Comparison between various bituminous binders modified with crumb tyre rubber

Davide Lo Presti, Prof. Gordon Airey, Naeem Memon, James Grenfell

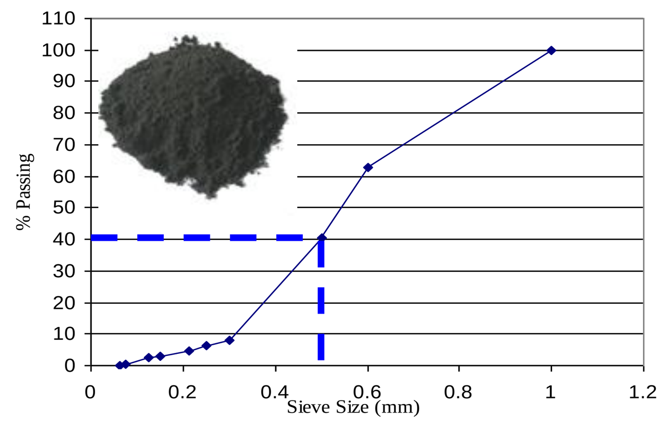
The University of Nottingham — Università degli Studi di Palermo

Materials

- ***Bitumen*** — *PG 64-16* **LOW** % asphaltenes; *PG 64-22* **HIGH** % asphaltenes

- ***Crumb rubber (powder)***

Origin :	ambient car
Particle shape :	irregular
Fibre content :	0.5 %
Steel content :	0.1 %

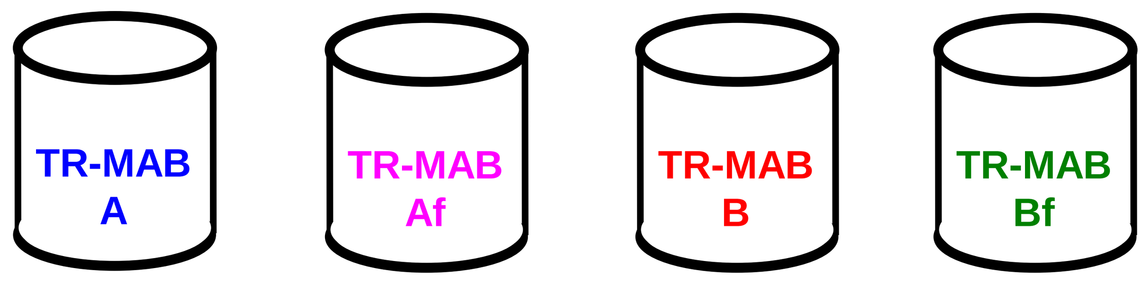


- ***Oil extender 7.5%***
commercial used to produce SBS - MB

Base binder (with or without oil) **85%** + crumb tyre rubber **15%** = **TR-MAB**

base A: *PG 64-16*
base Af: *PG 64-16 + 7.5% oil*
base B: *PG 64-22*
base Bf: *PG 64-22 + 7.5% oil*

4 Tyre Rubber Modified Asphalt Bitumen



Blending protocol

- High shear mixer with RPM control (duplex head)
- Temperature control with Hot plate method

base binder (85%) Bitumen	Oil	rubber (15%)	rubber size	total weight	mixing time	mixing speed	mixing temp.	
g	g	g	mm	g	min	rpm	°C	
1700	0	300	0-0.5	2000	60	1000	180	*NO oil*
1572.5	127.5	300	0-0.5	2000	60	1000	180	*7.5% oil*

- ✓ Required amount of bitumen was heated at 180°C
- ✓ High shear mixing up to 2000 rpm was applied for first 10 minutes while firstly the oil extender then the rubber later was feed into the bitumen.
- ✓ Time was allowed for the temperature to settle at 180°C.
- ✓ Once the temperature reached 180°C, blending time was noted and mixing undertaken at 1000 rpm for one hour

