SUSTAINABLE PAVEMENTS FOR EUROPEAN NEW MEMBER STATES

SIXTH FRAMEWORK PROGRAMME

SPENS

SUMMARY REPORT

http://spens.fehrl.org

The aim of the specific targeted research project named Sustainable Pavements for European New Member States (SPENS) is to develop appropriate tools and procedures for the rapid rehabilitation of road pavements using materials 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.

6th Framework Programme
Theme: Mobility & Transport, Safety & Security
Started: 1 September 2006
Duration: 36 months
Budget: 2.5m EUR

L'objectif du projet de recherche spécifique Sustainable Pavements for European New Member States (SPENS) 'Chaussées durables pour les nouveaux Etats Membres européens' est de développer des moyens et des procédures appropriés pour réhabiliter rapidement les chaussées des routes. Les matériaux utilisés doivent répondre aux critères suivants :

- Très bon comportement face aux conditions climatiques locales
- Respect des règles de protection environnementale
- Intégration facile aux technologies existantes
- Coût rentable et entretien facile

Das Ziel des speziellen gezielten EU-Forschungsprojektes (Specific Targeted Research Project, STREP) namens 'Nachhaltige Straßenoberflächen für neue EU-Mitgliedsstaaten (Sustainable Pavements for European New Member States, SPENS)' ist es, geeignete Werkzeuge und Methoden für die schnelle Instandsetzung von Straßenoberflächen zu entwickeln, wobei Materialien verwendet werden sollen, die:

- zufriedenstellende Leistungsfähigkeit unter den typischen klimatischen Einflüssen zeigen
- nur einen geringen Einfluß auf die Umwelt haben
- einfach in existierende Verfahren integriert werden können und
- kostengünstig und einfach zu warten sind.

Projektet SPENS (Sustainable Pavements for European New Member States; Hållbara vägbeläggningar för nya medlemsstater) har som syfte att utveckla effektiva verktyg och tillvägagångssätt för uppgradering av vägbeläggningar med användande av material

- med tillfredsställande prestanda under typiska klimatförhållanden
- med acceptabel miljöpåverkan
- som passar befintliga tekniksystem
- som är kostnadseffektiva och enkla att underhålla

Az 'Európai Uniós új tagországok számára fenntartható burkolatok' (SPENS) tárgyú speciális kutatási célprojekt célját az képezi, hogy az útburkolatok gyors felújításához megfelelő eszközöket és eljárásokat dolgozzon ki olyan anyagok felhasználásával, amelyek:

- a régió éghajlata mellett megfelelő viselkedést mutatnak,
- környezeti hatásuk megfelelő,
- az elterjedt technológiák alkalmazásakor felhasználhatók,
- ráfordítás-hatékonyak és fenntartásuk nehézség nélkül elvégezhető.

Lo scopo del progetto di ricerca specificamente dedicato ai Nuovi Stati Membri dell'Unione Europea, Sustainable Pavements for European New Member States (SPENS), è quello di sviluppare strumenti e procedure appropriate che consentano una rapida riabilitazione delle pavimentazioni stradali usando materiali che:

- si comportino in modo soddisfacente nello specifico clima,
- abbiano un impatto ambientale accettabile,
- siano facili da inserire nelle tecnologie esistenti
- rappresentino soluzioni economicamente valide e siano facili da riparare.

Celem projektu badawczo-rozwojowego pt. 'Nowoczesne nawierzchnie drogowe dla nowych krajów członkowskich Unii Europejskiej' (SPENS) jest rozwój odpowiednich metod i procedur szybkich odnów nawierzchni drogowych z zastosowaniem materiałów, które:

- spełniałyby oczekiwania w typowych warunkach klimatycznych,
- miałyby akceptowalny wpływ na środowisko,
- byłyby łatwe do wdrożenia z wykorzystaniem dostępnych technologii,
- byłyby efektywne ekonomicznie i łatwe w utrzymaniu.

Cieľom výskumného projektu s názvom 'Udržateľné vozovky pre nové členské štáty Európskej únie (SPENS)' je vyvinúť vhodné prostriedky a technologické postupy na rýchlu rehabilitáciu cestných vozoviek s použitím materiálov, ktoré by:

- mali vyhovujúce vlastnosti v typických klimatických podmienkach,
- mali akceptovateľný vplyv na životné prostredie,
- boli ľahko implementovateľné do existujúcich technológií,
- boli ekonomicky efektívne a ľahko udržiavateľné.

Namen ciljnega raziskovalnega projekta z naslovom Trajne vozišče konstrukcije za nove članice Evropske unije (SPENS) je razvoj primernih postopkov za hitro obnovo vozišč s takšnimi materiali:

- ki se ustrezno obnašajo v značilnih klimatskih razmerah,
- ki so ekološko sprejemljivi,
- ki jih bo možno vgraditi z obstoječo tehnologijo,
- ki so cenovno ugodni in jih je enostavno vzdrževati.

Cílem evropského projektu s názvem Udržitelné vozovky pro nové členské země Evropské unie (SPENS) je vyvinout vhodné nástroje a procedury pro rychlou modernizaci silničních vozovek s použitím materiálů, které:

- budou vyhovovat klimatickým podmínkám jednotlivých zemí,
- nebudou mít negativní dopad na životní prostředí,
- budou snadno využitelné při uplatnění stávajících technologií,
- budou rentabilní a údržba vozovek s jejich použitím nebude náročná.

Целта на проекта 'Трайни пътни настилки в новите страни-членки на Европейския Съюз' (SPENS) за провеждане на определено изследване, е разработването на подходящ инструментариум и процедури за бърза рехабилитация на пътните настилки като се използват материали, които:

- имат съответните качества за определени климатични условия;
- оказват приемливо въздействие върху околната среда;
- лесно се комбинират със съществуващите технологии;
- са рентабилни и лесни за поддържане.

Cilj istraživačkog projekta pod nazivom Održivi kolnici za nove europske zemlje članice je razvoj prikladnih alata i postupaka za brzu rehabilitaciju kolnika korištenjem materijala:

- koji bi se u uobičajenim klimatskim prilikama ponašali na zadovoljavajući način
- koji bi imali zadovoljavajući učinak na okoliš,
- koje bi bilo jednostavno uklopiti u postojeće tehnologije,
- koji bi bili financijski isplativi i jednostavni za održavanje.

Uurimisprojekti 'Säästvad teekatted uute Euroopa liikmesriikide jaoks' (Sustainable Pavements for European New Member States – SPENS) eesmärk on sobivate töövahendite ja meetmete väljatöötamine teekatete kiireks taastamiseks, kasutades materjale:

- mis toimivad antud kliimas rahuldavalt,
- millel on vastuvõetav keskkonnamõju,
- mida on lihtne olemasolevatesse tehnoloogiatesse kaasata,
- mis on kuluefektiivsed ning kergesti hooldatavad

Svrha konkretnog ciljnog istraživačkog projekta pod nazivom 'Održive kolovozne konstrukcije za nove zemlje - članice EU' (SPENS) ogleda se u razvijanju primerenih alatki i postupaka za ubrzanu rehabilitaciju kolovoznih konstrukcija na putevima uz korišćenje materijala koji bi trebalo da ispune sledeće i to:

- da se ponašaju na zadovoljavajući način pod tipičnim klimatskim uslovima,
- da uticaj na životnu sredinu bude prihvatljiv,
- da se ugrađuju bez teškoća uz pomoć postojećih tehnologija,
- da budu ekonomični i jednostavni za održavanje.

