SPENS Final seminar
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Evaluation of materials for road upgrading

Marjan Tušar - ZAG Ljubljana
WP4 leader

Ljubljana, Slovenija

Objectives- SPENS

The objective of this research project is to develop appropriate tools and procedures for the rapid and cost-effective rehabilitation and maintenance of roads in the EU New Member States (NMS).

The overall objective is to search for materials and technologies for road pavement construction and rehabilitation that would:

- behave satisfactorily in a typical climate,
- have an acceptable environmental impact,
- be easy to incorporate within existing technologies,
- be cost-effective and easy to maintain

Starting points – WP4 Evaluation of materials for road upgrading

1. Insufficient information is available on the actual performance of asphalt mixtures with modified bitumen.
2. High Modulus Asphalt Mixture is technical solution providing improved durability of road asphalt pavement with possibility to reduce the pavement thickness and road construction costs. Further it requires less maintenance operations, thus giving the reduction of maintenance cost.
3. To investigate the effect of different thicknesses of asphalt pavement and strengthening treatments on existing pavements accelerated load test should be performed with Heavy Vehicle Simulator, HVS-Nordic. This cost-effective facility can be used on selected field trial

Objectives - WP4 Evaluation of materials for road upgrading

The main objective of this work package is to evaluate materials and pavement layers appropriate for road upgrading, taking into account the conditions in New Member States.

Modified bitumens as asphalt binders and high modulus asphalt mixtures are more and more popular in road construction, but insufficient information is available on the actual performance of these mixtures. The objectives of this work package are:

- To evaluate the efficiency of the use of different modified bitumens.
- To deepen the knowledge about performance-related laboratory tests by test section evaluation.
- To implement and further develop the technology of High Modulus Asphalt Mixtures in Central and Eastern European Countries.

Objectives - WP4 Evaluation of materials for road upgrading

Further objectives of this work package are:

• To study possible technologies of upgrading low-volume roads to higher bearing capacity and also cost-benefit analyses of different procedures.

• To perform accelerated loading tests in test fields of the New Member States, in order to evaluate the upgrading techniques and new materials.

• To evaluate the behavior of improved materials and pavement structures.

Final results are:

Guidelines for different types of performance-related binder tests, as well as recommendations for selecting binder properties for different types of asphalt mixtures based on the results of performance-related binder tests.

Guidelines and the required properties for choice of materials for High Modulus Asphalt Mixtures (binders, aggregates, additives).

Guidelines for selecting the most cost-effective strengthening treatments on asphalt macadam and light asphalt pavements.

Tasks - WP4 Evaluation of materials for road upgrading

Task 1 Investigation of the Performance of Conventional and Polymer Modified Bitumen

Task 2 Material Recommendations and Performance-based Requirements for High Modulus Asphalt Mixtures and Flexible Pavement Design

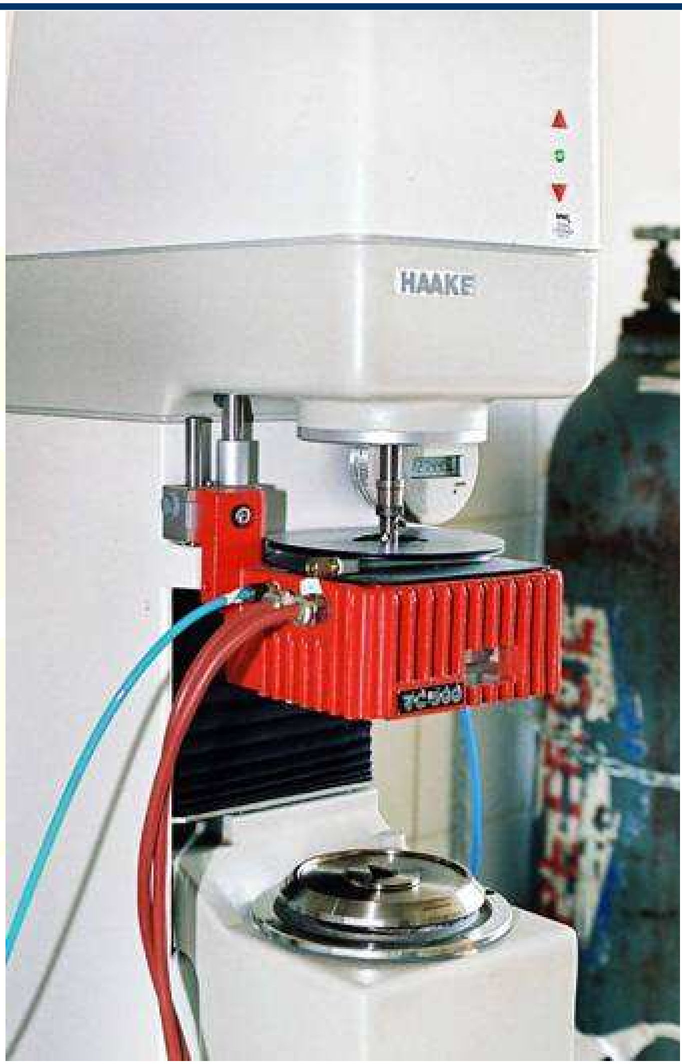
Task 3 Upgrading of asphalt macadam and light asphalt pavements to the bearing capacity level needed by EU-regulations

The binders (conventional and modified bitumen) used in the asphalt mixtures were varied to accomplish a large variation in their characteristic properties. The binders were characterized with a range of fundamental test methods as well as traditional test methods and these results were compared and correlated to the results from the asphalt mixture testing program.

The tasks to accomplish

- **Recommendations for the choice of performance related binder tests**
- **Recommendations for selecting binder properties for different types of asphalt mixtures based on the performance related binder tests**

*Bitumen are tested on RB (EN 1427), pen. (EN 1426), Fraass (EN 12593), RTFOT (EN 12607-1), RFT (EN 12607-3), kinematic viscosity (EN 12595), capillary viscosity (EN 12596), rotating spindle viscosity (EN 13302), cone-plate viscosity (EN 13702-1), coaxial cylinders viscosity (EN 13702-2), elastic recovery (EN 13398), storage stability (EN 13399), Force ductility (EN 13589), DSR zero shear viscosity and SHRP parameters***.**



Used bitumen- Paving grade bitumen

EN 12591	70/100	50/70	20/30
Penetration @25 °C	78	57	28
Softening Point, °C	50	55	62
Fraass Breaking Point, °C	- 22	- 19	- 11
Density @25°C, Mg/m ^{3}	1,014	1,017	1,017
Kinematic viscosity @135°C, mm ^{2}/s	372	579	1340
EVT (170), °C	153	160	178
EVT (280), °C	140	148	165

Used bitumen- Polymer modified bitumen

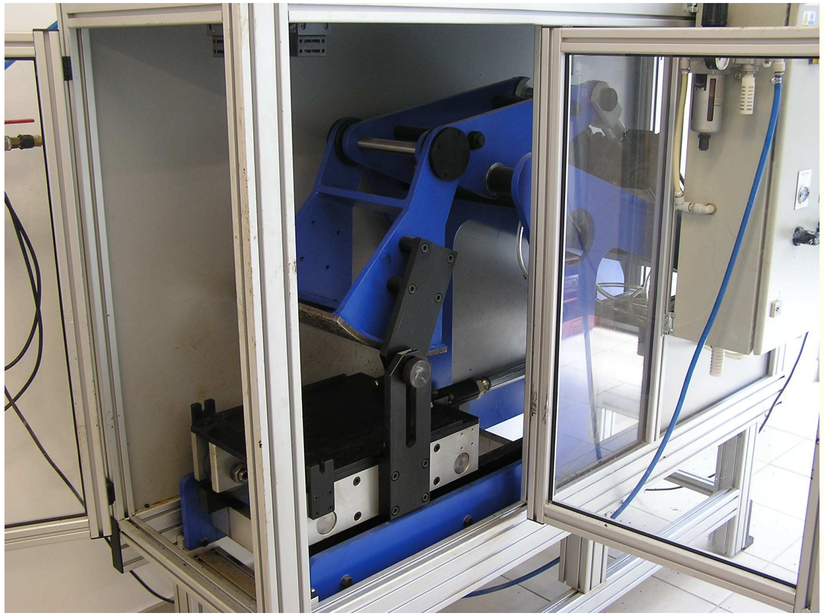
EN 14023	PmB 1	PmB 2	PmB 3	PmB 4
Penetration @ 25 ℃	70	45	79	30
Softening Point, ℃	72	73	48	67
Fraass Breaking Point, ℃	- 18	- 16	- 16	- 13
Density @ 25℃ (Mg/m^3)	1,014	1,017	1,017	1,016
EVT (170), ℃	170	193	160	-
EVT (280), ℃	155	176	148	-

