Action 4.4

Road pavement monitoring
Technical and environmental parameters

POLITECNICO DI TORINO

Project partners

With the contribution of

Introduction

The goal of Action 4.4 was to provide an initial assessment of the structural performance and of the environmental compatibility of the innovative solutions adopted for the construction of the full-scale pavement sections (Actions 4.1 and 4.2). In particular, it was anticipated that structural monitoring would be carried out for a limited time period (6 months), while environmental parameters would be evaluated by mainly considering gaseous emissions produced during laying operations.

Although in the initial proposal it was indicated that the so-called technical parameters would be obtained from non-destructive tests carried out on site, a different choice was made as the project progressed. This was due to the fact that the adopted paving solutions consisted in the production and laying of wearing courses which due to their limited thickness contribute only marginally to the overall structural performance of pavements. Thus, their structural potential was highlighted by means of advanced performance-based tests which consider:

- stress-strain response under loading (by means of repeated compression tests carried out in triaxial conditions in the Asphalt Mixture Performance Tester, AMPT);
- resistance to crack propagation (by beans of semi-circular bending tests, SCB);
- resistance to accumulation of permanent strains (by means of Flow Number tests, FN).

Results of laboratory tests were supplemented by field monitoring activities which were carried out by means of periodic field surveys. In particular, pavements were inspected for the detection of the possible occurrence of surface distresses such as rutting, cracking and ravelling.

With respect to environmental compatibility, gaseous emissions at the paver, which were characterized in terms of their content of Volatile Organic Compounds (VOCs) and Polycyclic Aromatic Hydrocarbons (PAHs). Techniques for sampling and analysis were those developed by the Politecnico di Torino in previous research projects, with the parallel evaluation of fumes at the paver's driving seat (position D) and at the screed (position S). Wind speed and laying temperature were also recorded since they may significantly affect the release and migration of fumes.

Investigations were performed in the Road Materials Laboratory and in the Environmental Chemistry Laboratory of the Politecnico di Torino. No major problem was reported in any phase of the Action.

In synthesis the following conclusions were drawn (for details, see the Report provided in attachment, included as an additional deliverable of the TYREC4LIFE project):

- Structural properties of bituminous mixtures containing asphalt rubber are totally satisfactory with respect to future required field performance;
- Gaseous emissions are affected by laying temperature and by binder content, but the presence of rubber does not seem to cause major effects on the concentrations of VOCs and PAHs.

Results

Technical parameters

	SP 503_1	SP 503_2	SP 503_3	SP 503_4	SP 503_5	Media
Vuoti [%]	6.35	6.62	7.32	6.16	6.42	**6.57**
F_{max} [N]	1544	1560	1452	1604	1529	**1538**
□W [mm]	1.394	1.489	1.463	1.353	1.349	**1.409**
□$_{max}$ [%]	1.89	2.02	1.99	1.84	1.83	**1.92**
□$_{max}$ [N/mm^2]	0.852	0.869	0.811	0.885	0.864	**0.856**
$K_{1,c}$ [N/mm$^{3/2}$]	5.1	5.2	4.8	5.3	5.1	**5.1**
U_{Fmax} [Nmm]	1539	1585	1515	1643	1579	**1572**

Table 1 – Results of *SCB* tests - SP 503

	1_A	1_B	3_A	3_B	Mean
Voids [%]	7.81	7.81	7.64	7.64	**7.73**
F_{max} [N]	2553	2480	2351	2261	**2411**
□W [mm]	0.626	0.407	0.805	0.484	**0.581**
□$_{max}$ [%]	0.85	0.56	1.10	0.66	**0.79**
□$_{max}$ [N/mm^2]	1.451	1.410	1.334	1.283	**1.369**
$K_{1,c}$ [N/mm$^{3/2}$]	8.6	8.4	7.9	7.6	**8.2**
U_{Fmax} [Nmm]	1134	894	1322	842	**1048**