CONTENTS

Project Coordinator
ZAG
Ms. Mojca Ravnikar Turk
E-mail: mojca.turk@zag.si
Phone: +386 (1) 28 04 393
Dimiceva 12
1000 Ljubljana, Slovenia

INTRODUCTION

The European Commission has set up a research project named 'Sustainable Pavements for European New Member States' (SPENS). This three year project, which is funded within the EU Sixth Framework Programme, Sustainable Surface Transport priority, ended in August 2009.

The standard of the road infrastructure differs throughout the European Union member states, but the present volume of heavy road transport requires a sustainable road infrastructure immediately. There is a constant need for new resistant pavement materials, which should comply with the EU regulations.

Due to the priority of motorway construction, the standard of maintenance of other roads has lowered, resulting in an increased need for effective road maintenance and improvement over the years to come. The materials and technologies now used in the New Member States differ from those adopted in common practice in the EU-15.

The objective of this Specific Targeted Research Project was to develop appropriate tools and procedures for the optimum and cost-effective rehabilitation and maintenance of roads in the EU New Member States. The overall objective was 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.

Since September 2006 ten partners together with four institutes under the FEHRL umbrella have been working together doing laboratory and field testing of asphalt materials, as well as evaluating the impact of roads on the environment. The project, with a total budget of 2,5m EUR, has been coordinated by the Slovenian National Building and Civil Engineering Institute (ZAG).

A consortium of the following partners have conducted the SPENS project.

Partner	Partner acronym	Country
Slovenian National Building and Civil Engineering Institute	ZAG	Slovenia
Institute for Transport Sciences	KTI	Hungary
The Swedish National Road and Transport Research Institute	VTI	Sweden
Austrian Institute of Technology (arsenal research)	AIT	Austria
Transport Research Centre	CDV	Czech Rep.
Road and Bridge Research Institute	IBDiM	Poland
Zilina University	TUZA	Slovakia
Europe's National Road Research Centres with **	FEHRL	Belgium
DDC Consulting & Engineering Ltd.	DDC	Slovenia
Ferriere Nord SpA	FENO	Italy

** TECER- Transport and Road Research Institute (Estonia)
IGH - Civil Engineering Institute of Croatia (Croatia)
IP - The Highway Institute (Serbia)
CRBL - Central Roads and Bridges Laboratory (Bolgaria)

The research work has focused on developing procedures for producing and implementing materials for road construction, using only local materials and taking into account the tradition and existing construction techniques, as well as the specifics of already constructed roads. Laboratory and in-situ tests were performed in several European countries. Field trials and monitoring during the project were used to verify the research results.

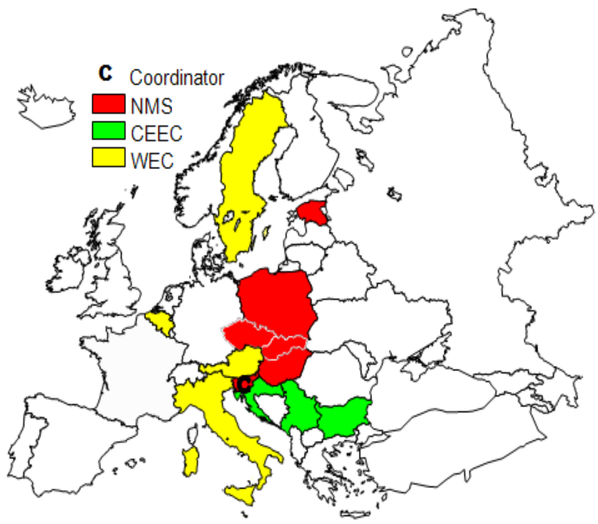
The research has been organized into four technical work packages (WP), which deal with:

- **The optimization of assessment techniques and procedures for roads** - WP2, led by László Gáspár (KTI)
- **The improvement of pavement structures** - WP3, led by Safwat Said (VTI)
- **Evaluation of materials for road upgrading** - WP4, led by Marjan Tušar (ZAG)
- **Impact assessment of roads on the environment** - WP5, led by Manfred Haider (AIT).

Within WP6 Dissemination of results, a number of dissemination events were organized before the end of the SPENS project. Within WP1 Management, led by project coordinator Mojca Ravnikar Turk (ZAG), two Contractor's Committee meetings per year were held, whereas the management group had meetings even more often. We had the opportunity to work with several Project officers, the current person in charge is Mr. William Bird from the Research Directorate-General, European Commission. We would like to express special thanks to Mr. William Bird and Ms. Maria-Cristina Marolda.

Overview of SPENS task leaders

WP1 - Mojca Ravnikar Turk (ZAG)
WP2 - Slovenko Henigman (DDC), Roland Spielhofer (AIT), Darko Kokot (ZAG),
WP3 - Safwat Said (VTI), Ana Mladenovič (ZAG), Imre Pap (IP),
WP4 - Björn Kalman (VTI), Dariusz Sybilski and Wojciech Bańkowski (IBDiM), Leif G Wiman (VTI),
WP5 - Lennart Folkeson (VTI), Manfred Haider (AIT),
WP6 - Mojca Ravnikar Turk (ZAG), Steve Phillips (FEHRL), Adewole Adesiyun (FEHRL).



Based on the results of the research within the technical work packages, practical guidelines and recommendations have been produced. The dissemination of results is being done through national and international conferences, as well as on the SPENS web site. For more information and final deliverables please visit: **http://spens.fehrl.org**

The consortium mainly consisted of experts from the New Member States, in order to ensure that the research is focused on issues relevant to the latter. Within SPENS fourteen different languages are spoken.

Information on the research results are fully presented in the following project deliverables:

D8 **Laboratory and fiel implementation of high modulus asphalt concrete**
D9 **Long-term performance of reinforced pavements**
D10 **Practical mix design model for asphalt mixtures**
D11 **Guidelines of a complex methodology for non-destructive pavement measuring techniques**
D12 **Recommendations for traffic equivalency factors**
D13 **Guidelines on a systematic decision making methodology for the pavement rehabilitation of low volume roads**
D15 **Recommendations for modified binder usage in pavements**
D16 **Guidelines for the selection of the most convenient upgrading systems based on the results of heavy vehicle simulator tests**
D17 **Guidelines for the environmental assessment of various pavement types including recommendations to road authorities in New Member States**
D18 **A methodology for testing and implementing selected recycled materials and industrial by-products in road construction**
D19 **SPENS Final report**

The main dissemination events were :

- Transport Research Arena - TRA 2008, Ljubljana, Slovenia, where several presentations were held. A technical visit was organized to the SPENS test field at Dragučova near Maribor.
- Outcomes were presented in workshops organized by the CERTAIN clustered project in Tallin (Estonia), Kiev (Ukraine), Brno (Czech Republic), Budapest (Hungary) and Bled (Slovenia), and also in Moscow (Russia).
- The results of WP5 were presented in a workshop which was held in Bled, Slovenia, in May 2009.
- The SPENS final seminar on August 27th and 28th, 2009, which was held in Ljubljana, Slovenia

We also prepared a brochure, as well as two posters that have been on display for the last three years, and issued one Newsletter.

