Annex1: Stiffness & Fatigue tests on plant produced mixtures

Deliverable 2.2 - Development, Assessment, and Application of Innovations for Interurban Infrastructures

Innovation 2.1 A technical report - Development of high performance underlayers with low cost materials and high percentage of re-use

Purpose

The purpose of this study was to perform stiffness and fatigue measurements on plant produced mixtures which were recompacted in the LAVOC laboratory with the plate compactor. The results are compared with those obtained on the laboratory prepared mixtures.

Stiffness tests

Two mixtures were considered: the mix without reclaimed asphalt (M200) and the mixture with 40 % of RA (M220).

Table 1: Identification of the mixtures considered for stiffness and fatigue measurements with Swiss materials and mean density of the samples.

LAVOC Identification	BRRC Identification	Type of mixture	Mean bulk density (g/cm^3)
M200	OCW4737	HMM with 40 % RA	2.387 ± 0.032
M220	OCW4736	HMM with 0 % RA	2.385 ± 0.041

The mean values of the stiffness modulus and phase angle for different temperatures and frequencies for each mixture are given in the table 2 below. The isochrones (showing the stiffness modulus as a function of temperature) have been determined and are given in figure 1.

Table 2 : Mean stiffness modulus and phase angle for all mixtures

		M200 HMM with 40 %RA		M220 HMM with 0 %RA	
T (°C)	f (Hz)	E* (MPa)	phase (°)	E* (MPa)	phase (°)
30	1	2828*	26.4*	3341*	21.0*
30	3	3651*	23.1*	4777*	20.4*
30	10	4865*	21.6*	6328*	18.9*
30	30	6756*	18.4*	7867*	18.3*
20	1	6375 ± 75	21.6 ± 1.3	6773 ± 711	17.0 ± 0.3
20	3	7494 ± 63	19.9 ± 1.1	8063 ± 751	15.7 ± 0.1
20	10	8998 ± 211	18.6 ± 1.3	9518 ± 734	14.5 ± 0.1
20	30	10907 ± 122	17.0 ± 1.0	11477 ± 816	12.5 ± 0.5
10	1	9938 ± 214	15.6 ± 0.7	10472 ± 4	12.8 ± 0.6
10	3	11244 ± 223	14.5 ± 1.2	11807 ± 303	12.0 ± 0.5
10	10	12721 ± 176	13.7 ± 0.9	12711 ± 166	11.5 ± 1.4
10	30	15011 ± 41	11.4± 1.2	15399 ± 216	9.2 ± 0.2
0	1	14208 ± 79	10.7± 1.7	14521 ± 835	10.2 ± 0.3
0	3	15789 ± 255	9.1 ± 1.2	15524 ± 885	9.0 ± 0.4
0	10	17207 ± 319	8.2 ± 1.4	16686 ± 850	8.3 ± 0.7
0	30	19063 ± 635	6.3 ± 1.1	18770 ± 813	6.8 ± 0.4
-10	1	18712 ± 27	6.2 ± 1.0	17720 ± 267	7.0 ± 0.1
-10	3	19595 ± 123	5.4 ± 1.2	18491 ± 415	6.2 ± 0.1
-10	10	20672 ± 122	4.4 ± 0.9	19651 ± 520	5.8 ± 0.2

-10	30	22734 ± 243	3.1 ± 0.6	21587 ± 490	4.0 ± 0.2
-20	1	23809 ± 1399	4.2 ± 1.1	20800 ± 349	5.0 ± 0.1
-20	3	24149 ± 1236	3.3 ± 0.5	21374 ± 347	4.1 ± 0.2
-20	10	23353 ± 246	2.7 ± 0.2	22055 ± 443	3.2 ± 0.4
-20	30	25162 ± 227	1.5 ± 0.3	23868 ± 473	2.5 ± 0.6