Binders characterization: Physical, chemical, rheological and by performance

- ***Base binders***

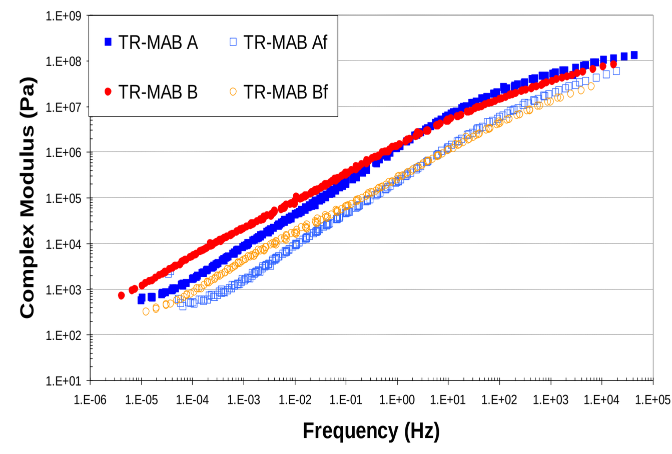
	binder A	binder Af	binder B	binder Bf
Penetration	42 dmm	136 dmm	54 dmm	157 dmm
Softening Point	51ºC	39.8ºC	52.2ºC	40.3ºC
Fraass breaking point	0ºC	-14ºC	-2ºC	-17ºC
Ductility	>1000 mm	>1000 mm	>1000 mm	>1000 mm
Asphaltenes Content	**3.4%**	**3.4%**	**16.7%**	**16.7%**
Rotational viscosity	Pa.s			
@ 100ºC	3.86	1.57	5.13	2.14
@ 135ºC	0.40	0.20	0.45	0.23
@ 160ºC	0.12	0.07	0.19	0.13

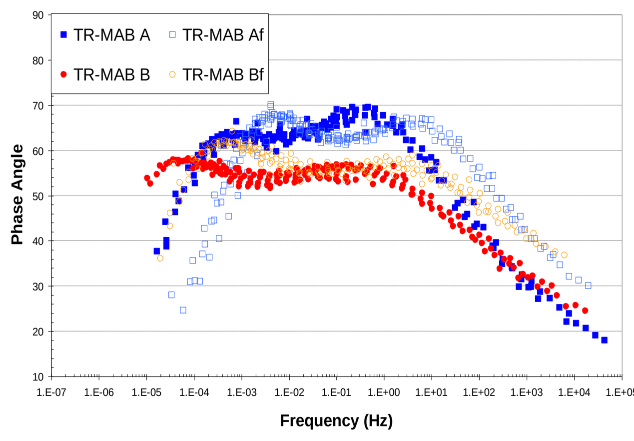
- ***Tyre Rubber – Modified Asphalt Bitumen***

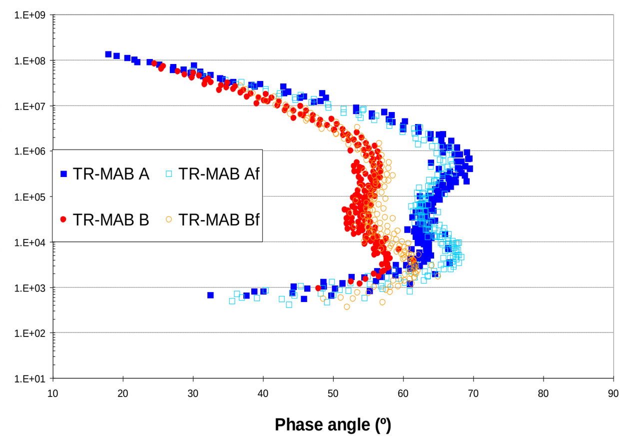
Performance: All the TR-MABs have got a better performance temperature range in comparison with the base bitumen. TR-MAB obtained from the binder with higher asphaltanes content show higher PG and higher increase of performance if compared with the base.