A sustainable infrastructure is vital for the economic progress of a country. Especially at a time of economic decline, we must put more effort into the implementation of new knowledge in everyday road construction practice, without delay.

TRA 2008, Ljubljana, Slovenia The TRA exhibition

National seminar Bled, Slovenia 2009

National seminar Kiev, Ukraine 2009

TRA 2008 - Technical visit to test site in Dragučova, Slovenia

WP2 Road Assessment and Monitoring

The main objective of the WP2 was to contribute to the development of various road assessment and monitoring topics mainly for the use in New Members States of the European Union.

WP 2.1 Traffic load equivalency factors

The Work Task deals with the estimation of traffic load equivalency factors for various road pavement structures typical for Central and Eastern Europe. Considering the financial and time constraints and investigating 6 test pavement structure types, the following research methodology was applied:

- The Swedish Heavy Vehicle Simulator (Figure 2.1) was applied to create different wheel loads repeatedly on test pavements, and the reactions (strains, stresses, temperatures etc.) in the structures were regularly recorded,
- it was decided to exclude section 1 from the investigation since the pavement structure was too weak (the only one with just one asphalt layer) and was destroyed too early to supply sufficient performance data for the analysis,

Figure 2.1 Swedish HVS

- similarly, section 6 was excluded from the investigation due to the unknown influencing behaviour of steel grids built into it; consequently, the sections 2-5 were analysed,
- a preliminary investigation has proved that a linear relationship can be accepted for the evolution of asphalt strains as a function of load repetitions (in the range investigated, the differences between the linear, the second power and the third power functions are minor and negligible),
- the linear functions between wheel load repetition numbers and asphalt strains were visualised for each wheel load applied (30 kN, 40 kN, 50 kN, 60 kN) in a common figure, for each trial section to be investigated,
- the Slovenian pavement design methodology was used to determine the end-life load repetition numbers of 100 kN standard axle loads for the pavement structures of Sections 2-5,
- using the relationships between the load repetition number and the asphalt strain created in the structure the critical asphalt strains causing deterioration were determined for each section investigated,
- the critical number of repetitions – for each wheel load applied and using the critical asphalt strains – were obtained from the graphs developed,
- the powers of the wheel load ratios were calculated for the repetition number ratios for each section,
- The powers for 40 kN/50 kN wheel load ratio (that is 80 kN/100 kN axle load ratio) were selected for the estimation of traffic equivalency factors,
- the following powers as characteristics of traffic equivalency factors were given:

Section 2	1.95
Section 3	3.62
Section 4	2.10
Section 5	2.33.

- these values can be taken as useful but preliminary information.

More information can be found in D12 'Recommendations for traffic equivalency factors'.

WP 2.2 Non-destructive testing of pavement condition

The objective was to carry out and evaluate the results of a harmonisation test covering pavement skid resistance, longitudinal evenness and bearing capacity measuring devices as an example, see (Figure 2.2).

For the skid resistance measuring exercise, six test pavements were selected with various skid resistance. The 9 devices coming from 7 countries ran the 100-m long test sections at 30-60-90 km/h measuring speeds. At least 3 runs were performed for each speed. Measurements in the right wheel path were strived for. A water film thickness of 0.5 mm

Figure 2.2 Pavement condition measuring harmonisation test (example for the participated devices)

was applied on the pavement surface to be measured. The analysis of the test results was carried out in accordance with CEN/TC 227/WG-5 N202 E Rev. 4.

For the longitudinal unevenness measuring test, the device Primel in VTI was selected as reference instrument for the harmonisation exercise. Six test pavements were chosen with various unevenness. Seven devices coming from 6 countries ran the 500 m-long test sections at 30-60-90 km/h measuring speeds. At least 3 runs were performed for each speed. The devices measured during the test series along the same lines of the sections.

For bearing capacity measuring devices, the methodology developed in COST 336 action for calibration and harmonisation was applied. Seven Falling Weight Deflectometers (FWDs) from 6 countries participated in the exercise. The maximum surface deflection values were compared to each other. Deflection results are defined as being repeatable if a FWD operated by the same crew is able to reproduce the deflection bowl collected in a sequence of multiple drops at a specific test site without lifting the loading plate.

A certificate on the participation in the harmonisation test near Vienna was given to each participant coming from Austria, Czech Republic, Hungary, Norway, Poland, Slovenia, Slovakia and Sweden.

The outcomes together with the test results are presented in D11 'Guidelines of a complex methodology for non-destructive pavement measuring techniques'.

WP 2.3 Systematic decision making methodology on pavement rehabilitation and upgrading

The aim of the Work Task was to develop a systematic decision making methodology mainly on the pavement rehabilitation and upgrading of low-volume roads in Central and Eastern European countries.

The flow-chart based methodology was developed on the basis of a Slovenian procedure which was modified by the information coming from Poland, Slovakia, Hungary and Czech Republic. It covers the following condition parameters, skid resistance, transverse unevenness (rut depth), surface defects, longitudinal unevenness, bearing capacity. Among the road rehabilitation and upgrading techniques, resurfacing (surface dressing, slurry seal, thin overlay), overlaying, pavement strengthening (upgrading by asphalt layers, "sandwich systems", recycling) and reconstruction were considered. The approach presented in the flow-chart is a network-level approach which is afterwards usually followed by project level, where tests of the materials built in pavement structures are performed, the cause of the resulting damage is determined and subsequently, pavement design and the selection of the suitable materials for rehabilitation are done.

A questionnaire survey carried out in SPENS-project was also utilized in the development of the methodology proposed.

Several examples (see the site of one of them in Figure 2.3) were presented in order to demonstrate and facilitate the use of the flow-chart based methodology developed for the pavement rehabilitation and upgrading of low-volume roads.

The Deliverables D13 'Guidelines on a systematic decision-making methodology for the pavement rehabilitation of low volume roads' summarizing the output of the activities in relevant work tasks permit the dissemination of the results obtained mainly among the experts in Central and Eastern Europe.

Figure 2.3 Test pavement surface for rehabilitation design methodology (example)

WP3 Improvement of pavement structures

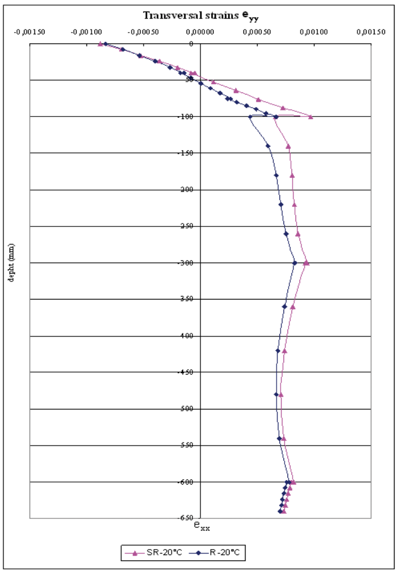
The main objective of this work package was the development and optimisation of methods, materials and technologies for improvement of pavement structures for new and existing flexible road pavements. Its aim was also to study the benefits and limits of waste and by-product materials including recycled materials for road construction.

