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Present Trends in Improving Quality of Pavement Bitumen

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SUMMARY:

The article presents the experience with modified bitumen in Romania, especially on national roads. More experimental sectors were set and evolution of the condition is observed. Laboratory tests results are presented for different sources of bitumen and different additives.

Tests were performed according to SHRP methods which are based on performance. Considering SHRP algorithm for temperature and traffic prediction may generate effective asphalt mixtures.

KEY WORDS: modified bitumen, roads materials, roads design.

1. INTRODUCTION

Studies on bitumen binder were a permanent concern for materials specialists from road area. In Romania, as in many other countries bitumen is the main road binding material. Asphalt pavements represent 98% from network while the rest of 2% are mainly concrete cement. Present trend is to use it for the entire country. Therefore, an increase of the performance is required. To achieve this, the quality of all components of the asphalt mix must be improved: bitumen, natural aggregates, additives, fibres etc. so the durability to be increased. Bitumen binders used for road works include the bitumen itself and derived products: emulsions, cutback bitumen, and fluxed bitumen.

Main components of the bitumen are oils, resins, asphaltenes, asphaltogen acids and their anhydrides.

Based on the origin, there are two types: the petrol bitumen resulted after processing crude oil in refineries; and natural bitumen obtained directly from natural sediments.

The petrol bitumen used in Romania for road works the composition of fractions corresponds as following:

- Oils 40…60%;
- Resins 18…48%;
- Asphaltenee 15…35%.

ISSN 1582-3024

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Natural bitumen extracted from Derna-Tatarus presents a higher content of oils and a lower percentage of asphaltens:

- Oils 67…72%;
- Resins 21…22%;
- Asphaltenes 1…11%.

The behaviour, composition and characteristics of the bitumen, are influenced by external factors (light, temperature, level of oxygen in air, etc.) which act continuously after laying in place. Due to these factors the bitumen suffers a generally irreversible ageing process characterized by the oxidation and polymerization of the oils which transform partly into resins and resins further into asphaltenes.

Increase of the asphaltene percentage over a certain limit produces a fragile and brittle binder, therefore unfit for roads, generating cracks.

Considering the paraffin content two types are considered:

- non-paraffin bitumen (<2% paraffin),
- paraffin bitumen (between 2% and 4% paraffin).

Bitumen is used for pavements in three forms:

- pure bitumen,
- bitumen with additives,
- modified bitumen.

Current laboratory tests on bitumen are:

- tests related to the consistency (penetration; and viscosity);
- tests concerning the plasticity (softening point; Ubberlohde; Fraass; and ductility)
- adherence test;
- bitumen ageing resistance in preparation of the asphalt mix and in operation:
    - mass loss through warming (standardized method);
    - stability in thin layer of the bitumen through TFOT and RTFOT (according to Romanian AND instructions)
    - accelerated ageing – PAV method (according to Romanian AND instructions)
- chemical composition (according to Romanian technical instructions 52R/1996)

Beside these specific tests the following standardized measurements are performed:

- density;
- solubility in carbon disulphide or carbon tetrachloride;
- flammability point;
- content of paraffin.

ISSN 1582-3024

Based on the composition, softening point IB and penetration at 25ºC other structural characteristics are calculated:
- colloidal instability index, IC
- aromaticity index, IA
- penetration index, IP.

2. USE OF MODIFIED BITUMEN FOR ASPHALT MIX

Improving the characteristics of asphalt mixtures to resist longer periods under traffic actions and severe meteorological conditions is a permanent concern for engineers. New polymeric additives, both reactive and non-reactive, are promoted for the road bitumen to obtain a elasto-visco-plastic material, where the elasticity component to be significant.

2.1. Polymer modified bitumen

Polymer modified bitumen is a binder with specific physical and cheminal characteristics. It is obtained in special installations by processing pure bitumen with certain types of polymers, at 160-180ºC.

The advantages of polymer modified bitumen, comparing with pure bitumen are:
- increase in resistance to permanent deformations at high temperatures;
- increase of resistance to cracking at low temperatures and to fatigue;
- decrease of ageing susceptibility both in preparation of the mix and in operation;
- improved cohesion and adherence to natural aggregates.