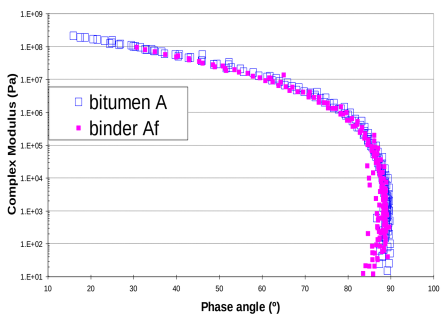
Rheology: Comparing all the TR-MABs and the respective original bitumens, the polymer network effect is clearly noticeable from the black diagrams that demonstrate the typical signs of modification with an elastomer. In both cases the addition of oil extender does not change the finger print. From a comparison between the TR-MABs, it is possible to notice that the modified binders obtained using the higher asphaltenes content bitumen are on average stiffer (higher G* values), more elastic (lower phase angles) and also less frequency and temperature susceptible over the considered range. It is finally possible to affirm that, after modification with TR, bitumen B (higher asphaltenes content) is the one which demonstrates the biggest improvements

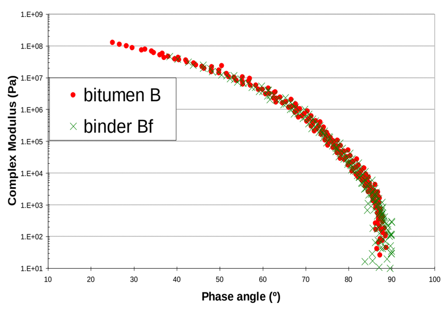
	TR-MAB A	TR-MAB Af	TR-MAB B	TR-MAB Bf
Rotational viscosity	Pa.s			
@ 100ºC	45.87	19.85	49.44	24.18
@ 135ºC	4.41	2.75	6.45	3.83
@ 160ºC	2.02	1.46	2.40	2.01











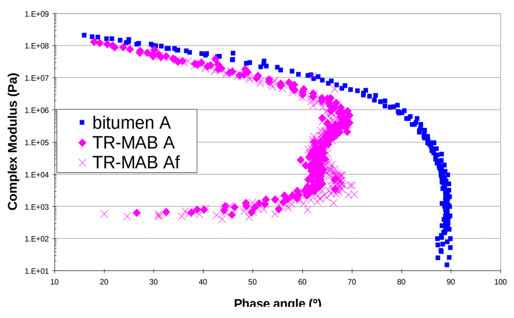
Oil extender effect

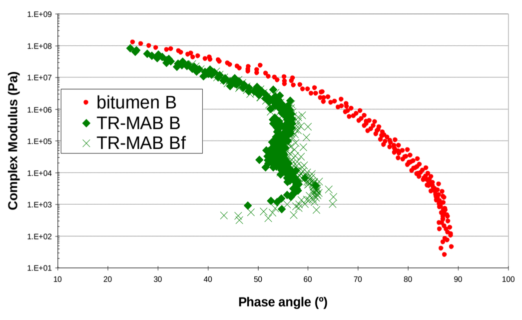
Characterization show that the oil extender affects the base binder by softening it and thereby enhancing its low temperatures properties.

Physical properties: lower Fraass breaking decrease in softening point and reduced viscosity.