WP 3.1 Reinforcement of pavement bound and unbound layers

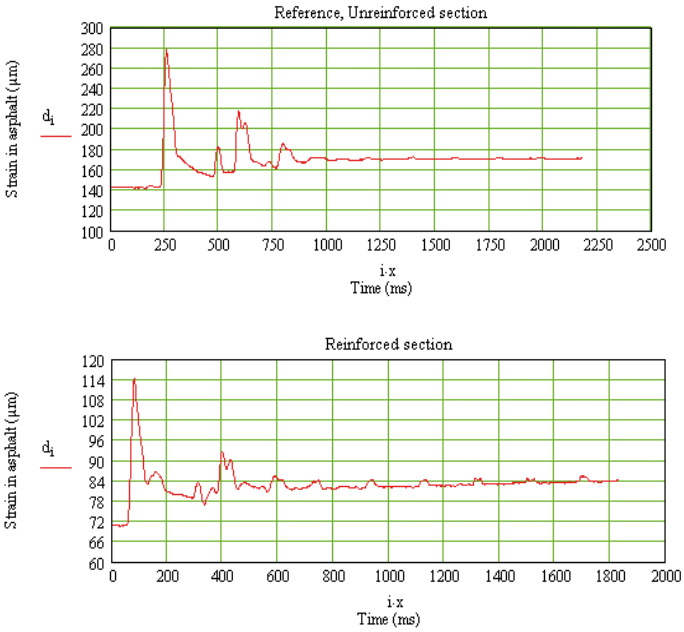
Usually roads are rehabilitated by removing one or several layers of pavement that are substituted by new layers or just overlaid by a new layer. The pavement layer can be strengthened with different types of materials and layer thicknesses. The main objective of this task group wa to study methods and technologies for improvement of pavement structures for new and existing flexible road pavements. This work focused on the methodology of pavement performance evaluation of reinforced structures, the modelling of reinforced flexible pavement structures as well as guidelines/ instructions for the implementation of reinforcement in road construction.

- It is quite evident that the use of reinforcement gives a clear benefit, if we consider the whole life of the road, based on the estimation of several types of deterioration.
- Almost 100% of steel meshes used in the reinforcement of pavements are manufactured from recycled steel products.
- A user-friendly pavement design methodology has been evaluated and presented in this work.
- Calculated strains in reinforced and un-reinforced structures when using a theoretical model has shown identical conclusions in respect to ranking of the tested structures when compared to strain measurements in the field when using strain gauges and calculated strains from FWD measurements.
- Structural rutting development is smaller in the structures with a reinforced pavement than in the traditionally constructed road structures. The reinforced structures have shown that it takes almost two years longer time to reach the same rut depth.
- Experiences from pavement performance evaluations have shown that steel reinforcement of pavement layers is a very effective method to minimize the risk of frost cracks in the flexible pavement.
- Best practice and practical guidelines have also been presented in this work.

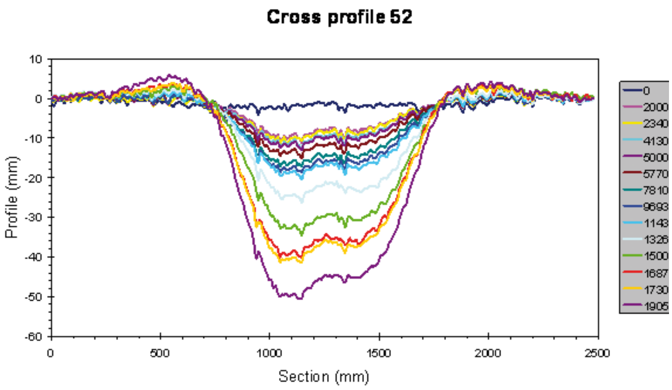
It is concluded from several performance evaluations that the reinforced structure has prolonged the service life of pavement with more than 20 per cent. The full report is in deliverable D9 'Long-term performance of reinforced pavements'.



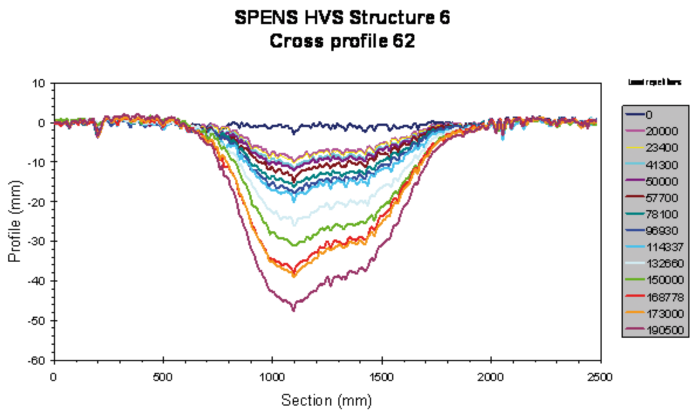
Graph 3.1 Calculated transversal strains at T=20°C in the un-reinforced section (SR) compared with the reinforced one (R)



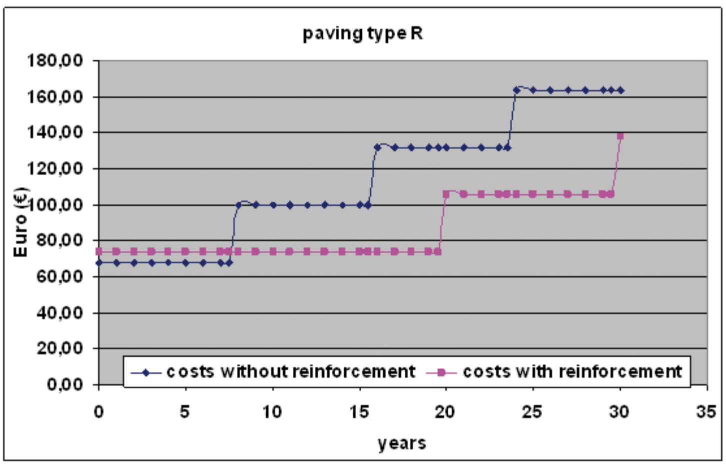
Graph 3.2 Measured strain signals in reinforced and unreinforced pavements



Graph 3.3 Rutting development at the reference section (no reinforcement), ca 55 mm