2.2. Types of polymers

The polymers used for preparation of modified bitumen are grouped in two main categories:
- elastomers: products consisting in styrene co-polymers, the most important being: SBS – styrene-butadiene-styrene; SIS – styrene-isopropene-styrene;
- plastomers: products based generally on ethylene co-polymers, like: EVA – ethylene-vinyl-acetate; EMA – ethylene-methyl-acryl.

Both elastomeric and plastomeric form similar networks while incorporate in bitumen, a continuous one with flexible strings connected by thermo-reversible links.

Main factors which influence the existence of these networks and improvement of the performances of the bitumen are:

ISSN 1582-3024

- chemical composition of the bitumen, especially the asphaltene contents;
- polymer's structure
- the compatibility between bitumen (i.e. oils and resins) and the flexible network of the polymer;
- polymer's dosage.

Mainly, the elastomeric polymers (i.e. SBS) are compatible with aromatic bitumen, while the plastomeric polymers (i.e. EVA) are compatible with paraffin and less aromatic bitumen.

2.3. Studies and test performed on polymer modified bitumen

Between 1996 and 2007 studies were carried to CESTRIN Bucharest and DRDP Timisoara for different dosages of SBS polymer modified bitumen (trade marks Carom, Cariflex and CAPS) and reactive polymer (trade mark Elvaloy).

2.3.1 Bitumurile Petrolsub D 60/80 si Arpechim D 60/80 modificate cu Carom si Cariflex

For usual characterization of the modified bitumen the influence of the polymer on penetration, softening point, and Fraass were observed.

After modification of two types of Romanian bitumen, the following observations were made: penetration decreases remarkable, softening point increases, and Fraass improves. Also, from elastic behaviour at 13ºC test, it was observed that Carom and Cariflex polymers induce elasticity in bitumen, more than 70% (minimal condition is 60%).

Bitumen ageing through RTFOT produces the same changes in original and modified bitumen, with the remark that they are smaller in modified bitumen, which reflects a better resistance to ageing justified by the higher level of elastic behaviour.

Concerning the rheological characteristics tested according SHRP methodology on Petrolsub and Arpechim bitumen, the modification with polymer increases the viscosity no matter the penetration class of the original bitumen.

DSR (Dynamic Shear Rheometer) test indicates that the modifier improves the superior temperature to which the bitumen resists (increasing for Petrolsub bitumen from 64ºC to 76º for Carom modifier, and to 70ºC for Cariflex; for Arpechim bitumen the increase is from 58ºC to 70ºC for Carom modifier).

When using BBR test, no change of the resistance to low temperature is detected, but modified bitumen is less rigid and therefore able to relax after thermal efforts accumulated at low temperature.

In tables 1 and 2 characteristics of D60/80 Petrosub P1 and Arpechim A1 bitumen both original and modified with SBS.

Table 1. Physical-mechanical characteristics of the bitumen (i.e. D 60/80 Petrolsub P1 and Arpechim A1; original and modified with SBS)

Characteristic	**Petrolsub D60/80 bitumen**				**Arpechim D60/80 bitumen**			Norm. 549/1999
	original	+4% Carom	+5% Carom	+4% Cariflex	Original	+4% Carom	+4% Cariflex	
Penetration (1/10mm)	70.2	38	33	35	61	45.6	44.3	55…70
Softening point (°C)	46	58.5	64.4	58.6	44.7	50	52.2	min.55
Ductility @25°C (cm)	150	55	49	30	130	94	114	min.100
Ductility @13°C (cm)	-	32	31	31.5	-	45	55	min.40
Elastic behaviour @13°C (%)	-	74	78	80	-	70	71.5	min.60
Fraass (^{0}C)	-23	-24	-24	-24	-15	-18	-18	max.-20
RTFOT ageing								
Mass loss (%)	0.513	0.310	0.282	0.406	-0.05	-0.08	-0.105	max.0.8
Ductility @25°C (cm)	120	26.3	43.3	30	100	75	90	
Ductility @13°C (cm)	-	24	22.5	23	-	28.2	36	min.40
Elastic behaviour @13°C (%)	-	72	75	70	-	63.5	66	min.60
Increase in softening point (°C)	7	4	1.7	5.1	3.3	8	4.8	max.9
Residual penetration (%)	50	76.3	77	74.3	50	78	55	min.50