Investigation of the Performance of Conventional and Polymer Modified Bitumen

Binder → Test ↓	Unit ↓	A	B	C	D	E	F	G
Penetration	dmm	82	30	29	68	44	74	54
Penetration mod.I	dmm	147	43	42	104	66	141	88
Softening point	℃	47.6	62.2	67.6	71.2	66.8	49.6	54.8
Fraass Break Point	℃	-17.5	-9.5	-10	-12	-14	-19.5	-18.5
Kinematic viscosity	mm2/s	599	1370	2234	713	2055	416	596
Dynamic viscosity	Pa s	271	2697	5184	1405	5029	181	528
Penetrati / RTFOT	dmm	53	23	25	44	32	51	41
Soft. Po./ RTFOT	℃	53.4	68.4	73.6	75.4	75.2	56.2	60.8
Dyn. visc./RTFOT	Pa s	666	7819	15758	1902	8886	825	2373
Elastic recovery	%	46			74	99	89	
Deformation en.II	J/cm2	2.2			12.6	4.3	9.1	
Deformation e.III	J/cm2	0.1			1.8	2.2	3.6	
Cone Plate v.IV	Pa s	227	2022	3219	1407	2624	141	460
Cone Plate v.V	Pa s	0.219	0.587	0.734	0.286	0.691	0.133	0.176
Ekviviscous t.VI	℃	145	162	167	151	168	138	144
Coaxial cyl. v.VII	Pa s	1.69	4.74	6.93	1.89	5.42	1.08	1.97
Coaxial cyl. v.VIII	Pa s	0.43	0.80	1.26	0.42	1.17	0.21	0.38

I Penetration at 35℃ with total weight of 50g; II At 1 0℃ and speed 50 mm/min
III At 25℃ and speed 50 mm/min; IV At 60℃; V At 150℃
VI According to ASTM D 1559 (2382); VII At 120℃; VIII A t 150℃

Asphalt mix program



- 1-2 stone aggregates
  - Diabase (Croatia) – A1
  - Limestone (Croatia) – A2

- 3 gradings of mineral mixture
  - AC (asphalt concrete) – G1
  - SMA (stone mastix asphalt) – G3
  - PA (porous asphalt) – G4
  - *MA (mastic asphalt) – G2*

Binder content	*Default*	*C1*
	High (+0.5%)	*C2*
	Low (-0.5%)	*C3*

Asphalt tests were mainly performed in Croatia. The testing program included wheel tracking tests (EN 12697-22) and Marshall stability at different temperatures. Stiffness (EN 12697-26) was performed in Bulgaria. Water sensitivity (EN 12697-12) was preformed in Slovenia. For some mixtures TSRST tests was performed in Poland.

Binder → Test ↓ Unit ↓	A	B	C	D	E	F	G
Asphalt test on SMA/basalts							
Wheel tracking rut mm	*2.45*	*1.86*	*1.53*	*1.54*	*1.33*	*2.48*	*1.98*
IT-CY stiffness, 15℃ MPa	*1657*	*4413*	*4031*	*2174*	*3218*	*1369*	*2 279*
Asphalt test on AC/basalts							
IT-CY stiffness, 15℃ MPa	*1974*	*4163*	*4121*	*2171*	*2823*	*1696*	*3 043*
Asphalt test on AC/limestone							
IT-CY stiffness, 15℃ MPa	*2494*	*9132*	*5297*	*4320*	*4572*	*2225*	*4 934*
Asphalt test on PA/basalts							
IT-CY stiffness, 15℃ MPa	*838*	*2670*	*2889*	*1435*	*1975*	*969*	*198 7*

Investigation of the Performance of Conventional and Polymer Modified Bitumen

Asphalt mix test → *Binder test ↓*	*SMA/wheel tracking*	*AC(basalts)/stiff.*	*AC(limest.)/stiff.*	*PA(basalts)/stiff.*
Penetration	*0.43*	***0.88***	***0.67***	***0.97***
Penetration mod.I	*0.58*	***0.87***	***0.70***	***0.96***
Softening point	**0.90**	*0.23*	*0.22*	*0.37*
Fraass Break Point	*0.50*	*0.55*	*0.55*	*0.57*
Kinematic viscosity	*0.57*	*0.50*	*0.19*	*0.58*
Dynamic viscosity	*0.66*	*0.44*	*0.18*	*0.56*
Penetration / RTFOT	*0.53*	***0.89***	***0.72***	***0.94***
Soft. point / RTFOT	**0.94**	*0.25*	*0.23*	*0.40*
Dyn. visc. / RTFOT	*0.44*	*0.67*	*0.25*	*0.75*
Elastic recovery	*0.47*	*0.00*	*0.03*	*0.00*
Deformation energy II	*0.48*	**0.93**	**0.78**	**0.97**
Deformation energyIII	**0.86**	*0.08*	*0.50*	*0.23*
Cone Plate viscosityIV	*0.72*	*0.54*	*0.30*	*0.66*
Cone Plate viscosityV	*0.57*	*0.57*	*0.34*	*0.63*
Ekviviscous temp.VI	*0.68*	*0.54*	*0.36*	*0.61*
Coaxial cyl. visk.VII	*0.50*	*0.67*	*0.32*	*0.73*
Coaxial cyl. visk.VIII	*0.55*	*0.51*	*0.20*	*0.58*

Statistics:

Univariate correlations between test methods:

Correlations between binder test methods

Univariate correlations between binder test methods and asphalt test methods.

Univariate correlation between binder properties and asphalt stiffness

Univariate correlations between binder properties and water sensitivity.

Univariate correlations between binder properties and asphalt rutting

Univariate correlations between binder properties and Marshall stability and between Marshall stability and other asphalt mix properties.

Statistics:

Multivariate analysis of relation between binder test methods and asphalt properties:

Principal component analysis of binder data

Partial least squares analysis of asphalt stiffness and binder data

PLS2 model of asphalt stiffness versus category data

PLS2 model of asphalt stiffness versus binder properties and category data

Partial least squares analysis of water sensitivity and binder data

PLS1 model of ITSR versus category data.

PLS1 model of ITSR versus binder data and category data

Partial least squares analysis of asphalt rutting and binder data

PLS2 model of rutting propensity versus category data.

PLS2 models of rutting propensity versus binder data and category data

Conclusions:

The stiffness modulus is correlated to penetration, the complex modulus or measures derived from the complex modulus,

We didn’t find any relation between water sensitivity of asphalt and the mechanical and visco-elastic properties of the binder.

Rutting of asphalt as characterized by wheel tracking parameters is correlated to softening point or for example Ln(G’/(η/G’)) at 60℃, which has been suggested as a surrogate method for the ductility, could be used to model the wheel tracking parameters.