Graph 3.4 Rutting development at steel reinforced section, ca 45 mm

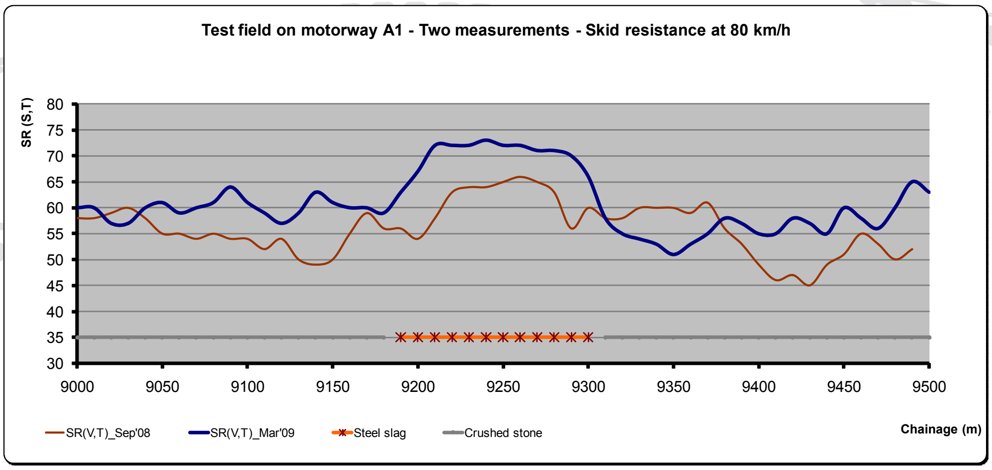


Graph 3.5 Costs vs Time and comparison with and without steel reinforcement.

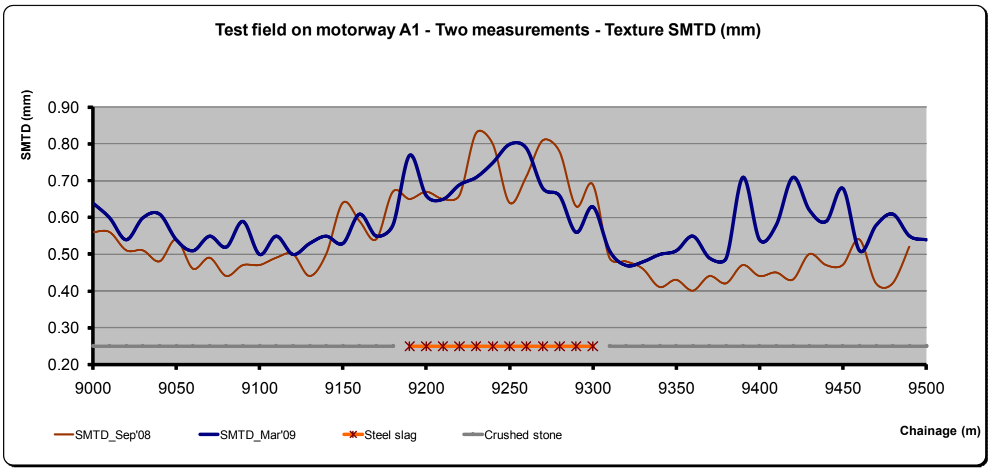
WP 3.2 Sustainable road construction processes that include recycling of materials and use of industrial by-products

Rapid industrial growth during recent decades has resulted in the production of a wide variety of waste that imposes severe environmental problems on mankind. Several attempts have been made to increase the reuse of waste materials, with the aim of achieving several goals: (a) reducing the size of landfills, and thus protecting the environment, (b) technical benefit from the use of waste materials in different applications, (c) economical benefit, by reduction in the consumption of natural materials and energy and (d) social-ecological benefit, by following a sustainable development policy.

The most promising waste materials for road construction purposes are crushed building rubble and industrial byproducts such as slag. Four test fields, with slag aggregate for the wearing course and surface dressing, and natural aggregate for comparison, were constructed in Slovenia, one on the highway and the others on the regional roads. The purpose of these test fields was to validate the suitability of slag aggregate for use in wearing courses. It was found that no problems had been encountered by the firm carrying out the works, either in the designing of the mix, or in its transport to the asphalt plant, or in the placing of the asphalt in the test fields. The surface properties appear to be better on the field with slag aggregate (Graphs 3.6 and 3.7). It is planned that the test fields be subject to further monitoring, in order to detect any long-term changes in surface characteristics.

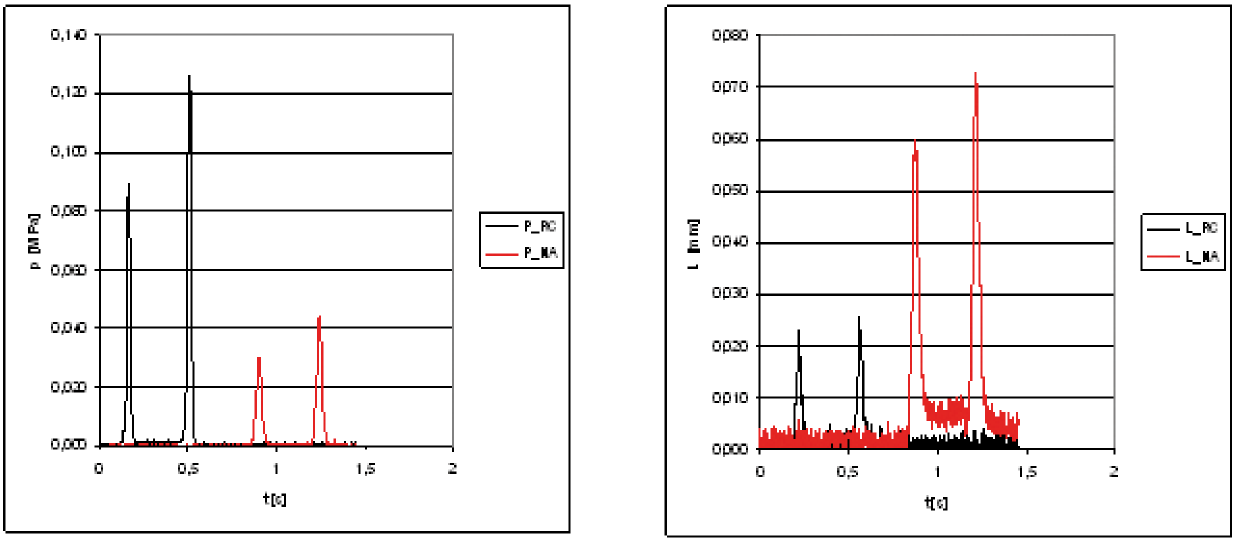


Graph 3.6 Skid resistance measurement – September 2008 versus March 2009



Graph 3.7 Texture measurement – September 2008 versus March 2009

To validate suitability and long term behaviour of crushed concrete in unbound layers an instrumented test section on section of Slovenian national road Ivančna Gorica – Muljava was constructed. The research shows that crushed concrete exerts lower permanent deformations and lower decrease of modulus of elasticity in same environmental conditions,



Graph 3.8 Behavior of Crushed concrete (CC) and Natural aggregate (NA)

thus showing better long term behaviour than compared natural aggregate with no negative environmental effects. In all cases, independently of induced pressure, we can observe higher deformations in part with natural aggregate (See Graph 3.8).

On the basis of these research results, we can conclude that crushed concrete can be a good and environmentally acceptable replacement for the natural aggregate for construction of the unbound layers. Of course quality of these materials must be in line with the technical and legislative regulations for intended use. Construction of test fields, results of laboratory and field investigations are presented in D18 'A methodology for testing and implementing selected recycled materials and industrial by-products in road construction'.