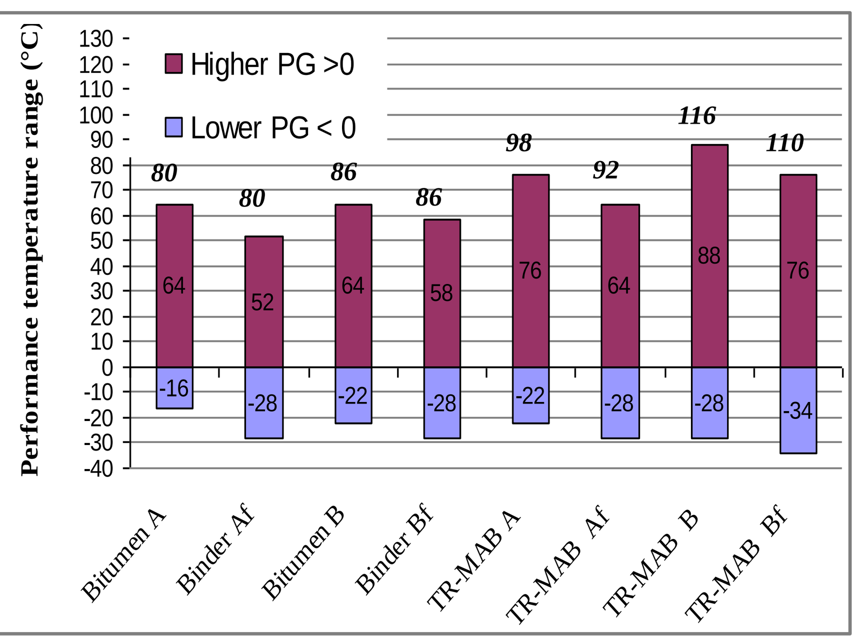
Performance: PG moves towards lower values but maintains the same performance temperature range

Rheology: Black diagrams show that even if the base binders contain flux, it has got the same black curve as that of the base bitumens. The finger print does not change.