High Modulus Asphalt Mixtures are not yet widely used in the Central and Eastern European countries.

The technology transfer has to take into account local climatic conditions as well as the availability of raw materials (binders, low quality aggregates, additives) and existing equipment, both for the road construction and for laboratory testing.

Within this task material recommendations were prepared based on laboratory and field data from the NMS countries.

Two full-scale trial test sections were constructed in Poland with typical pavement design. They were subjected to accelerated loading tests to validate the laboratory results.

Goal: to develop a concept of high modulus asphalt mixtures (HMAC) for the implementation in the Central and Eastern European countries

General plan:

Preparation of initial recommendations

Laboratory implementation and tests

Preparation of trial sections

HVS tests

Analysis and final report (recommendations)

Binder selection for test field:

Property	Unit	DE 30B	35/50	20/30	MP10/20
Penetration at 15℃	0,1 mm	18	19	10	9
Penetration at 25℃	0,1 mm	41	45	23	21
Softening point	℃	61,2	54,6	61,8	70,0
Fraass breaking p.	℃	-17	-18	-9	-12
Ductility at 15℃	cm	-	-	-	16
Ductility at 25℃	cm	67	>150	118	-
Viscosity at 60℃	mPas	-	804000	3254444	-
Viscosity at 90℃	mPas	66444	23117	59431	233444
Viscosity at 135℃	mPas	1796	834	1502	4674

Property	Mineral mixture density, g/cm3	Asphalt mixture density, g/cm3	Asphalt mixture bulk density, g/cm3	Air voids content, % v/v	Mean rut depth, %	IT-CY, 10 ^{0}C, MPa	4PB-PR, complex modulus, 10 ^{0}C, MPa	Fatigue damage D, %	Water sensitivity, %
Require-ment, HMAC 2007	–	–	–	3,0 ÷ 5,0	≤ 5,0	–	≥ 14 000	≤ 50	≥ 80,0
HMAC16 – S, B=5,3 %	3,645	2,312	3,115	3,0	2,3	19 325	20 713	15,3	121,3
HMAC16 – L, B=5,5 %	2,698	2,479	2,403	3,1	3,7	23 511	19 837	31,7	95,3
HMAC16 – G, B=5,5 %	2,662	2,448	2,375	3,0	2,6	17 241	17 291	> 50	107,8
HMAC16 – C, B=4,9 %	2,691	2,493	2,419	3,0	2,0	18 918	16 927	19,7	104,8
HMAC16 – B, B=4,6 % / B=5,1 %	2,850 / 2,850	2,636 / 2,617	2,550 / 2,568	3,3 / 1.9	2,7 / 6,3	21 118 / 19 272	19 756 / 17 950 >	>50 / 49	114,9 / 118,7

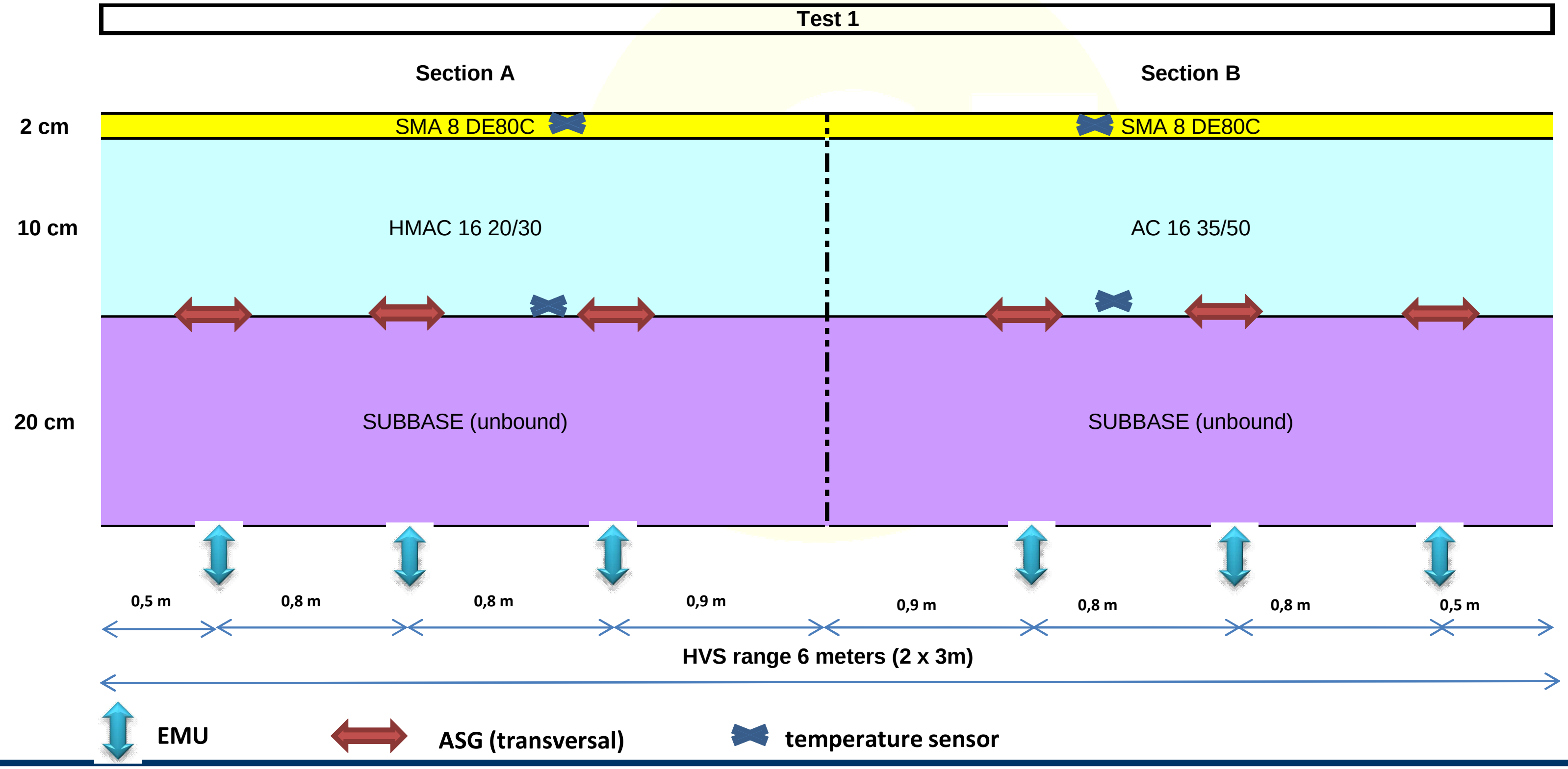
Performance-based Requirements

Resistance to rutting large device (30000 cycles, 60˚C)≤ 5,0%.
Stiffness 4 PB test method (10 Hz, 10˚C) ≥ 14000 MPa.
Fatigue 4 PB test method (10 Hz, 10˚C) ε_6 > 130 μm/m