Table 2. Reological properties according to SHRP methodology: simple and SBS polymer modified D60/80 bitumen

Test	**SHRP - Rheological properties**						
	Petrolsub P1				**Arpechim A1**		
	simple	**+4% Carom**	**+5% Carom**	**+4% Cariflex**	**simple**	**+4% Carom**	**+4% Cariflex**
Brookfield Viscosity	**@135^{0}C, max. 3.0 Pa.s**						
	0.285	1.020	1.250	1.100	0.300	0.970	0.975
DSR on original bitumen	**G*/sin δ (SHRP condition: min.1.0 KPa)**						
T=64°C	**1.01**	6.01	5.8	4.0	0.86	5.2	**3.5**
T=70°C	0.51	2.90	2.90	**1.8**	0.50	**2.01**	0.94
T=76°C	-	**1.47**	**1.50**	0.93	0.30	0.92	-
T=82°C	-	0.82	0.86	-	-	-	-
DSR on residual bitumen RTFOT	**G*/sin δ (SHRP condition: min.2,2 KPa)**						
T=64°C	**3.51**	10.7	11.9	12.6	**2.28**	8.7	10
T=70°C	1.60	5.1	6.3	6.7	1.5	**4.3**	5.2
T=76°C	-	**2.8**	**3.4**	**3.9**	0.8	2.0	3.
DSR on residual bitumen PAV	**G*sin δ (SHRP condition max..5000 KPa)**						
T=22°C	1555	1463	1276	1289	**3834**	3620	3500

ISSN 1582-3024

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Test	SHRP - Rheological properties						
	Petrolsub P1				Arpechim A1		
	simple	+4% Carom	+5% Carom	+4% Cariflex	simple	+4% Carom	+4% Cariflex
T=19°C	2190	2049	1758	1784	5028	**4800**	**4600**
T=16°C	2975	2769	2151	2446	8555	8020	7890
T=13°C	4067	3769	2843	3301	-	-	-
BBR	**SHRP** Condition S = max.300Mpa m= min.0.3						
	S m	**S m**	**S m**	**S m**	**S m**	**S m**	**S m**
T=-12°C	-	-	-	-	**174 0.378**	169 0.345	**175 0.330**
T=-18°C	**-**	**-**	**-**	**-**	317 0.340	**280 0.320**	309 0.312
T=-24°C	**181 0.372**	**178 0.367**	**121 0.364**	**175 0.354**	- -	432 0.308	482 0.263
T=-30°C	378 0.336	343 0.340	323 0.332	316 0.320			
Class of performance	**64-34**	**76-34**	**76-34**	**70-34**	**58-22**	**70-28**	**64-22**

2.3.2 ESSO D 50/70 bitumen: simple and modified with Elvaloy

After ESSO D50/70 bitumen is modified with reactive polymer Elvaloy the following changes are observed:

- increase in softening point from 44.3ºC to 49.9ºC;
- decrease of the penetration from 77.1 to 75.7 1/10mm;
- improving the Fraass from -10.1 to -17.3.

Ageing with TFOT/RTFOT is manifesting with small mass variations and with the decrease of ductility which implies the lack of elasticity of the material. This happens because of the presence of highly volatile compounds.

SHRP tests indicate the followings:

- the modifier enhances the superior temperature to which the road bitumen resists: increasing from 58ºC for the original bitumen to 64ºC for the modified bitumen;
- the modifier improves the fatigue resistance of the bitumen (i.e. 4546.9 kPa @19ºC for modified bitumen comparing to 4423.1 kPa for original bitumen).
- for ESSO D50/70,

Table 3 presents, in detail, the characteristics of ESSO D50/70 bitumen simple and modified with Elvaloy.

