EVALUATION OF PERFORMANCE GRADES AND POLYMER DISPERSION OF POLYMER MODIFIED BINDERS

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ABSTRACT

In contrast to conventional binder grading system relying basically on needle penetration and viscosity, performance grading system can be used for classification of both neat and modified binders and constitute one of the most prominent focus area for Bituminous Binders Technical Committee CEN/TC 336. In this study, the four different penetration grade bitumen samples from the all four crude oil refineries of Turkey, one is of distinctly higher asphaltene content, were modified with SBS, Elvaloy, SBR and Lucobit modifiers. Both unmodified and polymer modified bitumens were subjected to conventional and SHRP binder performance tests, namely penetration, softening point, force ductility, rotational viscometer (RV), rolling thin film oven (RTFO), dynamic shear rheometer (DSR) and bending beam rheometer (BBR). Additionally, SARA (saturates, aromatics, resins and asphaltenes) contents of neat bitumens by thin layer chromatography and polymer dispersion of modified binders by fluorescent microscopy as per EN 13632 were determined to correlate with performance grades. The results showed the base bitumens of the high aphaltene content refinery and its modified bitumens have generally one grade better performance grade than the others, which was verified by polymer dispersion tests. This paper presents all the details of the test results and evaluations.

Keywords: Dynamic Shear Rheometer, Bending Beam Rheometer, Polimer Modifed Bitumen, SARA Content, Polimer Dispersion, Fluorescent Microscopy

1. INTRODUCTION

The performance of road pavements is highly dependent on the type of bitumen to be used. In fact, three major distress types in pavements are thermal cracking in low temperature, fatigue cracking in intermediate temperature and permanent deformation in high temperature and the role of the bitumen in those distresses is such a high level that it is roughly %90 in thermal cracking, %60 in fatigue cracking and %40 in permanent deformation [3]. Therefore, the serviceability of roads with long service life and low maintenance cost significantly depends upon the use of proper type of bitumen required for climate and traffic conditions.

Conventional binder classification system is based on simple concept of consistency characterized by penetration and softening point test related to in-service temperature and viscosity test related to mixing and compaction temperature. These empirical tests based on experiences and only valid for penetration grading are not directly related to performance of pavement.

However, bitumen specifications are being evolved rapidly from conventional methods to performance specifications, namely Superpave binder specification, entailing mechanical and rheological tests for binders in all temperature ranges the pavement can be exposed to. In this system, binder is classified on the basis of temperature ranges that binder can resist without failure using some newly introduced rheological parameters such as complex modulus, phase angle, stiffness, m-value and rotational viscosity. Furthermore, traffic volume and vehicle speed are taken into account in Superpave as well as short term and long term binder aging.

2. SUPERPAVE BINDER GRADING SYSTEM

Due to inadequency of penetration and viscosity based grading systems, the Strategic Highway Research Program (SHRP) in US conducted a Project between 1987 and 1993 in order to overcome the shortcomings of empirical systems. One consequence of this Project was a performance based binder specification with a new set of tests. The final product of the SHRP bitumen research program is a new system referred to as SUPERPAVE, which stands for Superior Performing Asphalt Pavements and called as binder specification because it is intended to function equally well for modified and unmodified bitumens.

In Superpave grading system, binders are classified according to their performance in extreme hot and cold temperatures and called as performance grading (PG) bitumens. The main purpose of grading and selecting asphalt binder using the PG system is to make certain that the binder has the appopriate properties for environmental conditions in field. PG asphalt binders are selected to meet expected climatic conditions as well as traffic speed and volume adjustments. Therefore, the PG system uses a common set of tests to measure physical properties of the binder that can be directly related to field performance of the pavement at its service temperatures by engineering principles.

It is one of the most important changes introduced in Superpave that acceptance limits are the same but have to be met at specific pavement temperature and traffic conditions. In other words the grading is based on pavement conditions (temperature and traffic) but all grades meet the same criteria. Actual climatic conditions of the regions where bitumen is to be used play very important role in the selection of the binder.

The Superpave performance grading (PG) specification classifies asphalt binders into performance grades that change at 6°C intervals according to the service temperature. As an example, in Superpave Performance Grade Bitumen PG 64-22, PG indicates that it is a performance graded binder. The first number (64) means that the binder meets high temperature physical properties up to 64 degrees centigrade. The last number (-22) indicates the binder meets low temperature physical properties down to -22 degrees centigrade. These numbers also correspond to average seven day maximum pavement temperature and minimum pavement temperature respectively for a level of reliability determined using temperature data from weather stations in the region where binder is to be used.

2.1. Superiorities of Performance Grading

1. Traditional penetration and viscosity bitumen grading systems were developed in accordance with the past experiences. The aim of these empirical procedures is to avoid bad applications in the past and repeat those are successful. Empirical methods can be applicable as long as the past conditions still exist. But, current traffic and climatic conditions are highly different from those prevailed when penetration and viscosity systems were developed, hence past experiences are no longer sufficient to establish binder grading. In PG system, it is possible to use actual traffic volume and vehicle speed which represents the duration of load application.
2. Conventional tests is conducted at unique test temperature which is 25 ^{o}C in penetration and d 60 ^{o}C in viscosity test, which means that penetration test does not give any information about low temperature and high temperature performance. Superpave grading indicates working temperature range of binder.