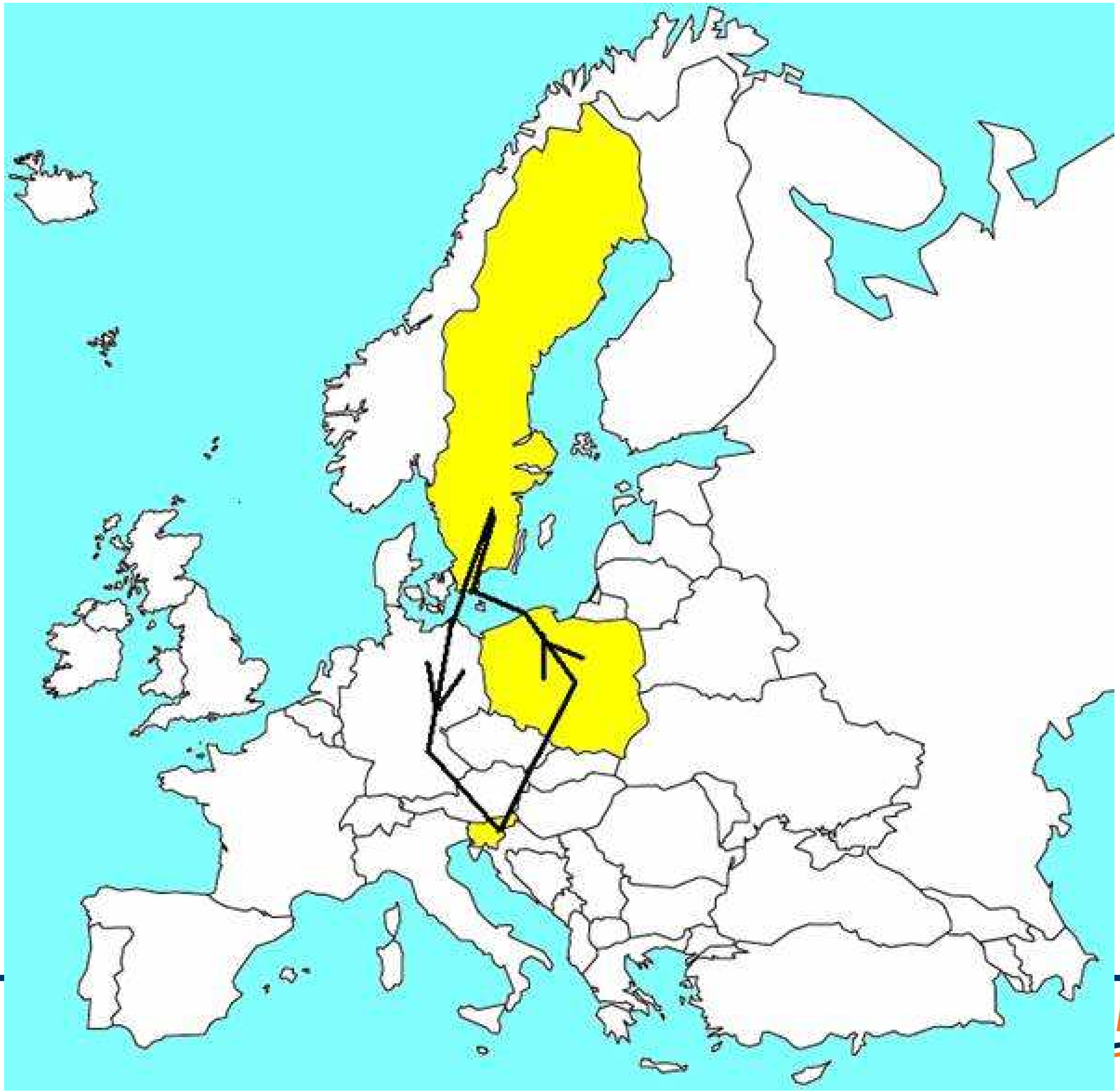
For test field was selected:
The HMAC 16 with 20/30 binder – high modulus asphalt concrete appropriate for base and wearing courses, was designed according to requirements from WT NA- 2008 and 70-ZW-WMS 2007 for traffic category KR3-KR6:

- 20/30 binder ,
- limestone filler,
- limestone 0/5,6; 4/8, 8/16 [mm]

The next step of the task was construction work of test sections that was subjected to HVS loading. Test section was divided into two halves of the same layer thickness, but with two different mixes for base course: asphalt concrete (AC) and HMAC.



HVS travel



HVS testing conditions

• Wheel type	Single
• Wheel load	60 kN (80 kN after 190 000 cycles)
• Tire pressure	800 kPa
• Lateral distribution	
• Speed	10-12 km/h
• Temperature	+10 °C

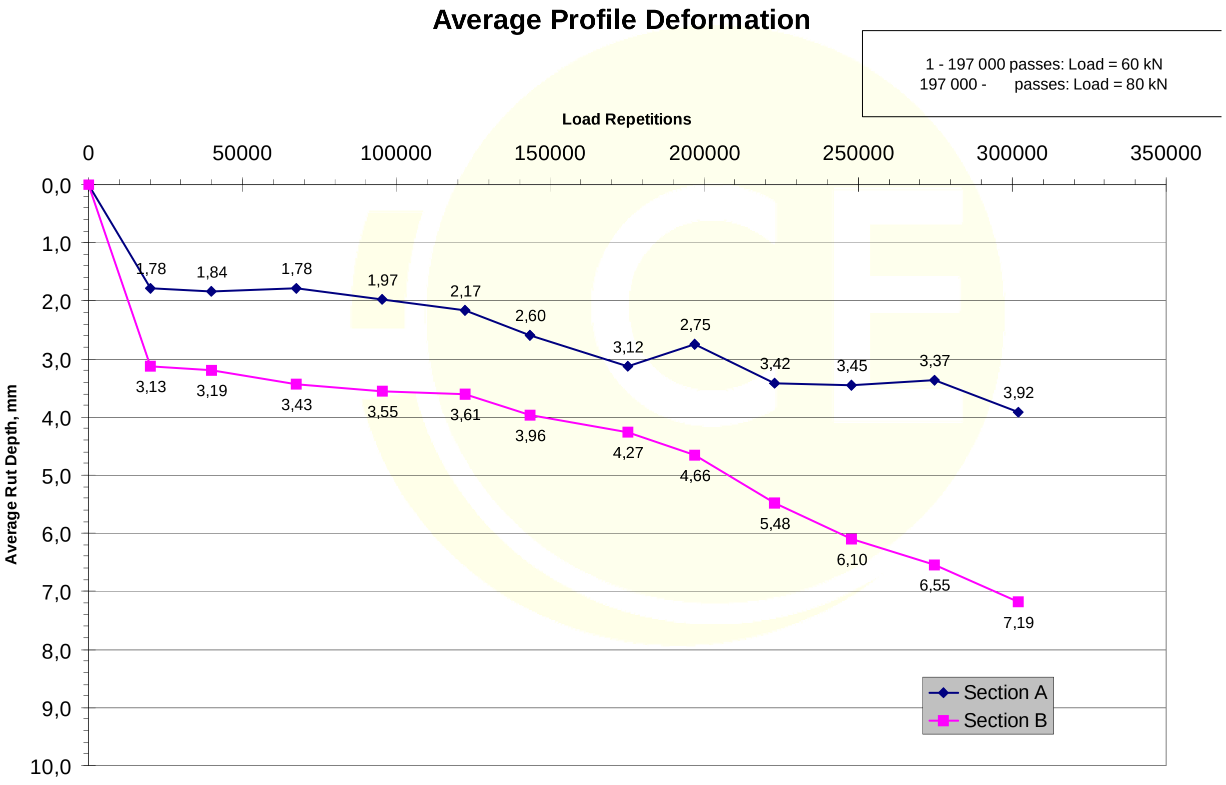
The type and frequency of the measurements are listed below:

• Transverse profile	daily
• Vertical strain in the top of the subgrade	daily
• Vertical permanent deformation of the subgrade	daily
• Transverse hor. strain in the bottom of asphalt	daily

Measurements frequency for different loading levels:

- Transverse horizontal strain in the bottom of asphalt layers (second and the last day of the testing)
- Vertical displacement of the subgrade (second and the last day of the testing)
- Wheel loading: 30, 40, 50 and 60 kN

Average profile deformation:



Recommendations for Poland have been already prepared.

For implementation of HMAC in Slovenia, Serbia, Sweden, Croatia, and Estonia climate analysis was performed:
Evaluation of effective temperature for fatigue (TEFF)
PG temperatures for different layers.