*only one sample was measured at +30°C

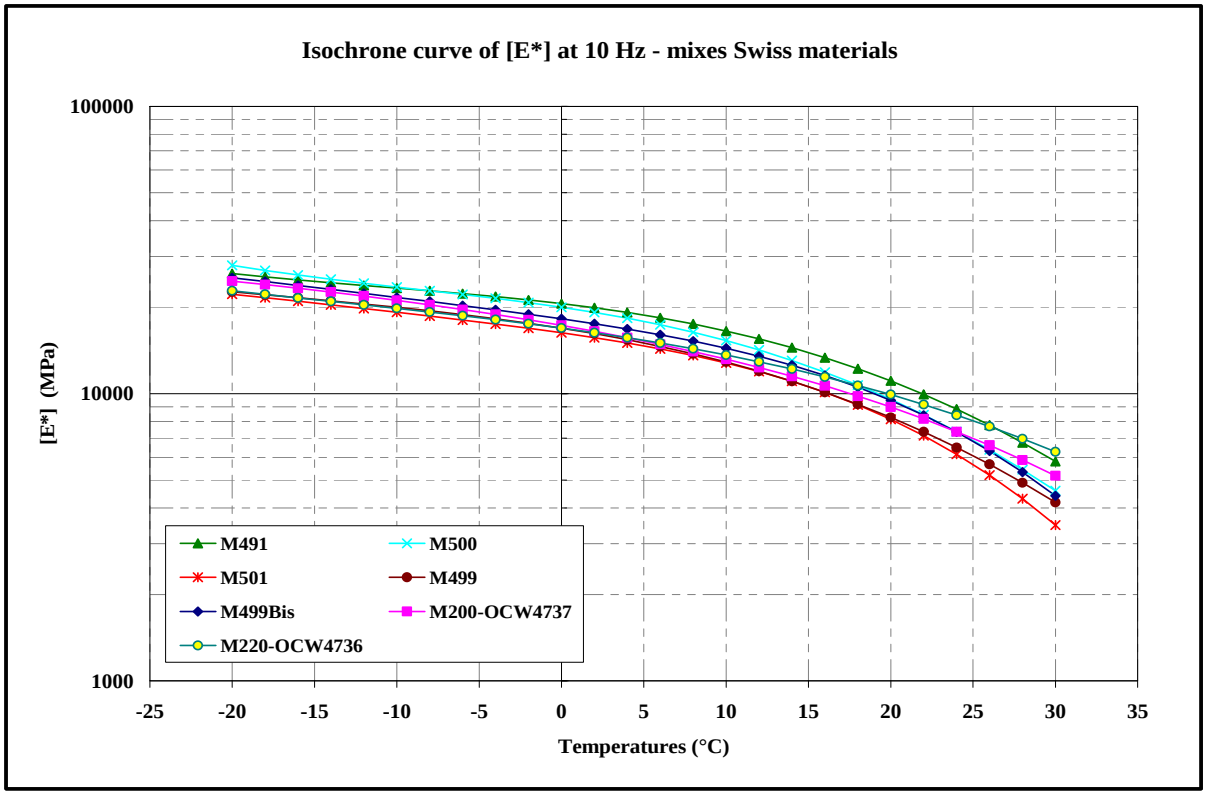

Figure 1 Isochones showing the stiffness modulus as a function of temperature for the various mixtures. Two mixtures (M499 and M501) were less compacted.

Table 3 gives a comparison of the mean stiffness modulus and phase angle of the different mixtures at temperatures of 0, 20 and 30°C and for a frequency of 1 and 10 Hz. The modulus value at 15°C is also given, as it is taken up in the French tender specifications (> 14000 MPa).

The values at 15°C and 10 Hz are interpolation values determined from the master curves.

Table 3 : Comparison of stiffness moduli and phase angles at 30, 20, 15 and 0°C.

Mix	T (°C)	f (Hz)	M491 without RA	M499* with 40% RA, 5.8%b	M499 Bis with 40% RA, 5.8%b	M200 with 40%RA	M220 Without RA
E* (MPa)	30	10	5490	3880	4200	4865	6328
	20		11140	8330	9700	8998	9518
	15		13900	10580	12050	11065	11808
	0		20580	16590	18230	17207	16686
	30	1	3160	2150	2300	2892	3341
	20		7920	5340	6700	6375	6773
	0		17600	14240	15350	14208	14521
Phase (°)	30	10	19.6	22.8	24.1	21.6	18.9
	20		13.6	15.7	14.7	8998	14.5
	0		7.2	6.9	6.9	17207	8.3
	30	1	22.5	25.6	28.1	26.4	21.0
	20		15.1	19.0	16.9	21.6	17.0
	0		8.5	7.6	7.9	10.7	10.2

* less compacted mixture

From figure 1 and table 3 it can be concluded that comparable results were found for the plant produced and laboratory produced mixtures, however with some differences. The plant produced mix without RA is less stiff at moderate and low temperatures than the laboratory produced mixture. The mixture with 40 % RA shows more similar results with the laboratory produced mixtures and is somewhat stiffer at high temperatures. These differences do however not change the earlier conclusions.