Table 3. ESSO D50/70 bitumen: simple and modified with Elvaloy

	Characteristic	**U.M.**	**Results**			
			ESSO 50/70 (1st load)	+ 1.5% ELVALOY (1st load)	ESSO 50/70 (2nd load)	+ 1.5% ELVALOY (2nd load)
1.	Softening point	ºC	44.3	49.4	43.2	49.5
2.	Penetration @25ºC	1/10 mm	77.1	75.7	72.7	70.2
3.	Ductility @25ºC	cm	150	150	150	150

4.	Ductility @13ºC	cm	-	-	-	-
5.	Elastic behaviour @13ºC	%	-	52.5	-	55.0
6.	Fraass	ºC	-10.1	-17.3	-13.2	-10.2
7.	Penetration @0ºC	1/10 mm	4.8	5.5	4.9	7.4
8.	Penetration index	-	-1.75	-0.3	-2.24	-0.5
	RTFOT					
9.	Mass loss	%	+0.105	+ 0.112	+0.039	+0.099
10.	Increase in softening point	ºC	3.7	3.7	5	2.3
11.	Residual penetration @25ºC	%	56.5	67.4	57.6	66.7
12.	Ductility @25ºC	cm	150	98.1	150	112.3
13.	Ductility @13ºC	cm	-	-	-	18.5
14.	Penetration @0ºC	1/10 mm	3.3	5.2	4.0	4.9
15.	Penetration index	-	-2.0	- 0.4	-2.0	-0.9
	TFOT					
16.	Mass loss	%	+0.087	+0.089	+0.045	+0.101
17.	Increase in softening point	ºC	3.7	2.8	4.6	2.0
18.	Residual penetration @25ºC	%	56.5	66.0	59.3	68.7
19.	Ductility @25ºC	cm	150	106.0	150	105
20.	Ductility @13ºC	cm	-	25.0	-	19.7
21.	Elastic behavior @13ºC	%	-	-	-	-
22.	Penetration @0ºC	1/10 mm	4.3	-	3.8	3.6
23.	Penetration index	-	-2.0	- 0.7	-2.1	-0.9

Test	**Results**			
	ESSO 50/70 1st load	ESSO 50/70+1.5% Elvaloy 1st load	ESSO 50/70 2nd load	ESSO 50/70+1.5% Elvaloy 2nd load
Brookfield viscosity	La T = 135^0 C, max. 3.0 Pa*s			
	0.316	0.710	0.361	0.760
DSR on original bitumen	G*/sinδ (SHRP condition min. 1.0 kPa)			
T= 58ºC	1.929	2.362		2.634
T= 64ºC	0.942	1.228		1.375
T= 70ºC		0.659		0.747
DSR on RTFOT residual bitumen	G*/sinδ (SHRP condition min. 2.2 kPa)			
T= 58ºC	*3.650*	4.626		4.423
T= 64ºC	1.636	*2.417*		*2.224*
DSR on PAV residual bitumen	G*/sinδ (SHRP condition max.5000 kPa)			
T= 16ºC		5468.3		
T= 19ºC	5372.5	4546.9		6813
T= 22ºC	4423.1	3070.4	2986.4	4339.7

BBR	SHRP condition; s=max.300MPa; m=min.0.3							
	S	m	S	m	S	m	S	m
T= -12°C	287.81	0.307	316.29	0.304	277.69	0.302		
T= -18°C	533.6	0.251	580.6	0.235	540.3	0.243		
	PG=58-22		PG=64-22				PG=64-22	

2.4. Assessing colloidal instability index IC

Bitumen used for modification were Petrolsub and ESSO from import. The modifier was Elvaloy AM (1%; 1.5%; 1.75%). Glycidyl-methacrylate (GMA) and asphaltenes is followed by measuring the viscosity.

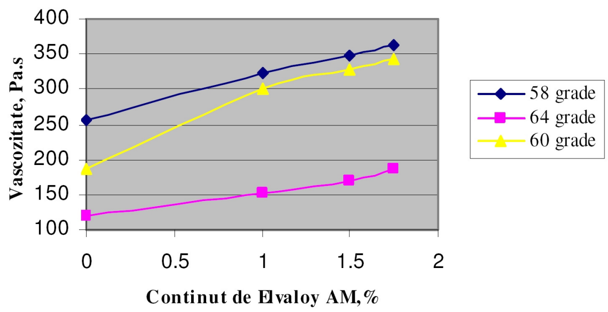

Fig. 1: Viscosity evolution for different temperatures

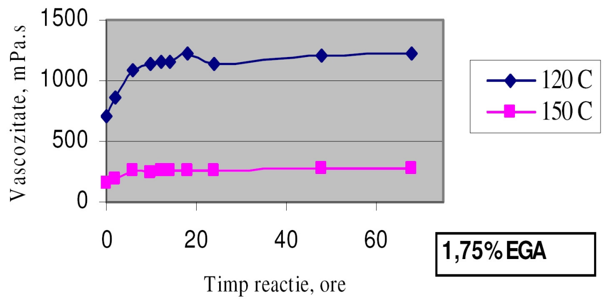

Fig. 2: Viscosity evolution for different temperatures

EGA modified bitumen:

- eliminates the inconvenience of phase separation;
- used in reduced quantities (1…2%)
- improved characteristics using 1.5% of reactive polymer
- improved behaviour at high temperatures (superior CP)
- at low temperature, similar behaviour as the original bitumen.