3. Bitumen is a visco-elastic material where temperature and rate of load application have a great influence on its behavior. Although behavior of bitumen in lower loading rates corresponds to that of higher temperature, conventional grading systems does nor take into account the rate of load but Superpave does.
4. Binders of different petroleum source may have different rheological behavior even though they are same penetration or viscosity grade.
5. Conventional methods is used only for unmodified bitumens, whereas Superpave is developed for both modified and unmodified bitumens.
6. Conventional methods do not take into account long term aging behavior of binders. But Superpave cover both short term aging using the rolling thin film oven test (RTFOT) and long term aging using with the pressure aging vessel (PAV).
7. It recognizes that there are three main distress mechanisms affecting pavement performance, rutting, fatigue cracking and thermal cracking. Bitumen plays a very important role in resisting each of these distress mechanisms.
8. Bitumen properties measured at different temperatures contribute to resistance to the distresses in different level. Bitumen contributing to rutting resistance is measured at maximum pavement temperatures and it favours a more elastic and more stiff binder. Bitumen contributing to fatigue resistance is most critical at average pavement temperatures and while it still favours an elastic binder it requires a softer bitumen. Bitumen contribution to thermal cracking is critical only at minimum pavement temperatures and it favours a less elastic and soft bitumen.

2.2. Superpave Performance Graded Binder Tests

One goal of the Superpave is to measure the binder physical properties directly related to field performance in different conditions. PG binders are tested under three critical conditions. That is, it is tried to find out the performance of binders in low, intermediate (service) and high temperatures. Besides this, Superpave enables ageing properties of binders to be tested. The binder is first tested for the stage of transport, storage, and handling. A rolling thin film oven is used to process the binder for the second stage, mix production and construction, by exposing binder films to heat and air that approximate exposure during mixing and laydown conditions. For the third stage, long term aging, the binder is aged using a pressure aging vessel. The pressure aging vessel exposes samples to heat and pressure to simulate years of in-service aging of a pavement.
The one of the most important advantages of Superpave is that binders can be analysed with respect to three major distress type of pavements, thermal cracking in cold temperature, fatigue cracking in service temperature and permanent deformation in high temperature. Permanent deformation generally takes place within a few years after construction. Since bitumen gets hardened over time due to oxidative ageing with environmental effects and the rate of the permanent deformations gradually decrease over time and fatigue cracking becomes critical. Similarly, thermal cracking is a distress type emerging in a long term period depending on brittleness of bitumen as a consequence of aging. Therefore, in Superpave Specification, tests for measurement of resistance to permanent deformation is done on un-aged and short time aged binders, whereas fatigue and thermal cracking tests are performed on binder samples which are short term aged with RTFOT and long term aged with PAV. Other test done under Superpave is rotational viscosity test to measure the workability and handling properties of bitumen at the temperature of 135 ^{o}C. The Superpave tests and their purpose of use is given in the table below.

The name of test	**Binder to use**	**Purpose of the Use**
Rolling Thin Film Oven Test (RTFO)	Original Binder	Short Term Aging
Pressure Aging Vessel (PAV)	RTFO Aged Binder	Long Term Aging
Dynamic Shear Rheometer (DSR)	Original Binder	Behaviour in the high temperature (Permanent Deformation)
	RTFO Aged Binder	
	RTFOT and PAV Aged Binder	Behaviour in the intermediate temperature (fatigue Cracking)
Rotational Viscometer (RV)	Original Binder	Determination of workability temperature
Bending Beam Rheometer (BBR)	RTFOT and PAV Aged Binder	Behaviour in the low temperature (thermal cracking)
Direct Tension Test (DTT)	RTFOT and PAV Aged Binder	

Table 1: Superpave binder tests and purpose of the use.

3. EXPERIMENTAL

3.1. Tests on Unmodified Bitumens

In this study, Superpave tests were performed on neat bitumen samples with different penetration grades form Turkey's all crude oil refineries, namely İzmit, Aliağa (İzmir), Kırıkkale and Batman refineries. Of these, only Batman refinery uses national crude oil for the manufacture of bitumen, while the other three refineries use imported crude oils from various foreign sources. Refinery bitumens to be tested were selected as B 50/70, B 70/100 and B 160/220 penetration grades which are predominantly used in road applications in Turkey and three samples were taken from each one.

First of all, penetration and softening point of each sample were determined to set up the relationship between penetration and PG grades. To start with Superpave, Dynamic Shear Rheometer (DSR) test was performed on original (unaged) samples. In DSR, test temperature was changed until performance criterion G*/sinδ≥1.00 kPa was both passed and failed where complex modulus G* and phase angle δ are indicator of rutting susceptibility in Superpave. For example, if *G**/sin δ is higher than 1.00 kPa at 58 ºC and lower than 1.00 kPa at 64 ºC, then binder grade is stated as PG 58-. But if *G**/sin δ is higher than 1.00 kPa at 70 ºC and lower than 1.00 kPa at 76 ºC, the starting binder grade is PG 70-.

After binders were aged with Rolling Thin Film Oven (RTFO) at 163 ^{o}C for 85 minutes, percent change in mass was found and DSR test repeated on RTFOT aged bitumen. Rutting performance criterion G*/sinδ for RTFOT residue is minimum 2.2 kPa.