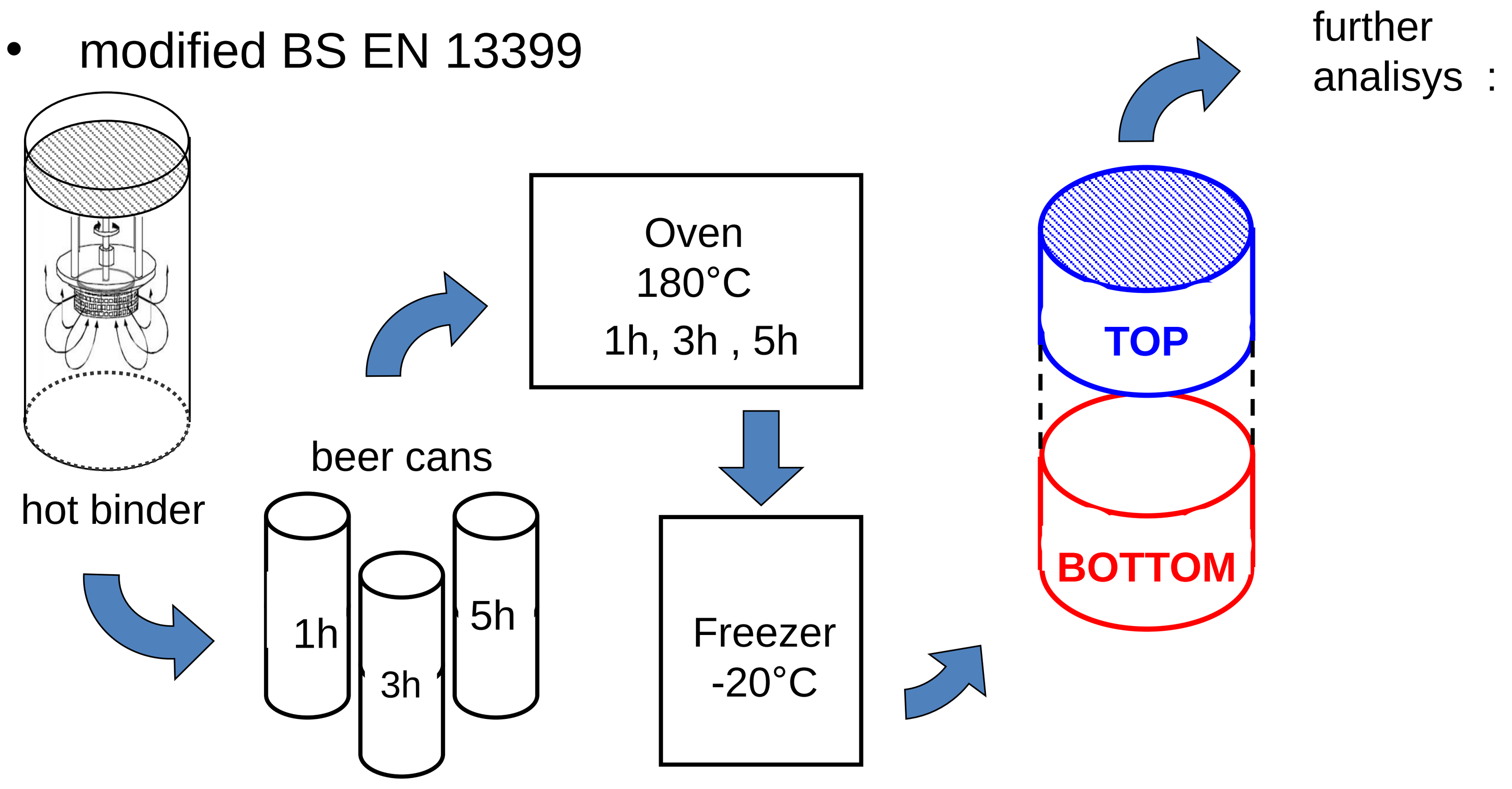


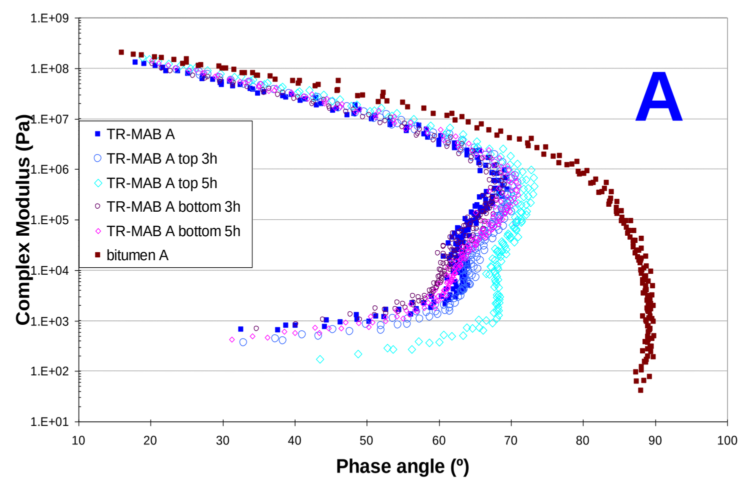


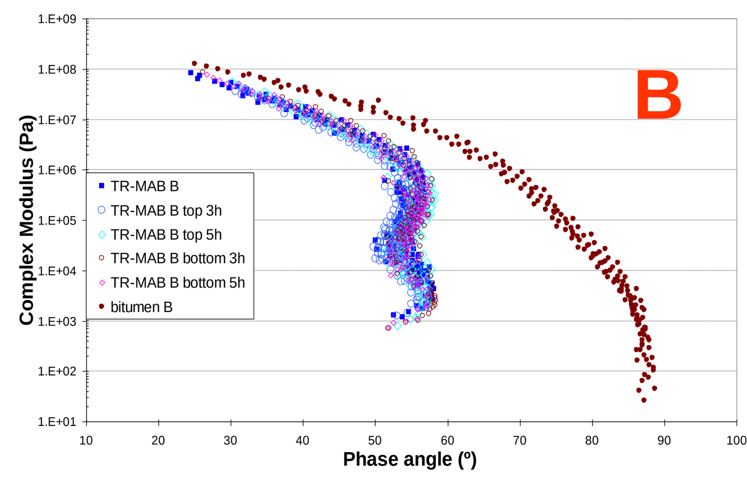
binder A: *PG 64-16*
binder Af: *PG 64-16*
binder B: *PG 64-22*
binder Bf: *PG 64-22*
TRMAB A: *PG 64-16*
TRMAB Af: *PG 64-16*
TRMAB B: *PG 64-22*
TRMAB Bf: *PG 64-22*