SBS modified bitumen:
- enhance resistance to permanent deformations;
- improved resistance to low temperatures for the original bitumen with weak properties;
- improved behaviour to high temperatures (superior CP)
- improved properties to fatigue.

2.5. Classical characterization of modified bitumen

SBS Polymers:
- decrease penetration;
- increase softening point;
- improve Fraass;
- improve elasticity.

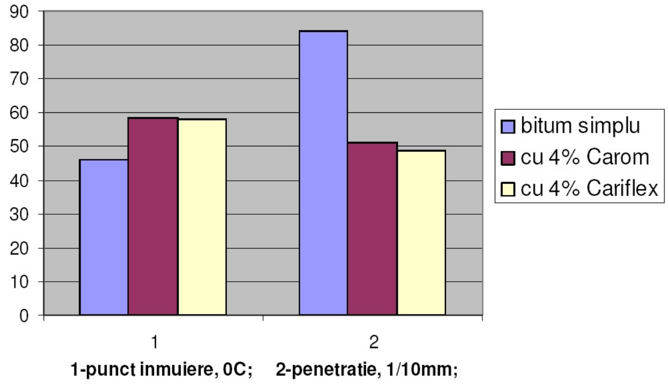

Fig. 3. (1. softening point; 2. penetration)

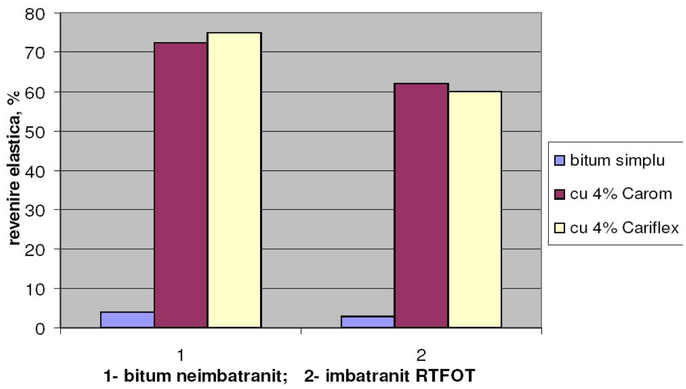

Fig. 4. Elastic behaviour (1. new bitumen; 2. aged bitumen)

ISSN 1582-3024

5. CONCLUSIONS

1. Using SHRP methods (based on performance criteria; using 7 consecutive days maximal temperature according to SHRP algorithm) for testing highway bitumen results in high performance asphalt mix design.

2. Early initiation of degradations, with unpleasant effects for traffic, is a consequence of the use of inappropriate bitumen.

3. Implementing SHRP methodology, that allows characterization of the bitumen on classes of performances through use of effective equipment, may bring supplemental indications concerning the behaviour of the bitumen at low and high temperatures, based on its viscosity and chemical composition.

4. Although the laboratory tests indicated several degrees difference in Fraass point and the temperature obtained trough BBR (Bending Beam Rheometer) it is necessary to adapt “technical conditions” to the specific climate from Romania when European Norms are adopted.

5. Use of polymer modified bitumen might be a proper solution to this issue.

6. Separation of phases (stability to storing) must be avoided and a uniform dispersion of the polymer in bitumen (homogeneity with fluorescent microscope) must be ensured.

7. To obtain effective asphalt mixes, it is recommended that design to be performed after a complete laboratory study, implying testing the aggregates, bitumen (including optimal dosage), binder, additives, fibres etc.

8. Performances of asphalt mixes depend firstly on the quality of materials, imposing to the material producers to observe and maintain a high and constant quality for the products according to technical parameters imposed by technical specifications.

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