TEFF temperature was calculated on the basis of mean annual air temperature (MAAT) and thickness of typical flexible pavement structures.

Temperatures and recommended bitumen in Slovenia:

	Layer	T_a(max)	T_a(min)	Depth	T_d(max)	T_d(min)	**PG**
		˚C	˚C	mm	˚C	˚C	
Ljubljana	binder	33,9	-17,0	80	45,3	-12,5	52-16
Ljubljana	base	33,9	-17,0	120	42,3	-12,6	46-16
Portorož	binder	33,3	-11,2	80	45,0	-7,5	52-10
Portorož	base	33,3	-11,2	120	41,9	-7,6	46-10

T_a(max) – maximum seven day temperature, ˚C,
T_d(max) – maximum temperature of the pavement at depth d, ˚C,
T_a(min) – minimum air temperature, ˚C,
T_d(min) – minimum temperature of the pavement at depth d, ˚C,

Many regional and local roads have insufficient bearing capacity due to the increasing number of trucks and heavier axial loads.
An instrumented full-scale trial section was designed and constructed. A new local road is upgraded with six different pavement structures. All six test sections are instrumented to monitor deformations during the full-scale accelerated loading tests.
Laboratory and field tests of the materials (for unbound and asphalt layers) were performed.
Based on the data gathered from these tests and test sections constructed in the past years within some other projects, these upgrading techniques were evaluated.

Type of road**: local (in Dragučova)**

Annual average daily traffic**: very low**

Date of construction**: November 2007 in March 2008 (SCT, d.d.)**

Type of road structures**: aspahlt – 6 different pavement structures**

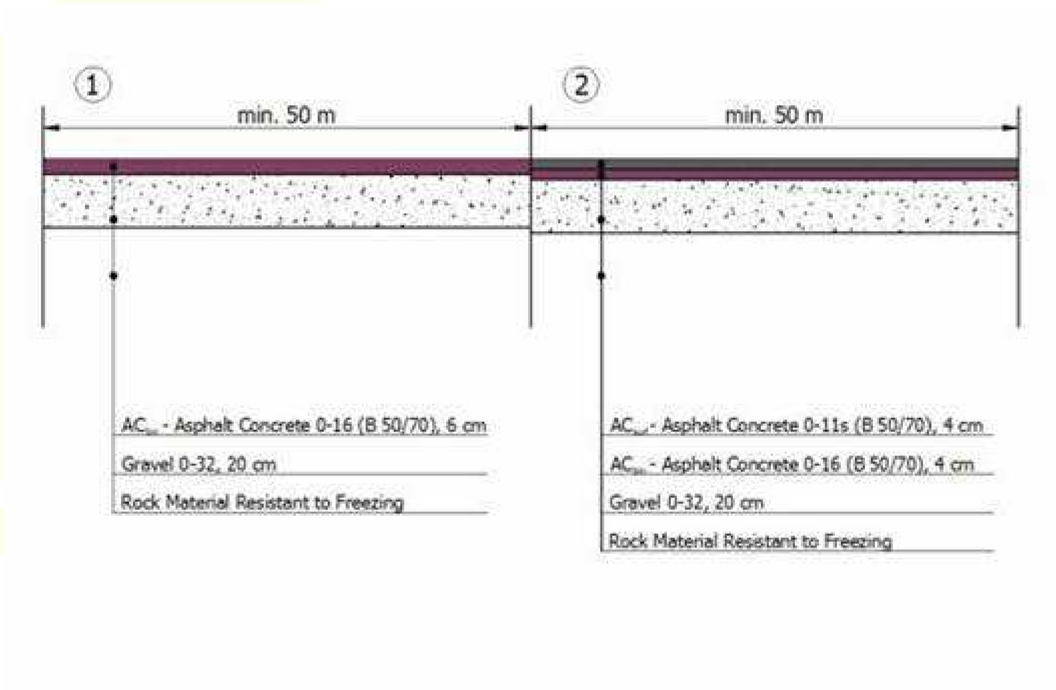
Width**: 3,6 m**

Length**: 6x50m=300 m**

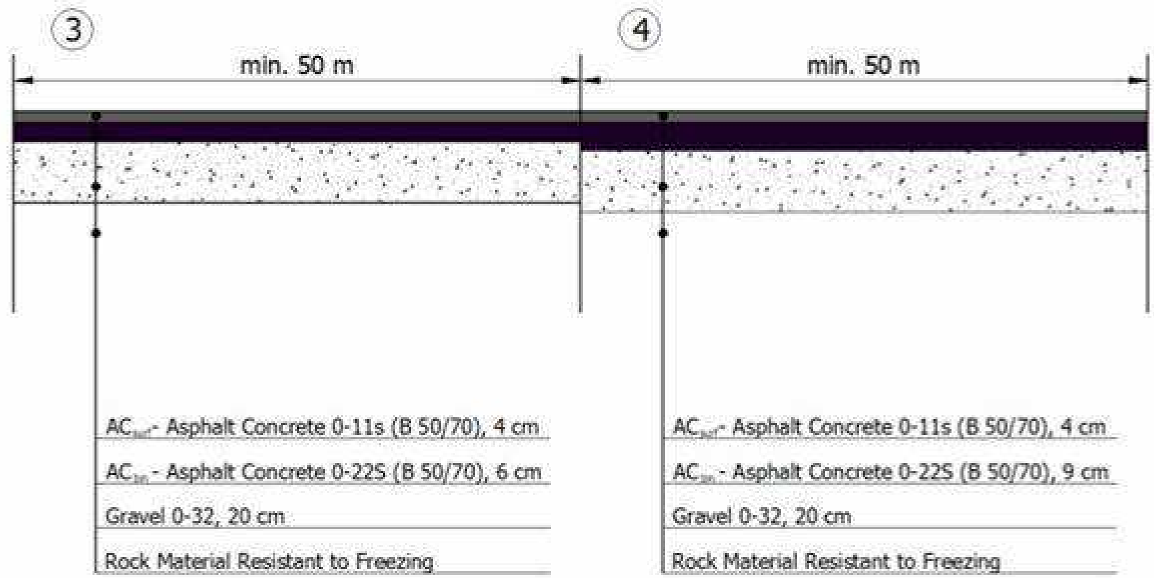
Thickness of unbound base layer**:**
20cm of gravel