Table 2 – Results of *SCB* tests - SP 53

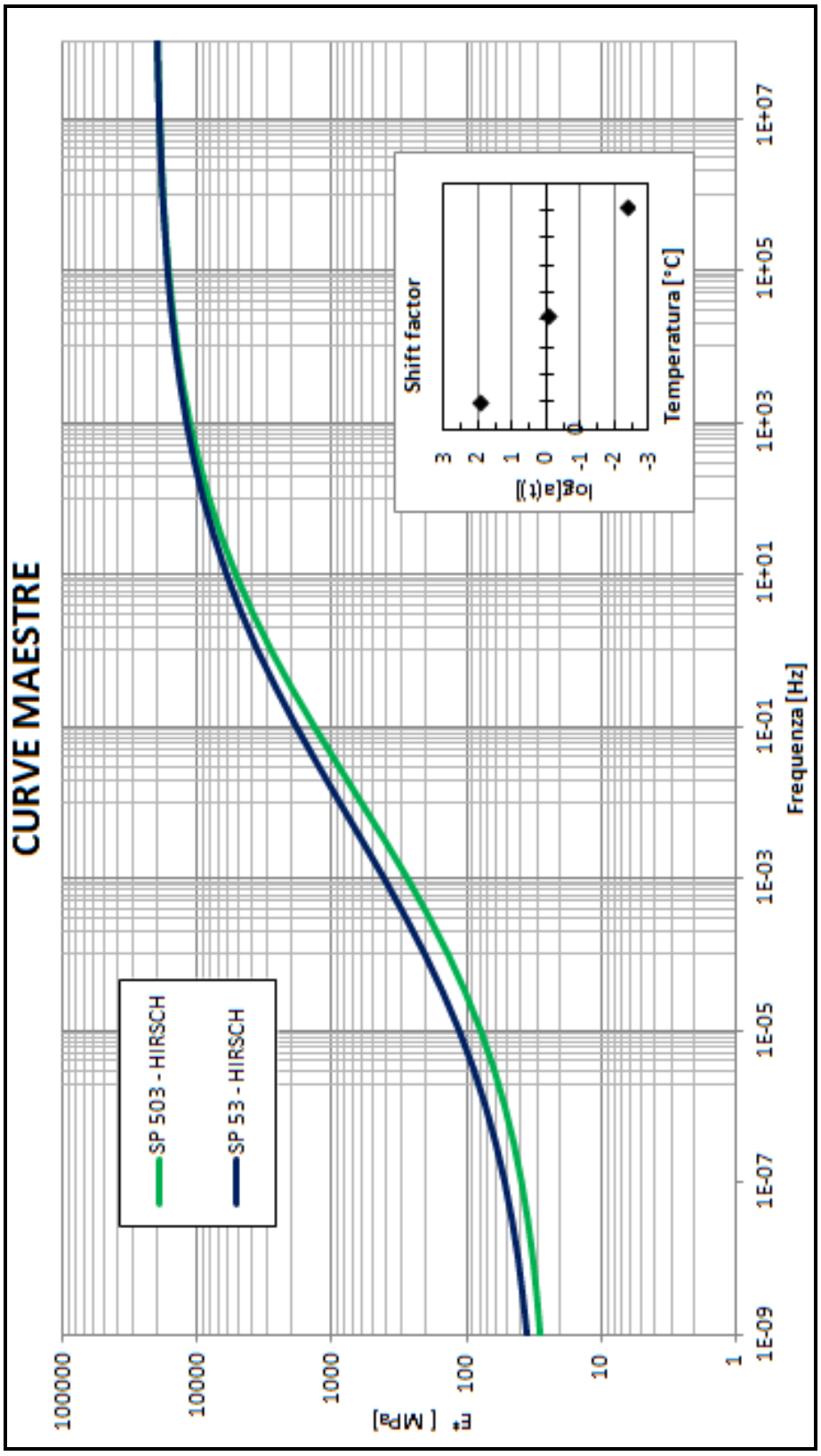

Figure 1 – AMPT master curves (SP 503 and SP 53)

			Flow number	Media
SP 503	**_1**	[-]	2146	**2130**
	_2	[-]	2113	
SP 53	**_1**	[-]	1641	**1220**
	_2	[-]	798	

Table 3 – Results of Flow Number tests (SP 503 and SP 53)