WP 3.3 Optimisation of asphalt mixture design to ensure favourable behaviour at low and high air temperatures

The research in this task was aimed at finding a practical model for the optimisation of asphalt mixture composition which will be related to the target functional properties of asphalt pavement, relevant for various climate and traffic conditions in the field.

Two different asphalt mix design methods (Marshall method and PRADO software), one silicate aggregate and four binders: B 50/70, B 70/100, PmB 50/90 and PmB 25/55-55 were used to evaluate the optimal composition of asphalt concrete type of mixture (AC-11).

The software package "Programme for Asphalt Mix Design and Optimization" (PRADO) was developed by Belgian Road Research Centre (BRRC) for the analytical study of asphalt mixture composition by volumetric calculation and it can be used for prediction of complex modulus of asphalt mixture from rheological properties of pure binder and prediction of mechanical properties and performance of a mix.

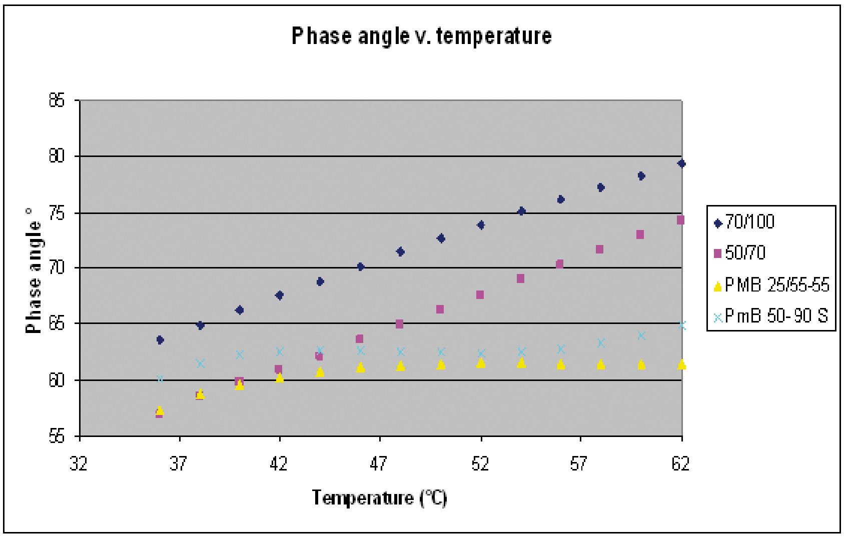
By variation mineral grading of AC-11 and binder contents using two mix design methods, the optimal volumetric composition of asphalt mixtures were established in a way that ensured favourable functional properties of asphalt mixtures: stiffness modulus, permanent deformation and fatigue.

Thorough research performed in Task 3.3, it was shown that the application of conventional binders in asphalt mixture depends of which dynamic parameters are needed to be emphasized, since none of them could satisfy the overall performance criteria. For higher stiffness modulus and resistance to permanent deformation, it is better to use a harder type of bitumen, while for better resistance to fatigue, softer bitumen is recommended. Among binder properties penetration, softening point, elastic recovery and phase angle with PmB are the most promising characteristics which influence to the dynamic parameters of asphalt mixture.

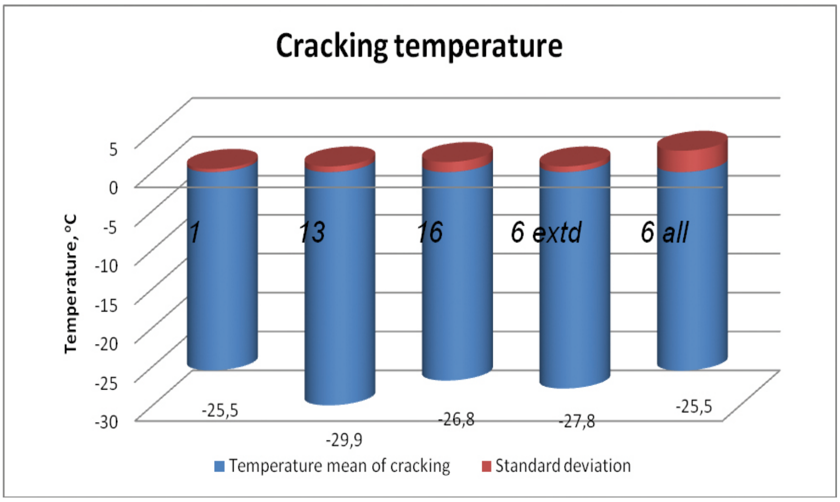
The recommendation is that asphalt mixtures with a softer type of binder can be used for regions with lower temperature and traffic volume where it is important for asphalt pavement to have good resistance to fatigue and thermal cracks, while in regions with higher temperature and higher traffic volume, it is recommended to use harder types of binder. These binders cannot be used for asphalt pavements in regions with extreme daily temperature changes and roads with heavy traffic.

Polymer-modified binders, especially PmB 25/55-55, are both resistant to rutting, fatigue and thermal cracking due to considerable amount of elasticity at low and high temperatures. Asphalt mixtures with these binders can be mainly used for application in asphalt pavement exposed to heavy traffic and extreme climate changes.

Detailed outcomes and test results can be found in the deliverable D10 'Practical mix design model for asphalt mixtures'.



Graph 3.9 Phase angle of binders versus temperature



Graph 3.10 Cracking temperature of asphalt mixtures (TSRST)

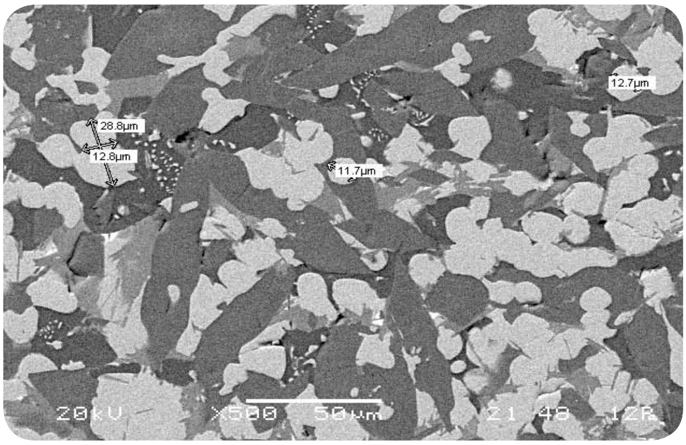
Quenching of hot slag

Quenching of cooled slag (for 15 days)

Aggening of slag for 30 days

Crushing and magnetic separation of slag

Fractioning



Microstructure of steel slag

WP4 Evaluation of materials for road upgrading

Within WP 4, materials and pavement layers appropriate for road upgrading, taking into account the conditions in the New Member States, were evaluated. The New Member States have mainly focused on the construction of new motorways, whereas less money has been available for the improvement of existing roads. However, at the same time there is a strong need for new, sustainable road pavement materials, with a high bearing capacity, in all of the EU countries. It is anticipated that maintenance costs in the New Member States could be lowered significantly by introducing better techniques and improving the prevailing procedures which are used to deal with the assessment of road conditions and maintenance planning for road upgrading. Increasing traffic volumes and loads mean that wider roads, with a higher bearing capacity and better pavement durability, are needed.