Fatigue tests

The different fatigue curves are given in figure 2.

Table 4: Results for fatigue experiments at 15 ° and 10 Hz (controlled stress)

Fully tested mixtures						
Mix	**a**	**K**	**ε_6 (μstrain)**	**n**	**r^2**	**$N_{\varepsilon\ 120\mu strain}$**
M491 : high stiffness without RA (Swiss)	0.097	544.3	143.2	10	0.92	6242340
M499* high stiffness (Swiss) with 40 % RA and 5,8 %b	0.158	946.1	106.9	12	0.87	480746
M499 Bis high stiffness (Swiss) with 40 % RA and 5,8 %b	0.131	760.5	123.7	12	0.87	1258614
M200 HMM with 40 %RA	0.121	664.3	125.5	10	0.88	1451251
M220 HMM with 0 %RA	0.096	501.7	134.0	10	0.85	3181948

* less compacted mixture

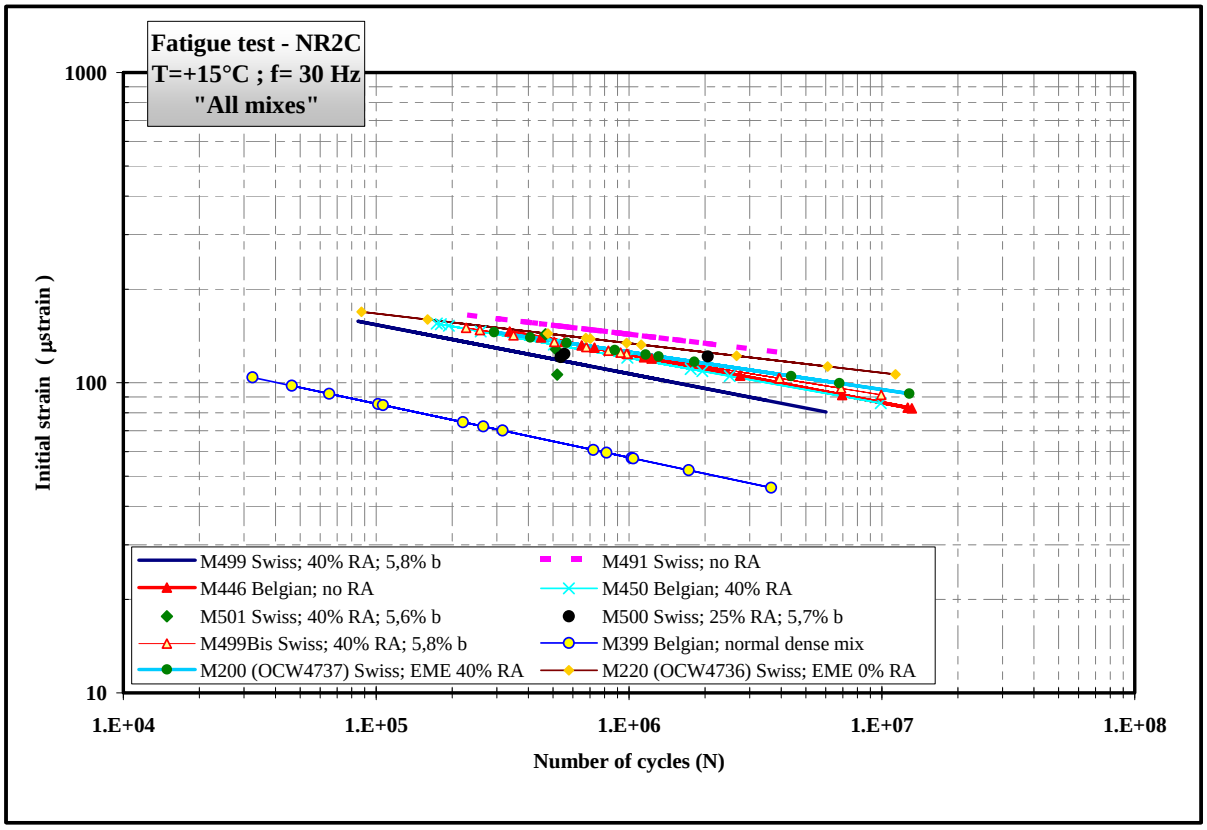

Figure 2: Fatigue curves for all mixes with Swiss and Belgian materials, without and with RA.(M499 and M501 were less compacted)

From table 4 and figure 2 we can conclude that comparable and even better results were obtained in fatigue for the plant produced mixtures than for the laboratory produced mixtures.