Next step was conditioning RTFOT-aged binder under the pressure of 2070 kPa (300 psi) and at the temperature specified in the Standard (90 ^{o}C or 100 ^{o}C or 110 ^{o}C) contingent on the determined high temperature performance grade for 20 hours in the Pressure Aging Vessel (PAV). Finally, PAV aged bitumens were exposed to DSR and Bending Beam Rheometer (BBR) tests. DSR test in this stage is used for determination of resistance to fatigue performance of binders and conducted at the intermediate service temperatures from 10 ^{o}C to 40 ^{o}C with 3^{o}C increments to reach pass or failure limit for the fatigue performance criterion G*sinδ<5000 kPa.

BBR test on PAV residue is done applying 100 g constant load to a standard prismatic binder beam for 240 seconds at temperatures from -34 to -6 with -6 ^{o}C increments to meet low temperature performance criteria S=300 MPa and m-value≥0.30. Stiffness and m-value which is slope of log Stiffness versus log time curve at 60 seconds are used as indicator of low temperature performance grade.

Binder grades of all samples designated as per the standard AASHTO M320 in line with test results are shown in table below.

BITUMEN		Tests on Original binder					Tests on RTFOT-Aged Bitumens			Tests on RTFOT and PAV Aged Bitumens								Performance Grade
Refinery	Grade	Penetration	Softening Point, °C	Brookfield viscosity, 135°C	DSR (G*/sinδ >1kpa)		Mass Loss, %	DSR (G*/sinδ >2.2kpa)		DSR (G*.sinδ<5000 kpa)		Bending Beam Rheometer (BBR)						
												Stiffness (S) (≤300MPa)			m-value (≥0,300)			
					Failure Temperature °C	Grade		Failure Temperature °C	Grade	Failure Temperature °C	Grade	-12	-18	-24	-12	-18	-24	
Kırıkkale	B 50/70	63.5	49	365	66.8	64	0.05	67.5	64	20.5	22	162	320	-	0.32	0.27	-	PG 64-22
	B 70/100	84.3	47	306	63.2	58	0.06	64.9	64	21.7	22	130	275	-	0.33	0.28	-	PG 58-22
	B 160/220	181	40	179	53.8	52	-0.02	57.2	58	16.8	19	42.9	92.7	329	0.38	0.33	0.25	PG 52-28
İzmit	B 50/70	71	51	333	64.8	64	0.11	64.4	64	23.1	25	193	345	-	0.32	0.26	-	PG 64-22
	B 70/100	97	48	255	61.4	58	1.99	60.2	58	21.5	22	154	307	615	0.32	0.27	0.2	PG 58-22
	B 160/220	190	40	165	54.4	52	-0.01	53	52	18.4	19	-	205	352	-	0.32	0.29	PG 52-28
Aliağa	B 50/70	59	50	408	67.9	64	0.04	67	64	27.6	28	288	528	-	0.31	0.23	-	PG 64-22
	B 160/220	198	40	201	55.6	52	0.74	54.4	52	14.55	16	-	204	447	-	0.35	0.25	PG 52-28
Batman	B 50/70	70	51	539	70.8	70	-	77.9	76	22.1	25	75.4	156	-	0.33	0.3	-	PG

							0.75												70-22/28
	B 70/100	95	47	408	66.6	64	-1.1	73.4	70	19.5	22	-	136	244	-	0.31	0.27		PG 64-28
	B 160/220	184	40	235	60.6	58	-1.8	65.5	64	13.5	16	-	81.7	153	-	0.34	0.3		PG 58-28/34

Table 2 : Summary of the test results of refinery bitumens.

3.2. Tests on Polymer Modified Bitumens

Test results of neat Refinery bitumens showed that Aliağa, İzmit and Kırıkkale Refinery bitumens have same performance grade, but Batman bitumens are explicitly different from and generally one grade higher than the others. Thus, Batman and Kırıkkale bitumens were selected as the bitumens to be modified. Same Superpave tests were conducted on modified bitumens of these refineries with different polymers. Polymer modifications were SBS and Elvaloy modification on B 50/70, B 70/100, B 160/220 grade Kırıkkale bitumens and B 50/70 penetration grade Batman bitumens; SBS modification on B 70/100, B 160/220 grade Batman bitumens and SBR and Lucobit modifications on B 50/70 grade Kırıkkale bitumens. Polymer content in modifications was %5 for SBS and Lucobit, %2 for Elvaloy, %3 for SBR. Table below shows the refinery bitumens used for modification and polymer contents.

Refinery	Penetration Grade	%5 SBS	%2 Elvaloy	%3 SBR	%5 Lucobit
Kırıkkale	B 50/70	√	√	√	√
	B 70/100	√	√		
	B 160/220	√	√		
Batman	B 50/70	√	√		
	B 70/100	√			
	B 160/220	√			

Table 3 : Table of the bitumens and polymer types used in production of PMBs.