Figure 2 – AMPT specimens after FN testing

ID	V	F_{max}	ΔW	ε_{max}	σ_{max}	$K_{1,c}$	U_{Fmax}
-	%	[N]	[mm]	[%]	[N/mm^2]	[N/mm$^{3/2}$]	[Nmm]
T-1	6.8	3894	0.715	0.97	2.171	12.2	1745.4
T-2	6.8	3867	0.975	1.35	2.163	12.1	1796.9
Mean		3881	0.845	1.16	2.167	12.1	1771.2
T-3	3.1	4693	0.942	1.27	2.844	15.9	2185.4
T-4	3.1	4386	0.91	1.25	2.602	14.6	2056.0
Mean		4540	0.926	1.26	2.723	15.2	2120.7

Table 4. Results of *SCB* tests – Via Brescia, reference mixture

ID	V	F_{max}	ΔW	ε_{max}	σ_{max}	$K_{1,c}$	U_{Fmax}
-	%	[N]	[mm]	[%]	[N/mm^2]	[N/mm$^{3/2}$]	[Nmm]
D-1	9.6	3712	0.705	0.96	2.096	11.7	1255.2
D-2	9.6	3012	0.672	0.92	1.701	9.5	1094.6
Mean		3362	0.6885	0.94	1.898	10.6	1174.9
D-3	6.1	4737	0.898	1.25	2.556	14.3	1642.3
D-4	6.1	4266	0.755	1.01	2.308	12.9	1498.6
Mean		4502	0.8265	1.13	2.432	13.6	1570.4

Table 5. Results of *SCB* tests – Via Brescia, dense-graded mixture

ID	V	F_{max}	ΔW	ε_{max}	σ_{max}	$K_{1,c}$	U_{Fmax}
-	%	[N]	[mm]	[%]	[N/mm^2]	[N/mm$^{3/2}$]	[Nmm]
G-1	9.8	1154	2.326	3.14	0.631	3.5	1859.8
G-2	9.8	1242	2.203	3.02	0.680	3.8	1827.0
Mean		1198	2.2645	3.08	0.655	3.7	1843.4
G-3	7.9	2158	1.711	2.34	1.216	6.8	2476.4
G-4	7.9	1846	1.682	2.26	1.037	5.8	2154.1
Mean		2002	1.6965	2.30	1.126	6.3	2315.2

Table 6. Results of *SCB* tests – Via Brescia, gap-graded mixture

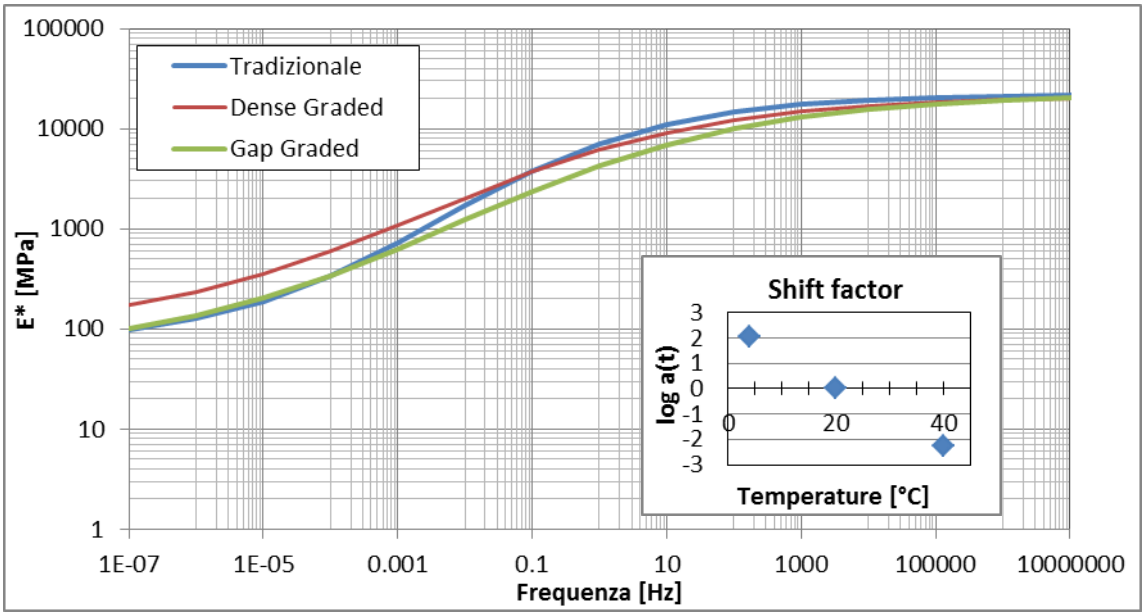

Figure 3 – AMPT master curves (Via Brescia)