Chemically-modified bitumens, as asphalt binders, are used more and more in road construction, although not much information is available about the actual performance of these materials. A reliable correlation between the laboratory and in-situ performance of mixtures with modified bitumen has not yet been established. This knowledge is necessary for the evaluation of the behaviour and appropriateness of these materials in different climatic and environmental conditions.

WP 4.1 Investigation of the Performance of Conventional and Polymer Modified Bitumen

To upgrade roads in NMS so that they would perform better with respect to traffic loads, climatic variations, environmental impact and cost efficiency, involves using new or improved materials and construction methods. Polymers and other additives used to modify bitumen are used in many places to improve asphalt mixtures. New and improved types of polymers for bitumen modification reach the market all the time. A reliable correlation between the laboratory and in-situ performance of mixtures with modified bitumen has not yet been established. This knowledge is necessary for the evaluation of the behaviour and appropriateness of these materials in different climatic and environmental conditions. Formula-based construction methods and traditional binder testing methods are not suitable for dealing with the complexities associated with polymer modified bitumen and asphalt mixtures made of these binders. Within Task 1 the objective was to find performance-based binder criteria founded on correlations between binder tests and critical asphalt performance tests. Within this objective, the already suggested performance-based binder criteria were investigated, and an attempt was made to find new or better criteria for those asphalt properties, where good and solid correlations have not yet been found. With sound performance-based binder criteria, the choice of binder for a particular application is simplified.

The most obvious performance-related properties of asphalt mixtures are resistance to wear, stiffness, resistance to plastic deformation, resistance to fatigue and durability (water sensitivity and ageing). All of these properties are, to a very large extent, influenced by the properties of the binder and the binder aggregate interaction. Binder test methods should guide the pavement engineer in selecting the most efficient binder for a certain type of aggregate and a certain type of asphalt layer. The traditional bitumen test methods have been frequently shown to be inadequate for evaluating modified bitumen. A combination of fundamental binder test methods, e.g. the complex shear modulus measured with DSR and methods characterizing the binder during severe stress have been suggested as being asphalt mixture performance related. The task has focused on selecting the most efficient combinations of binder test methods for predicting asphalt mixture performance. The testing program has included three different asphalt mixtures, whose performance have been characterized by wheel tracking tests, stiffness at different temperatures, water sensitivity and Marshall stiffness.

Seven binders, including three conventional bitumens ranging from 70/100 to 20/30 in penetration, and four polymer modified binders with softening points ranging from 45 to 70°C were chosen to ensure a wide range in binder properties. The binders were characterized with a range of fundamental test methods, as well as by traditional test methods, and the results were compared and correlated to the results from the asphalt mixture testing program.

Three types of mix gradations were chosen: an asphalt concrete mix (AC), a stone mastic asphalt mix (SMA), and a porous asphalt mix (PA). The AC mixes were made both with basalt aggregate and a limestone aggregate, whereas the other mixes were made with basalt aggregate only. The four different types of mixes should make it possible to check whether or not the performance-related connections between the binder tests and the asphalt mix tests are mix specific or of a more general nature.

All tests, of binders as well as of asphalt mixes, were performed according to the current European norms unless otherwise stated. The force ductility test and elastic recovery test were performed only on the polymer modified binders.

The number of binder tests was limited, so the data can be best used to corroborate or contradict proposed correlations made in other studies.

From Table 4.1 it seems that there is a fairly good correlation between the wheel tracking rut depth and the softening point, even though there are four polymer modified binders in the study. The stiffness modulus correlates fairly well with the results of the penetration tests, but the proportionality constants are different for different mixes (data not shown). The data in Table 4.1 suggest that the deformation energy measured at 10°C might be a candidate for a performance-related test vis à vis the stiffness modulus of asphalt mixes, but the data is very limited.

The results of this research may increase awareness of the benefits and drawbacks of different types of bitumen modification. They are beneficial for the rapid upgrade of the infrastructure in NMS, by introducing performance-related test methods. These test methods are necessary for promoting innovation and cost efficiency in the upgrading process.

The results of laboratory tests are presented and analysed in Deliverable D15 'Recommendations for modified binder usage in pavement'.

Asphalt mix tests Binder tests	SMA/wheel tracking r^2	AC(basalts)/stiff. r^2	AC(limest.)/stiff. r^2	PA(basalts)/stiff. r^2
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	0.5	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 energy III	0.86	0.08	0.50	0.23
Cone Plate viscosity IV	0.72	0.54	0.30	0.66
Cone Plate viscosity V	0.57	0.57	0.34	0.63
Equiviscous temp. VI	0.68	0.54	0.36	0.61
Coaxial cyl. visc. VII	0.50	0.67	0.32	0.73
Coaxial cyl. visc. VIII	0.55	0.51	0.20	0.58

I	Penetration at 35°C with a total weight of 50g
II	At 10°C and a speed of 50 mm/min
III	At 25°C and a speed of 50 mm/min
IV	At 60°C
V	At 150°C
VI	According to ASTM D 1559 (2382)
VII	At 120°C
VIII	At 150°C

Table 4.1 Correlation coefficient, r^2, in linear regression between the binder test results and the test results from the asphalt mixture tests.

WP 4.2 Material Recommendations and Performance-based Requirements for High Modulus Asphalt Mixtures and Flexible Pavement Design

This task deals with studies of High Modulus Asphalt Concrete (HMAC) as a technical solution which provides improved durability of road asphalt pavements, with the possibility of reducing the pavement thickness and road construction costs. Further, during the pavement service, well-designed pavements need fewer maintenance operations, thus achieving reductions in maintenance costs.

The aim of this task has been to develop a concept of high modulus asphalt HMAC for implementation in the Central and Eastern European countries. It is obvious that the technology transfer has to take into account local climatic conditions, as well as the availability of materials and equipment, both for road construction and for laboratory testing. The following countries were interested in the implementation of High Modulus Asphalt Concrete: Poland, Slovenia, Croatia, Serbia, Sweden and Estonia.

The first point of the task was the preparation of initial recommendations for High Modulus Asphalt Concrete (HMAC)

Figure 4.2a Placing of the sensors in the subgrade 4.2b Transverse strain gauges

in different countries. Poland had experience with this type of mix and the real-scale test was performed in Poland. Recommendations for Poland have been already prepared. They were adopted taking into account the climate, materials and test methods for countries that are interested in the implementation of HMAC (Slovenia, Serbia, Sweden, Croatia, and Estonia). Climate analysis consists of evaluation of the effective temperature for fatigue (TEFF) and PG temperatures for different layers.