sRefinery			Kırıkkale								Batman			
Penetration Grade			B 50/70				B 70/100		B 160/220		B 50/70		B 70/100	B 160/220
Polymer type			SBS	Elvaloy	SBR	Lucobit	SBS	Elvaloy	SBS	Elvaloy	SBS	Elvaloy	SBS	SBS
Polymer content, %			5	2	3	5	5	2	5	2	5	2	5	5
Original Binder Tests	Penetration		46	51	57	49	93	70.6	105.4	119	40	35	56	71.6
	Softening Point °C		81.2	67.1	60	55.9	47	61	70.6	58.7	69.8	75.8	64.3	61.6
	Penetration Index, PI		4.26	2.40	1.37	0.12	-0.40	2.17	5.27	3.47	2.23	2.83	2.15	2.33
	RV	135°C 20 rpm SR=18.6 Viscosity cP	335	779		790		547.5	430	355		827		
	DSR	Temperature, °C (G*/sinδ >1.0 kPa)	80		70.4	73.9		77.7	69.5	68.3	91.2	95.7	86.5	81.8
	DSR	High Temperature Performance Grade	76		70	70	76	76	64	64	88	88	82	76
After RTFOT	Mass Loss %			0.23	0.013	0.27		0.405	0.094	0.141	0.631	0.307	0.845	1,823
	DSR	Temperature, °C (G*/sinδ >2.2 kPa)	76	75	71.4	76		71.5	68.5	70.8	92.8	95.2		82.1
	DSR	High Temperature Performance Grade	76	70	70	70	64	70	64	70	88	88	88	82
After RTFOT + PAV	DSR	Temperature, °C (G*sinδ <5000 kPa)		21.3	20	24.3		26.2	16.7		19.2	23.5	12.8	11.2
	DSR	Intermediate Temp. Performance Grade		22	22	25		28	19		22	25	13	13
	BBR	Stiffness (≤300MPa) -6 °C	85.2	59.3		85	124	44.2	35.2	27.2		25.5	52.4	
	BBR	Stiffness (≤300MPa) -12 °C	217	155	178	163	240	121	86.4	68.8	106	60.8	63.8	66.6
	BBR	Stiffness (≤300MPa) -18 °C	-	317	239			242	193	187		87.1		132
	BBR	m -value (≥0.300) -6 °C	0.353	0.377		0.34	0.298	0.389	0.394	0.36		0.29	0.318	
	BBR	m -value (≥0.300) -12 °C	0.264	0.299	0.302	0.286	0.239	0.364	0.286	0.357	0.266	0.298	0.29	0.307

	-18 °C	-	0.274	0.29			0.285	0.237	0.29		0.255		0.253
PERFORMANCE GRADE		**PG 76-16**	**PG 70-22**	**PG 70-22**	**PG 70-16**	**PG 64-16**	**PG 70-22**	**PG 64-16**	**PG 64-22**	**PG 88-16**	**PG 88-16**	**PG 82-16**	**PG 76-22**

Table 4 : Summary of the test results of PMBs.

3.3. SARA Analysis of Refinery Bitumens

Chemical composition of crude oil has great effect on binder behavior. Bitumens chemically consist of a large variety of organic molecules generally classified into four major groups identified as saturates, aromatics, resins and asphaltenes (SARA). In this study, SARA fractions of bitumens were examined to explore the between chemical composition and performance of binders. The tests were done in the laboratory of Turkish Petroleum Corporation Research Center (TPAO) using thin layer chromatography (TLC) in combination with an automated flame ionization detector (FID) as described in the IP 469/01 standard [7].

According to the TLC-FID method which is also known as Iatroscan, the sample to be analyzed is diluted and spotted on quartz rods that are coated with sintered silica particles. The four SARA fractions are then separated to various positions on the rods. This is done by successively emersing the rods into three development tanks containing solvents of various polarity; nonpolar solvent for saturates and increasing polarity for the aromatics and resin fractions. In the first tank n-heptane is eluated almost to the top of the rod and thereby separating the saturates from the rest of the sample. The rods are then taken out and dried before being placed in the second tank containing 80% toluene and 20% n-heptane. Here the aromatics fraction is separated as the solvent moves up the rod. The solvent is eluated to a lower height on the rod than in the first tank so that the aromatic fraction does not mix with the already separated saturate fraction. In the last development tank 95% dichloromethane and 5% methanol is used to separate the resins from the asphaltenes, which will be irreversibly adsorbed to the silica rod and will stay at the same position where the sample was first spotted. The amount of the various fractions is determined by a moving flame ionization detector (FID), which moves along the entire length of the rods. SARA fractions of bitumens are shown Table.

The ratio of aromatics to saturates and that of resins to asphaltenes are generally used as key parameters that control the stability of asphaltene micelles. When these ratios decrease, asphaltene micelles will coalesce and form larger aggregates. These two ratios are explored in the evaluation of relationship between the group chemical composition and the physical properties of asphalts. They are expressed in terms of two indices: asphaltene index and Gaestel index [6].

Asphaltene Index; $I_A = \frac{\text{Asphaltanes+Resins}}{\text{Saturates+Aromatics}}$

Gaestel Index; $I_C = \frac{\text{Saturates+Asphaltenes}}{\text{Resins+Aromatics}}$

	Asphaltene	Saturated	Aromatics	Resin	Asphaltene Index, I_A	Colloidal Stability Index, I_C
Kırıkkale Refinery B 50/70	19.9	7.37	59.24	13.48	50.11	37.50
Kırıkkale Refinery B 70/100	20.25	8.09	58.92	12.74	49.23	39.55
Kırıkkale Refinery B 160/220	18.14	8.87	60.1	12.88	44.98	37.01
Batman Refinery B 50/70	32.56	6.29	54.02	7.13	65.81	63.53
Batman Refinery B 70/100	29.71	7.68	55.25	7.35	58.89	59.73
Batman Refinery B 160/220	29.13	7.7	56.08	7.07	56.76	58.32
Kırıkkale Refinery RTFOT Aged B 50/70	27.24	6.86	52.5	13.39	68.45	51.75
Batman Refinery RTFOT Aged B 50/70	36.62	6.02	49.31	8.04	80.72	74.35

Table 5 : SARA fractions of rafinery bitumens.