ID	Reference	Dense-graded	Gap-graded
1	546	14978	14936
2	473	13783	11915
Mean	510	14381	13426

Table 7. Results of *FN* tests – Via Brescia

Environmental parameters

	Gap-graded		Dense-graded	
	D	S	D	S
Naphtalene	0.55	1.06	1.08	1.71
Acenaphthylene	0.27		0.30	0.03
Naphthalene, 1-bromo-			0.43	0.05
Acenaphthene				
Fluorene		0.05		
Phenanthrene		0.03		
Anthracene		0.02		
Fluoranthene	0.61		0.93	0.08
Pyrene	0.55		0.82	0.23
Triphenylene	0.06			0.02
Benz[a]anthracene	0.15		0.25	0.01
Benzo[b]fluoranthene	0.39	0.04		0.42
Benzo[a]pyrene	1.51	0.03	1.55	1.59
indeno[1,2,3-cd]pirene	0.04		0.31	0.07
dibenzo[a,h]antracene	0.32	0.03	0.03	
Benzo[ghi]perylene				
Total PAHs	4.46	1.26	5.70	4.20

Table 8. PAHs recorded for the paving works carried out as part of Action 4.1

	Reference		Dense-graded		Gap-graded	
	D	S	D	S	D	S
Benzene	48.4	52.3	42.7	55.4	61.7	62.1
Toluene	73.9	76.3	55.1	70.8	88.9	94.7
ethylbenzene	17.5	31.4	16.2	16.3	20.1	75.3
p-Xylene	30.7	95.7	103.5	84.2	138.1	119.4
Styrene					3.0	24.8
Benzene, bromo-						
Benzene, 1,3,5-trimethyl-	17.6	54.0	16.2	20.2	17.2	24.1
Benzene, 1,2,4-trimethyl-	33.4	101.2	12.0	26.9	24.3	16.7
p-isopropiltoluene	7.2	19.0	33.1	31.2	55.5	83.9
Benzene, butyl-	4.3	10.4	0.0	0.8	0.0	0.0
Benzene, 1,3,5-trichloro-	1.9	2.5	1.4	1.5	1.5	1.5
Benzene, 1,2,4-trichloro-			2.9		2.3	
total VOCs	234.9	442.9	283.0	307.2	412.6	502.5
T laying (°C)	140.0	139.0	162.5	161.0	162.0	165.5
wind speed (km/h)	1.5	1.5	4.3	3.6	4.8	4.0

Table 9. VOCs recorded for the paving works carried out as part of Action 4.2

	Reference		Dense-graded		Gap-graded	
	D	S	D	S	D	S
Naphtalene	2.10	6.53	2.63	3.72	6.42	1.50
Acenaphthylene						
Naphthalene, 1-bromo-						
Acenaphthene						
Fluorene						
Phenanthrene						
Anthracene					0.44	
Fluoranthene	0.01		0.01		0.04	
Pyrene					0.01	
Triphenylene					0.05	
Benz[a]anthracene					0.06	
Benzo[b]fluoranthene	0.11	0.06	0.11	0.06	0.02	0.01
Benzo[a]pyrene	0.01	0.01				
indeno[1,2,3-cd]pirene				0.01	0.03	
dibenzo[a,h]antracene		0.01	0.03		0.01	
Benzo[ghi]perylene					0.18	
Total PAHs	2.22	6.61	2.78	3.79	7.26	1.51
T laying (°C)	140	139	163	161	162	166
wind speed (km/h)	1.5	1.5	4.3	3.6	4.8	4.0

Table 10. PAHs recorded for the paving works carried out as part of Action 4.2

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