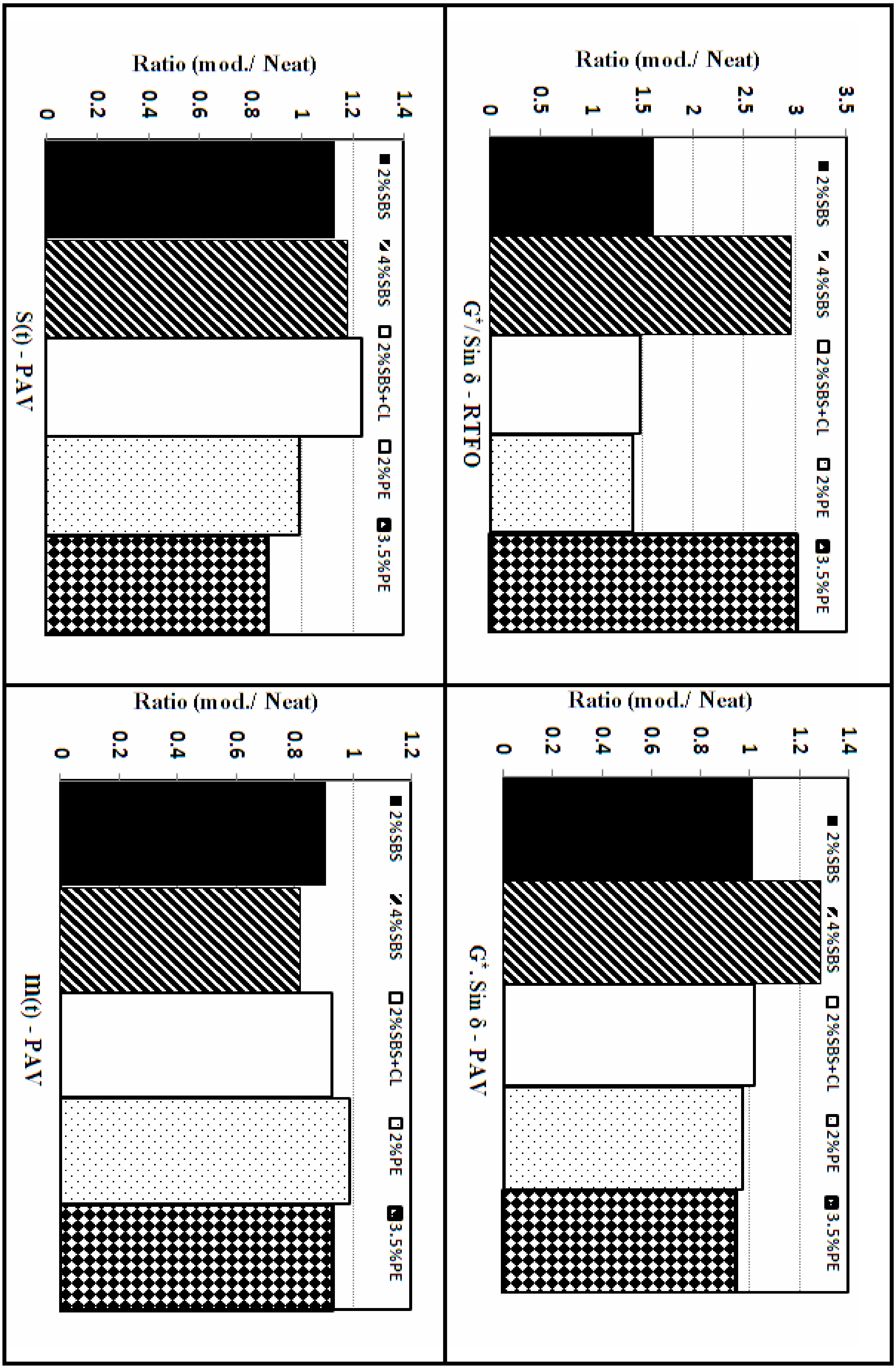


Fig. 1 Change in Performance Grade Parameter

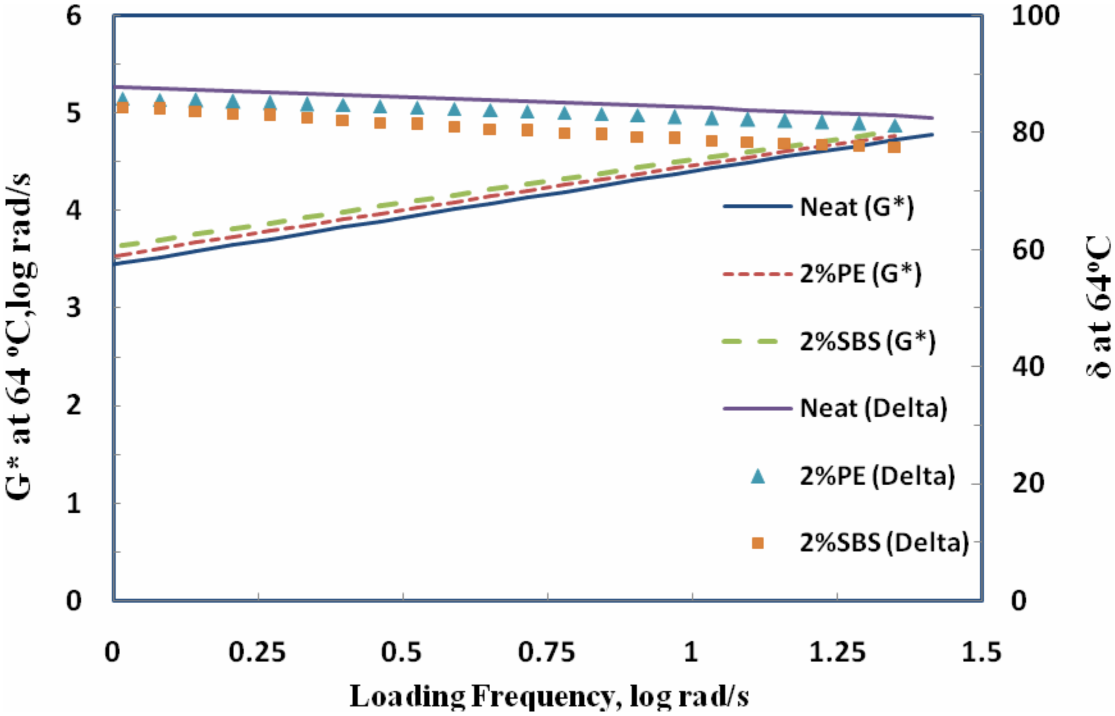


Fig. 2 Master Curve of Neat and Modified Asphalt at 64°C.