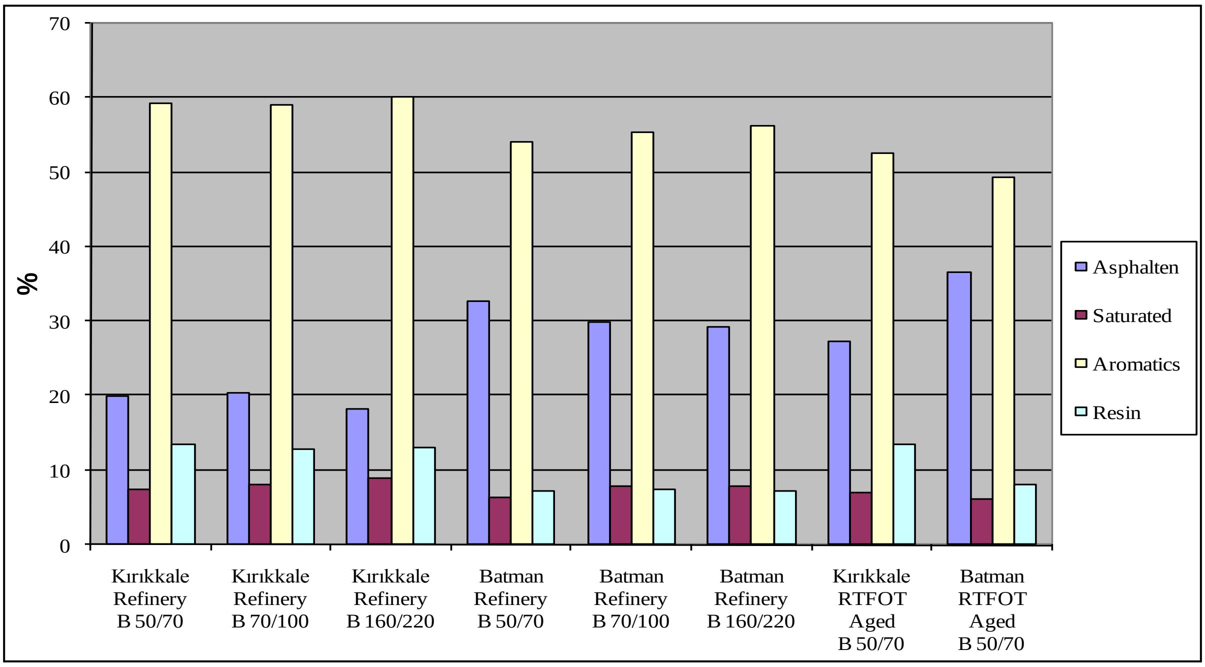


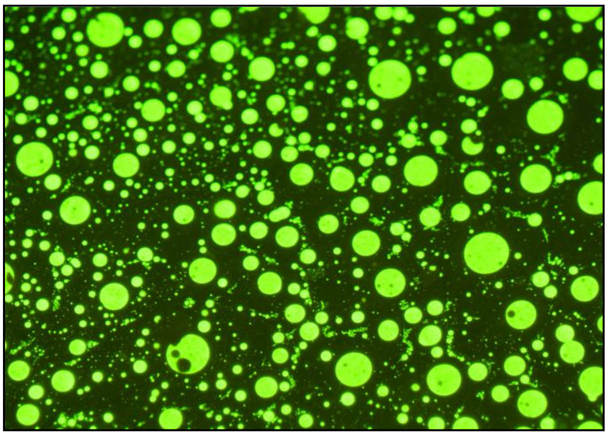
Figure 1 : Chart showing SARA fractions.

3.4. Polymer Dispersion Analysis in Florescent Microscope

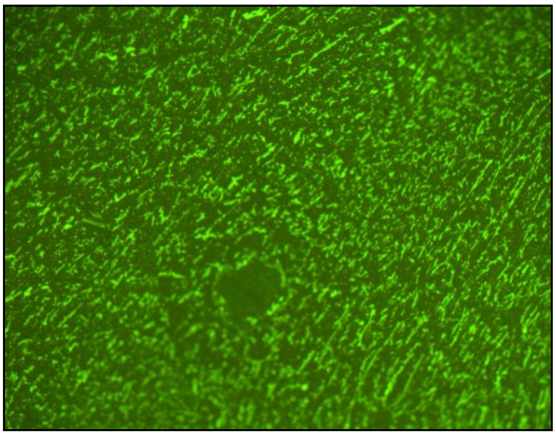
In order to determine the influence of base bitumen on phase separation and performance, PMBs were tested with respect to polymer dispersion and homogeneity in accordance with the standard TS EN 13632:2010 “Bitumen and bituminous binders - Visualization of polymer dispersion in polymer modified bitumen “.

In the test, Batman and Kırıkkale base bitumens were modified with %5 SBS with high shear laboratory mixer for two hours. PMBs homogenized by gentle stirring were then poured into a preheated aluminium basin placed in a sand bath. After a controlled cooling procedure to ambient temperature the samples were cooled to – 20 °C. After, the cooled bitumen samples were broken into small pieces, the freshly broken surfaces were viewed through a fluorescent microscope (Nikon Eclipse 80i).