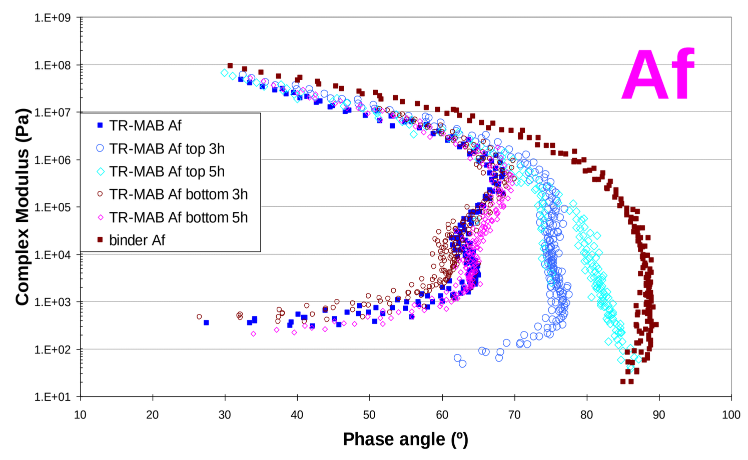


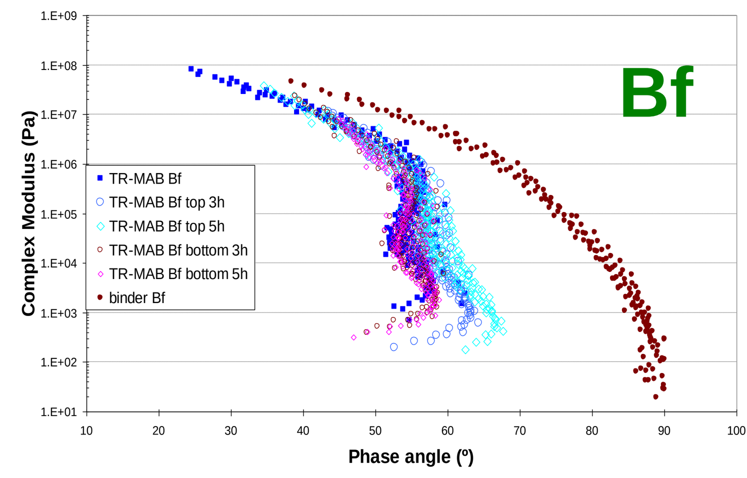
Storage stability analisys: R&B, PDA and DMA











Softening points *before and after hot storage*	TR-MAB A		TR-MAB Af		TR-MAB B		TR-MAB Bf	
	SP of top & bottom sections							
	°C							
before hot storage	60.5		49.8		71.0		60.5	
after 1h of hot storage	59.0	61.4	46.0	51.6	72.5	69.8	61.6	58.0
after 3h of hot storage	59.0	64.4	45.2	53.0	73.4	70.2	61.9	59.8
after 5h of hot storage	57.4	63.4	46.6	54.6	73.8	71.0	62.6	59.0
max ΔT	**6.0**		**8.0**		**3.8**		**3.6**	

Conclusions

The results have indicated that all the modified binders have a considerable improvement in terms of their rheological, physical and performance properties compared to the original base bitumens- However, fundamental differences have been found between the different blends:

- TR-MABs obtained from base bitumen B (higher asphaltenes content), seems to be a better product showing higher viscosity, but better performance grade, lower temperature and frequency susceptibility and better storage stability.
- The addition of the oil extender in the TR-MABs softens the modified binders and also reduces their performance ranges. The overall effect of adding the oil extender is the same whether it is added solely to the base bitumen or used as a component in the production of TR-MABs. The finger print of the material remain the same because the asphaltenes content does not change
- Furthermore, the addition of 7.5% in weight of oil extender in the base binder appears to have a general detrimental effect on the modification in terms of the materials stability. This fact is much more evident on the bitumen with low asphaltenes content
- It is possible to produce a high performance TR-MAB. In order to get a good storage stability, the best level of modification and an acceptable level of viscosity, it is mandatory to preliminary asses the chemical composition of the bitumen and on this base increasing, or not, the aromatics content of the base by adding a relative quantity of oil extender.