Thickness of asphalt layer**:**
6 to 13cm

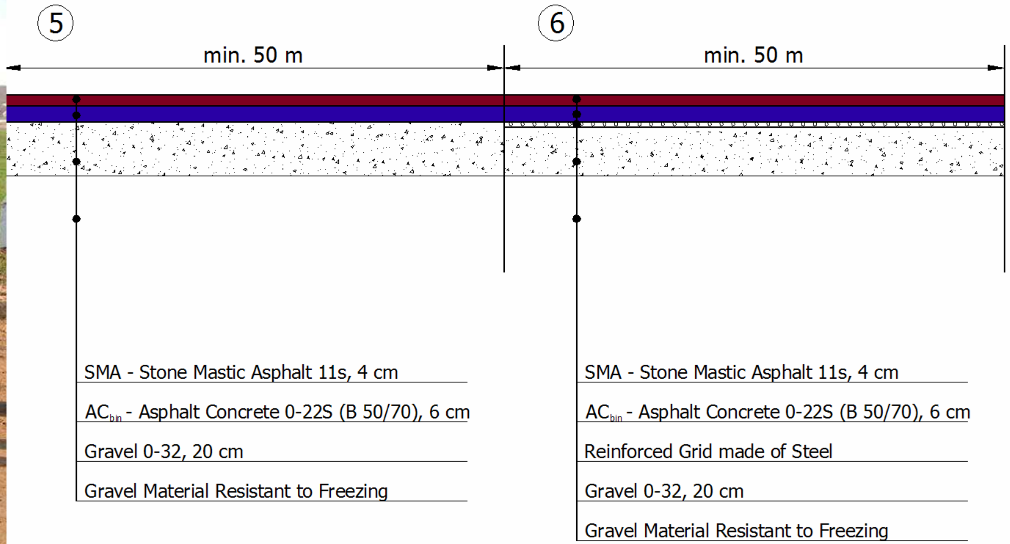
Test sections 1 and 2



Test sections 3 and 4



Test sections 5 and 6



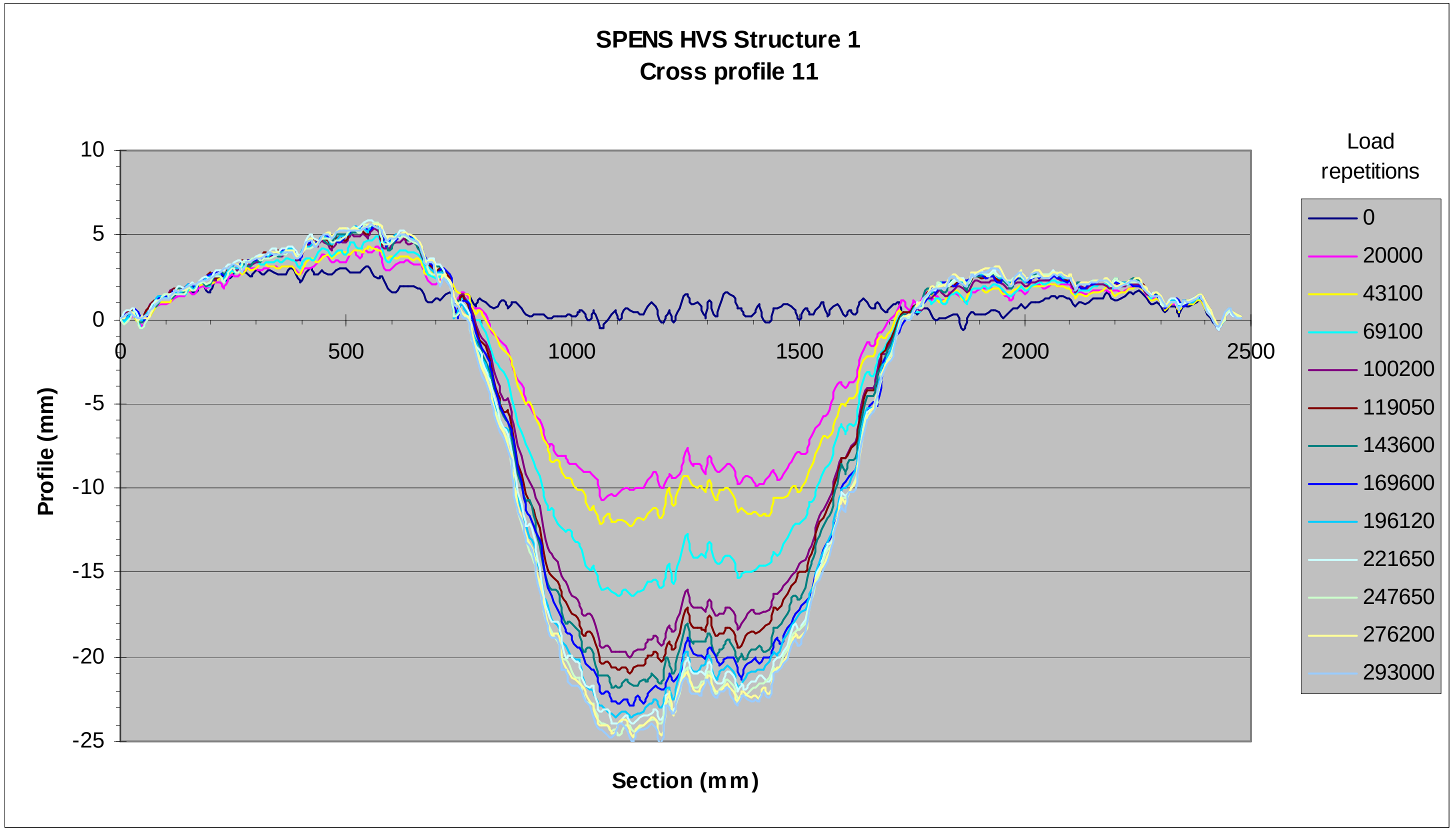
On subbase ground from crumble and clay, base gravel from sandy gravel (Pos) was built in. Thickness of base gravel was up to 60 cm. Unbound base layer (NNP) had thickness 20 to 25cm. Uncrushed gravel with grain size 0 to 32 mm was used.

Upgrading of asphalt macadam and light asphalt pavements to the bearing capacity level needed by EU-regulations