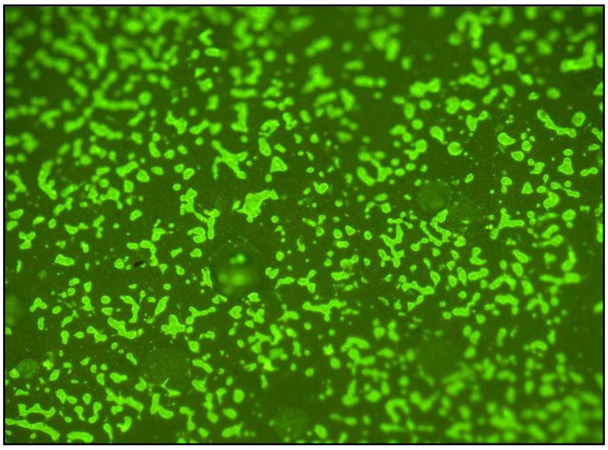
TS EN 13632:2010 specifies ten model pictures involving the information about the continuous phase, description of the phase, description of the size and description of the shape. Typical pictures and characterizations of refinery bitumens are given Figure 2.



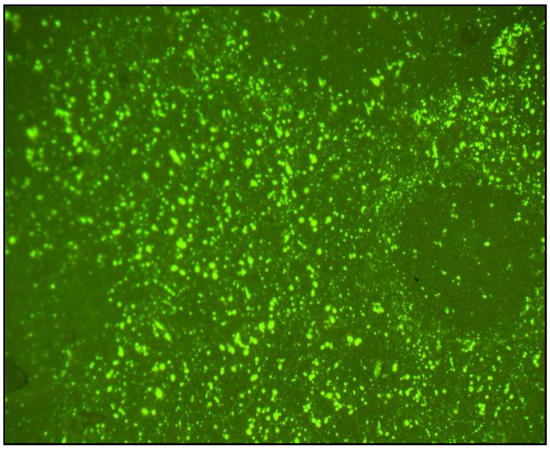
a) Batman B50/70 with %5 SBS (B/H/SL/r)



b)Kırıkkale B50/70 with %5 SBS (B/H/SM/o)



c) Aliağa B50/70 with %5 SBS (B/H/SM/o)



d)İzmit B50/70 with %5 SBS (B/H/SM/r)

Figure 2 : PMB pictures from the florescent microscope (H: continuous bitumen phase, H:homogenious, S:small, M:medium, L:large, r:roundish, o:other shape).

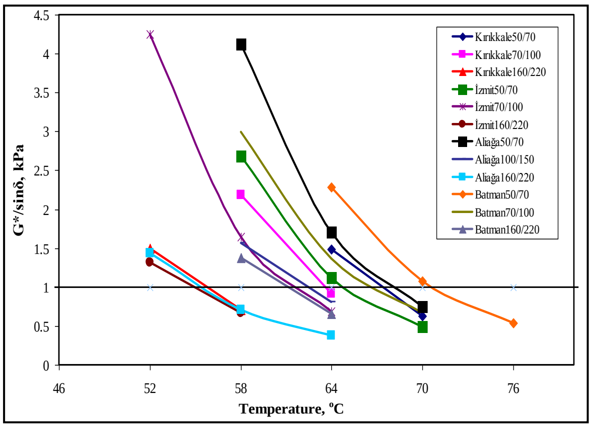
4. EVALUATION OF TEST RESULTS

4.1. Performance Grades Of The Bitumens In Elevated Service Temperature

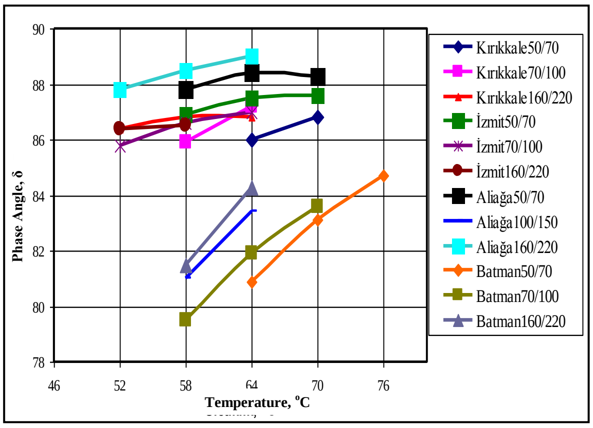
In Superpave specification, resistance to permanent deformation in elevated temperatures is specified with criterion G*/sinδ minimum value of which is 1.0 kPa for original binders and 2.1 kPa for RTFOT Aged binders.

Figure 3a,c shows the G*/sinδ values of all modified and unmodified bitumens. Resistance to permanent deformations in elevated temperature increases from the top left towards the bottom right . In addition, the delay between the imposed deformation and the measured mechanical stress induced by that deformation, which is cald as phase angle, gives great information about permanent deformation behaviors of binders. The lower phase angle or the less delay means the more elastic nature the binder has. This delay is minimum (0°) for an elastic solid-like rubber and maximum (90°) for a viscous liquid-like glycerol.