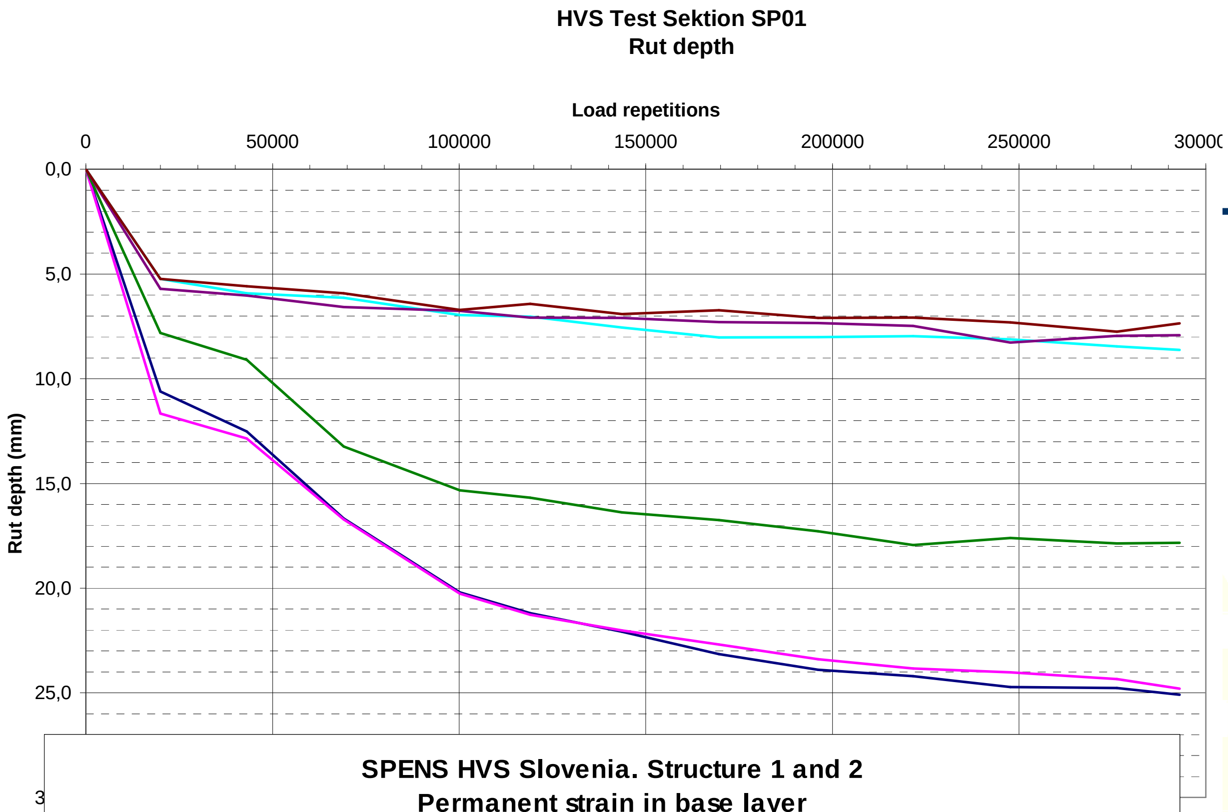
Laying asphalt over steel mesh

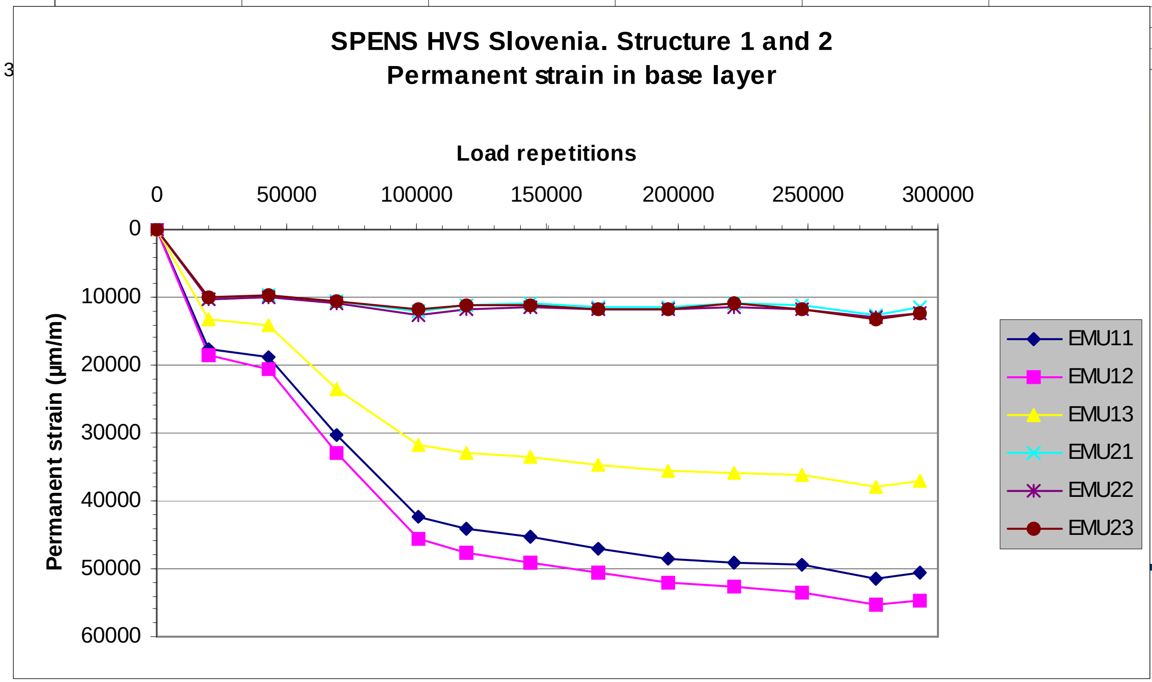
Upgrading of asphalt macadam and light asphalt pavements to the bearing capacity level needed by EU-regulations