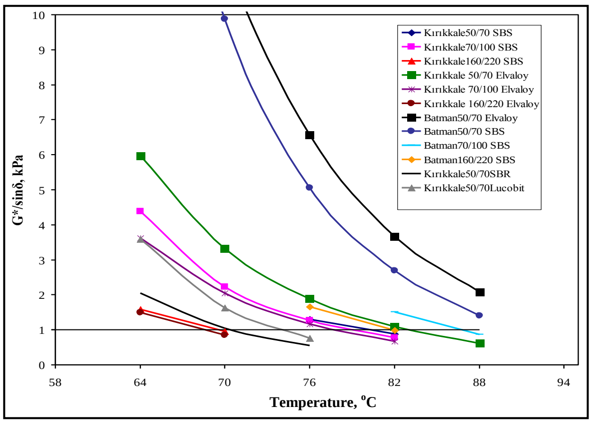
As seen in Figure 3, of the bitumens with same penetration grade, Batman bitumens have better performance at high temperatures than that of Kırıkkale. When the performance of modified Kırıkkale B 50/70 bitumens is evaluated in terms of four polymer types, Elvaloy (%2) has the best performance and is followed by SBS, Lucobit and SBR in the ranking respectively. Although Elvaloy modified B 50/70 grade bitumens of both Kırıkkale and Batman refineries have higher better performance grade than that of SBS, in the softer bitumens (B 70/100, B 160/220) it was seen that SBS modification gives better results than Elvaloy.
As can be seen in Figure 3, Elvaloy modified bitumens has the lowest phase angle. Even though this is compatible with higher G*/sinδ values for Elvaloy modified B 50/70 bitumens in Figure 1, SBS modified soft bitumens have higher complex modulus. Similarly, while the test temperature is proportional to phase angle in bitumens modified with Elvaloy, it is inverse proportional to that of SBS and SBR. It was concluded that as the bitumen get softened due to increase in temperature and reduction in viscosity, the polymeric network structure of SBS and SBR become dominant factor and determines the behavior of PMBs. But, Elvaloy and Lucobit stiffen the binder as a whole, hard bitumens harden even more, but, polymer network softens and weaken along with increase in the temperature, high temperature performance decrease more rapidly.



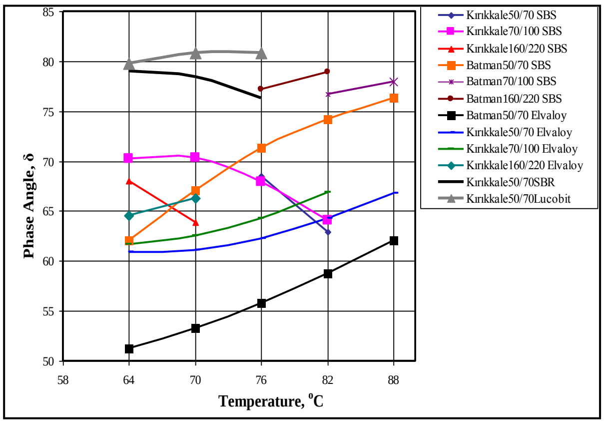
a) G*/sinδ value of refinery base bitumens



b) Phase angle of refinery base bitumens



c) G*/sinδ value of PMBs



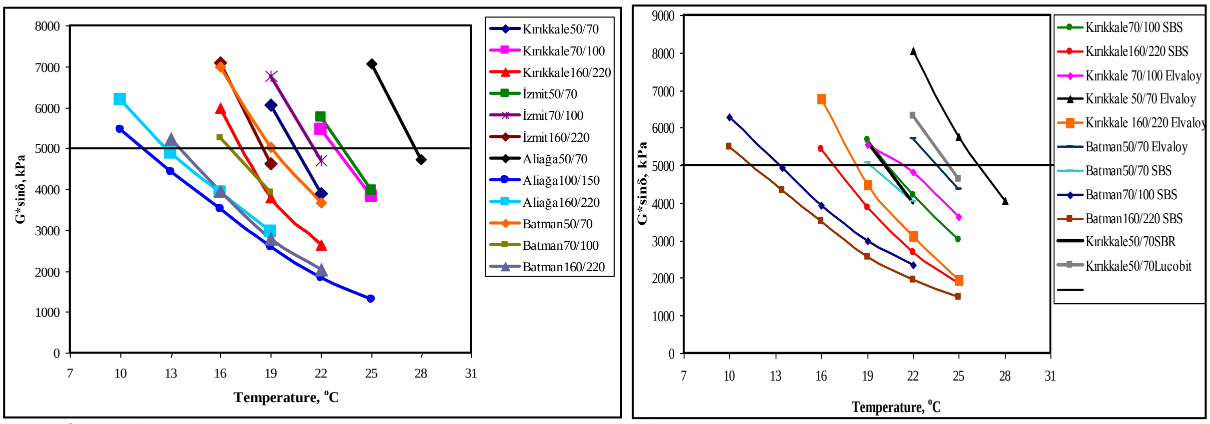
d) Phase angle of PMBs

Figure 3: Graph showing G*/sinδ and phase angle values of bitumens in high temperatures.

4.2. Performance Grades of Bitumens in Intermediate Service Temperature

Performance of binders in intermediate service temperatures is identified by the resistance to fatigue. The contribution of the asphalt binder to fatigue cracking is governed by specifying a maximum value of 5,000 kPa for the stiffness parameter, G*sinδ (G", the loss modulus), at the average pavement design temperature. This parameter is related to the contribution of the asphalt binder to the dissipation of energy in a pavement during each loading cycle.