Each day cross-profiles were measured

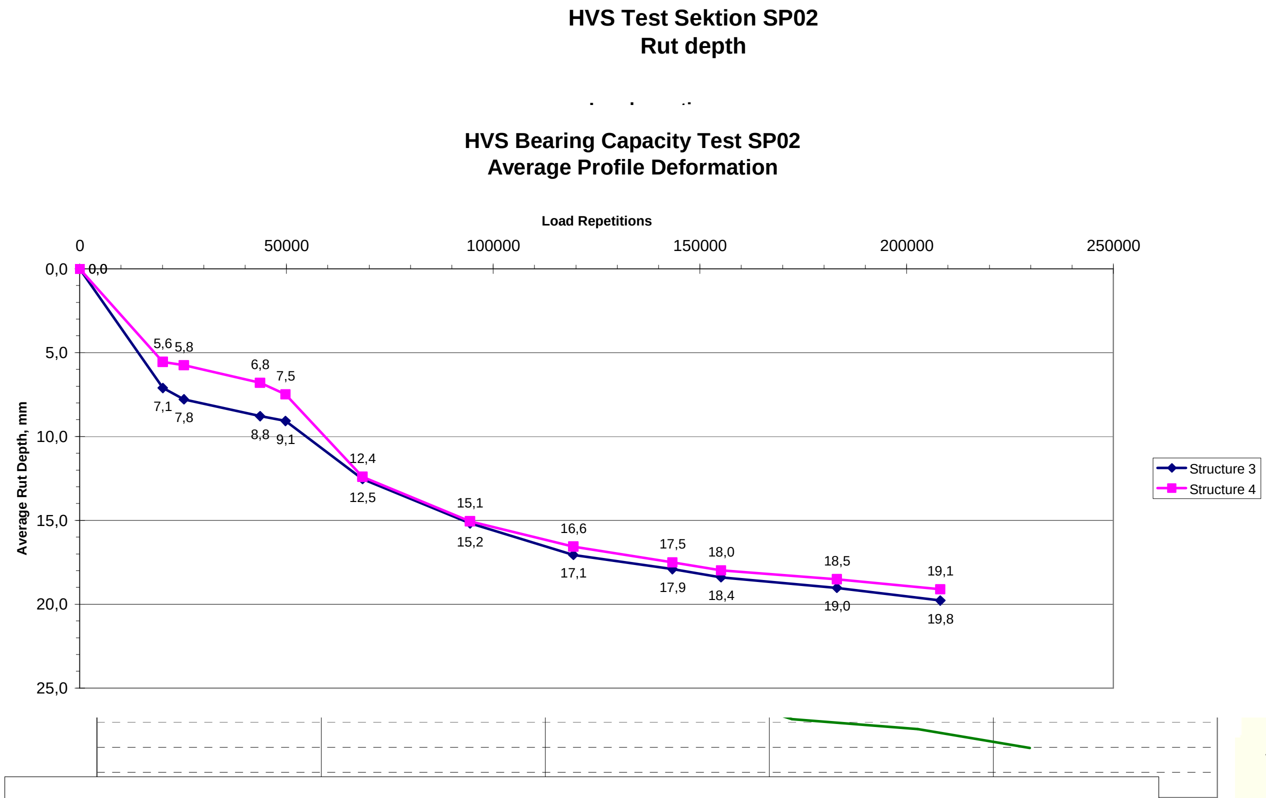


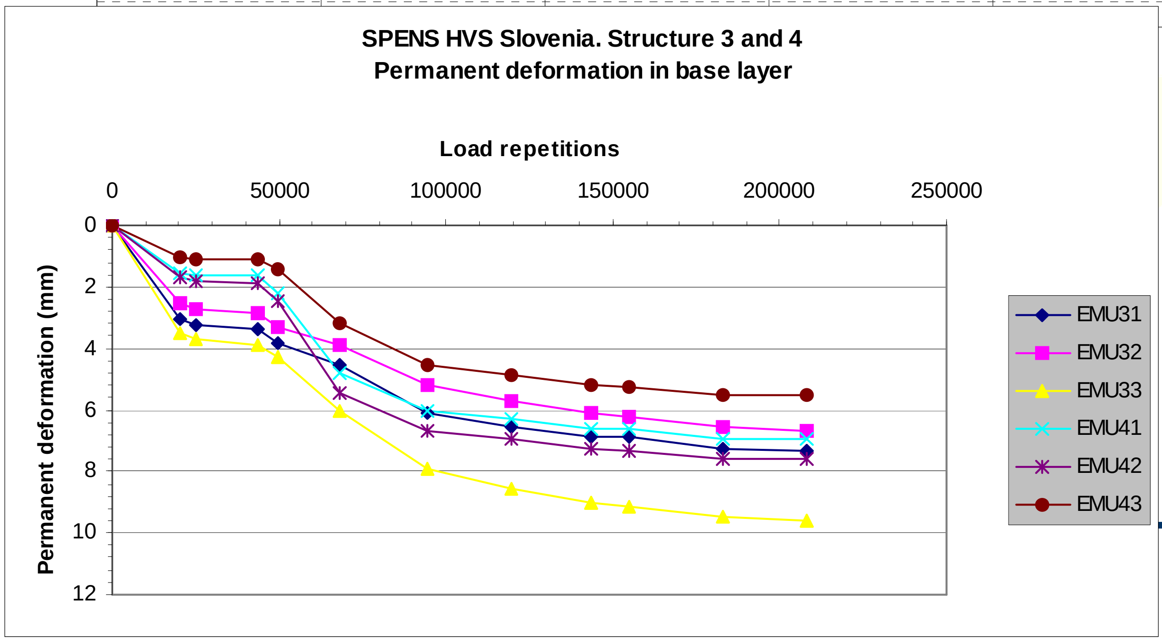
No. test field/position	Asphalt thickness cm	No. test field/position	Asphalt thickness cm
1/1	6,2	4/1	12,9
1/2	5,7	4/2	13,8
1/3	7,1	4/3	14,4
2/1	9,6	5/1	10,7
2/2	10,6	5/2	10,5
2/3	11,1	5/3	10,5
3/1	9,2	6/1	10,5
3/2	9,3	6/2	11,0
3/3	9,4	6/3	10,9





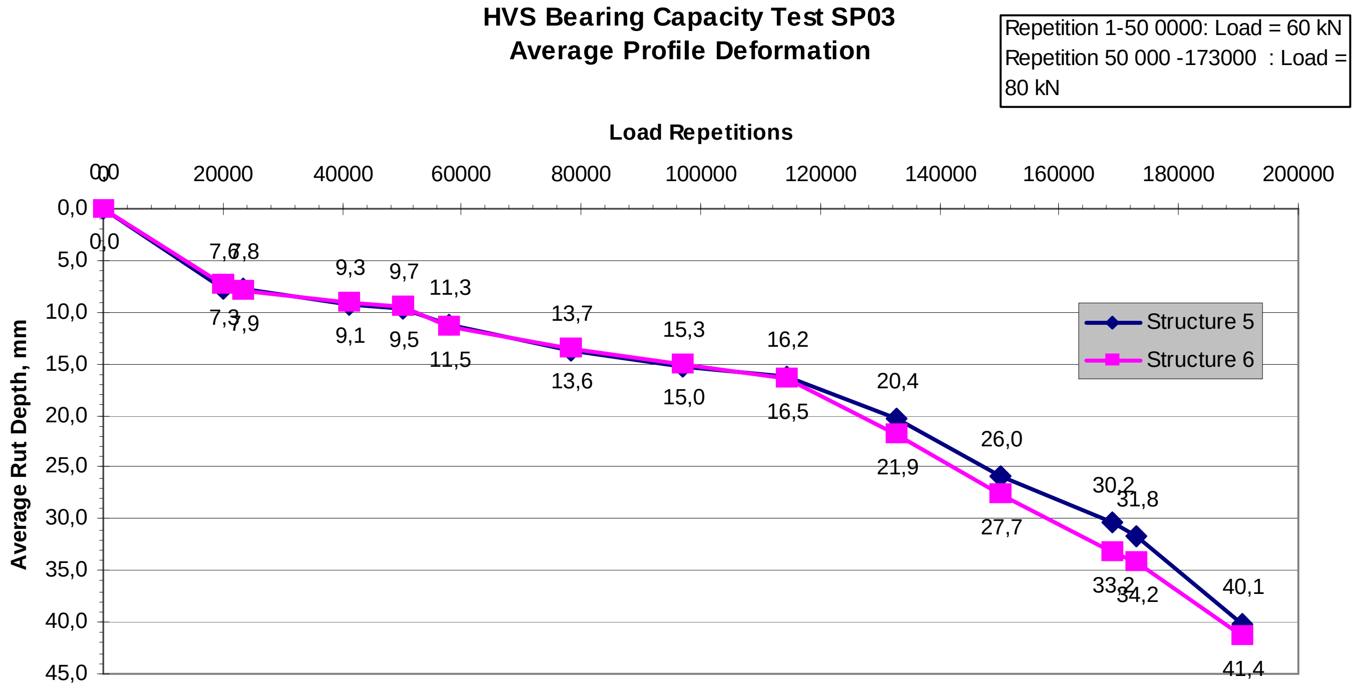
HVS-Heavy vehicle simulator –deformations in gravel and on the surface of test fileds 1 and 2

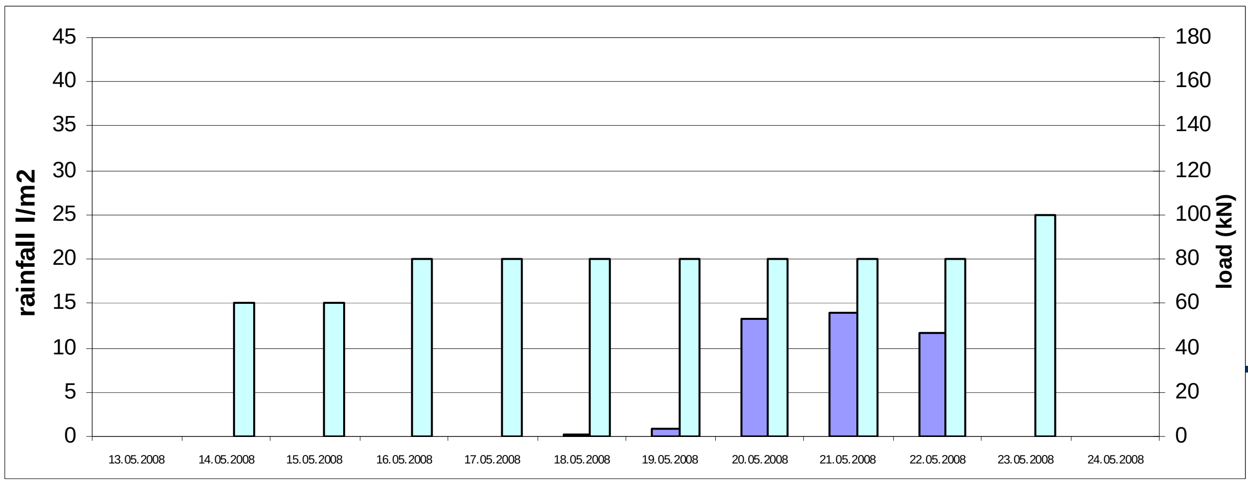




HVS-Heavy vehicle simulator –deformations in gravel and on the surface of test fileds 3 and 4

Upgrading of asphalt macadam and light asphalt pavements to the bearing capacity level needed by EU-regulations





HVS-Heavy vehicle simulator – deformations on the surface of test fileds 5 and 6 and rainfall.

On the asphalt surface reflects deformations from unbound layers. Absolute value of deformation in unbound layers is round 3 times smaller than on asphalt surface, but the shape of deformation curve is the same.

On test filed 1 there is clear dependence of thickness of asphalt layers on depth of permanent deformation, but on test field 2 all permanent deformations are the same and do not depend on thickness. From these data we can conclude there is some limit to which it is reasonable to go with thickens of asphalt pavement. Of course the limit depends on quantity and quality of layer beneath the asphalt pavement and on the applied loads.

We did not see effect of reinforcement due delaminating between asphalt and steel mesh. There was stronger effect of ground water on deformations.

Thank you for your attention!