Loss modulus of the bitumens are given in Figure 4 According to results, descending order of polymers regarding performance is SBS, SBR, Lucobit and Elvaloy.



a) **Refinery base bitumens** **b) PMBs**

Figure 4: Graph showing G*sinδ value of bitumens in intermediate temperatures.

4.3. Low Temperature Performance Grades of Bitumens

The contribution of the asphalt binder to low-temperature cracking is controlled by specifying limits for the creep stiffness (< 300 MPa), the slope of the stiffness-time relationship (>0.300), and the tensile strain at failure (> 1.0 percent) at test temperatures related to the lowest expected pavement design temperature. These properties affect the ability of the pavement to dissipate the tensile strains that result from rapid reductions in temperature or continual low-temperature cycling. Comparison of the measured values of these three properties for asphalt binders with PG specification limits will indicate how well they will perform with respect to low-temperature cracking.

In the AASHTO Superpave binder specification (M 320-03), Direct tension test (DDT) is indicated as a supplementary and optional test to be run only on binders which meet m-value criteria but do not meet the low temperature criteria of stiffness, and have a stiffness between 300 and 600 MPa. Since all binders reached the limiting m-value of 0.3 at higher temperature than by the limiting stiffness value of 300 MPa, Direct Tension Test has not been used in this study.

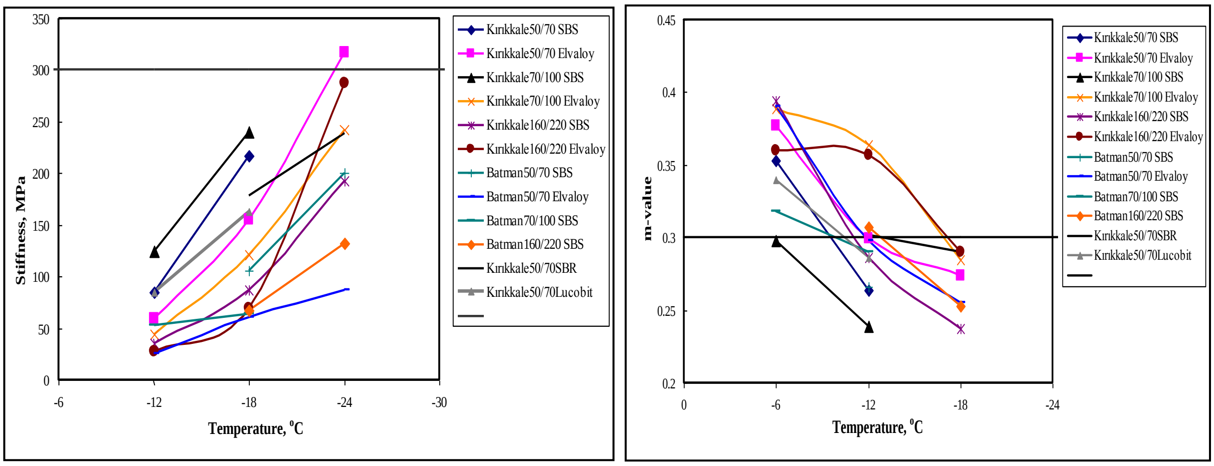


Figure 4: Graph showing stiffness and m-value of bitumens in low temperatures.

It was seen that polymer modification caused no increase in the low temperature performance grade but generally a decrease to a respective extent of polymer type. Low temperature performance grade of Kırıkkale bitumens was decreased one grade by SBS, mostly retained or in some cases decreased one grade by Elvaloy and retained at the same level by Lucobit and SBR. But, both SBS and Elvaloy caused to one or two grade reduction in the low temperature performance of Batman refinery bitumens.

5. CONCLUSIONS

The current European bitumen grading system relying on conventional empirical tests such as penetration and softening point actualy covers only unmodified base bitumens but not modified bitumens. Newly developed Superpave binder grading methods considering performance related test and used for both unmodified and modified bitumens seems to supersede other grading systems in near future.
This study investigated the Superpave performance grades of Turkish Refinery bitumens of different penetration grades and impact of some polymers most commonly used in the market on performance by means of Superpave binder tests, namely dynamic shear rheometer, rolling thin film oven test, pressure aging vessel, bending beam rheometer.
This study investigated the high, intermediate and low temperature performance of all refinery bitumens of Turkey by means of Superpave performance tests and impact of chemical composition and some polymers most commonly used in the market on performance. It was found that Batman refinery bitumens have the highest asphaltene content and modified and unmodified bitumens of which have generally one grade higher performance grade in both low and high temperature side than penetration equivalents of other three Refineries. On the other hand, polymer modification generally worsened the low temperature grade to some extend depending on te polymer type, but has largest effect on Batman bitumens which are highest asphaltene content. Chamical and microscopic analysis verified that Batman rafinery bitumens has the highest asphaltene content in Image analyis of photos taken from microscope also revealed that Batman bitumen has very poor compatibility with polymer. Altough, high asphaltene content, bad polymer compatibility, poor colloidal stabilisation are supposed to generate bad bitumen performance, that Batman bitumens have very good performance grade is thought to reveal the need for further research on especially low and intermediate temperature performance of binders.

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