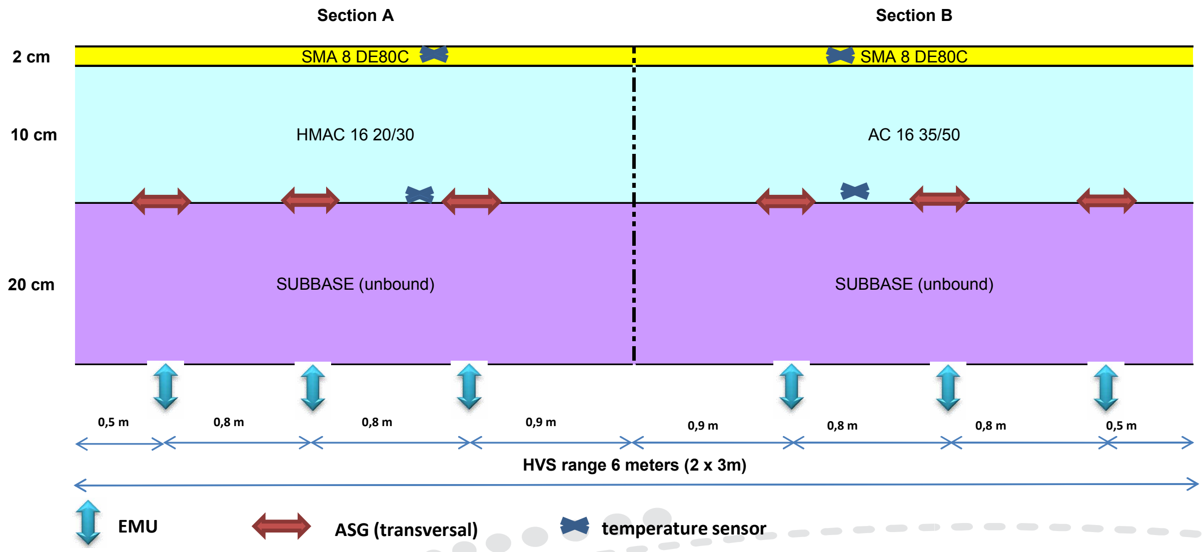


Figure 4.1 The test sections in Poland (Pruszków)

Polish recommendations were implemented and verified in the laboratory. Laboratory tests on materials were performed and several HMAC were designed. The tests included three binders: 20/30, DE30B (polymer modified), MG10/20 (multigrade), and five types of aggregates (basalt, granite, limestone, boulder, steel slag). The results of the performance tests (fatigue, stiffness, rutting) indicate the suitability of different binders and aggregates of different type, quality and origin.

Test sections were located at Pruszków, near Warsaw, and the construction works were performed by STRABAG in October 2007. The test section was divided into two halves of the same layer thickness, but with two different mixes for the base course: asphalt concrete (AC) and HMAC. This permitted direct evaluation of the influence of HMAC on pavement durability.

Pavements were equipped with two kinds of sensors: horizontal strain gauges placed at the bottom of the asphalt layers, and vertical strain gauges placed at the top of the subgrade.

The accelerated load test was performed by the Heavy Vehicle Simulator, which was used in Poland for the second time. Both times the HVS test was performed at a constant temperature of 10˚C, with the use of single wheel (wheel load 60kN, tyre pressure 800kPa). The wheel moved on a path 6 metres long at a speed of 10-12 km/h. Each day response measurements (the strain in the asphalt layers and in the subgrade) were performed, together with rut profile evaluations. After 190 000 cycles the deterioration of the pavement was very small, and it was decided to change the wheel load to 80kN. The test was stopped after 300 000 cycles.

4.2c Compaction of the wearing course

4.2d HVS on the test section at Pruszków

The HVS tests were accompanied by field tests (Falling Weight Deflectometer, Ground Penetration Radar) and a number of laboratory tests. A few dozen slabs and cores were cut from the pavement. The laboratory test program consisted of an evaluation of the composition (binder content, grading, air voids), resistance to rutting, stiffness and fatigue. The results of the laboratory tests performed on bituminous specimens cut from the pavement do not show any damage if loaded and non-loaded areas are compared. This is opposite to the results of the HVS measurement, which showed an increase in profile deformation (Figure 4.3) and an increase in the strains at the bottom of the asphalt layers (Figure 4.4). Unexpected laboratory test results can be explained by the healing of asphalt layers. The specimens were cut 6 weeks after the completion of the HVS test and an increase in pavement temperature (hot summer, direct insolation) may have caused the closing of fatigue microcracks. A general comparison of the results indicates better performance of the structure with high modulus asphalt concrete. Final conclusions are explained in details in Deliverable D8 'Laboratory and field implementation of high modulus asphalt concrete'. Requirements for HMAC mix design and pavement design.). It should be also noted that thickness of the structures was smaller than is typically used for this level of traffic (about 700 000 axles of 60 kN) and both structures withstood this loading.

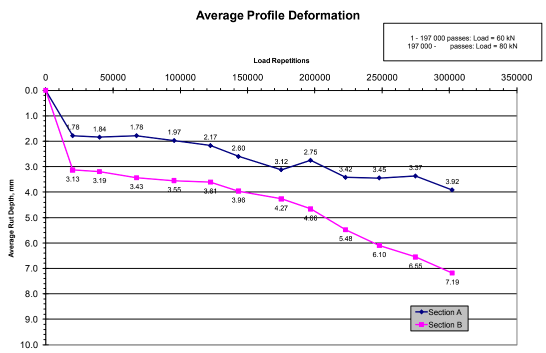


Figure 4.3 Evolution of profile deformation

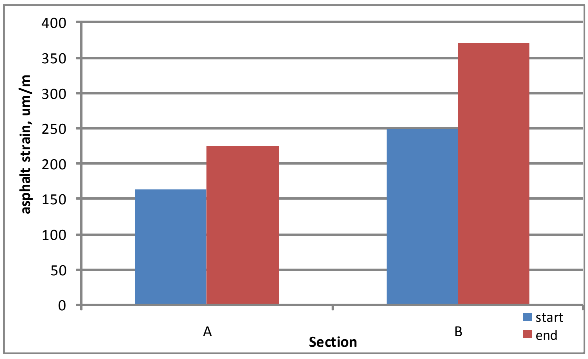


Figure 4.4 Comparison of strains at the bottom of asphalt layers at the beginning and end of the HVS test.

WP 4.3 Upgrading of asphalt macadam and light asphalt pavements to the bearing capacity level required by the EU

The reinforcing of pavements by means of geosynthetics, steel meshes or glass grids could prolong the service life of pavements by reducing deterioration. This type of strengthening has not yet been widely used in the New Member States, and the behaviour of such reinforced roads needs to be carefully investigated and the best practice developed. In this task the effect of different layer thicknesses and strengthening treatments in the pavement structure were evaluated. An accelerated load test (ALT) was performed on six test fields with a Heavy Vehicle Simulator (HVS-Nordic).

Six different weak pavement structures, presented in Figures 4.5, 4.6 and 4.7, were selected as the most representatives. They were constructed on a new local road (Figure 4.11) instead on an existing road to acquire uniform subgrade conditions. Tests fields were constructed in Dragučova in Slovenia. The subgrade consisted of clayey silt, on top of which a sub-base sandy gravel layer was placed. The thickness of this layer was up to 60 cm. The unbound base layer had a thickness of 20 to 25cm, and was made of uncrushed sandy gravel, very similar to the sub-base material. One test sections was reinforced with steel mesh. It was positioned between the asphalt concrete layers and the unbound base layer.

Full-scale accelerated load testing was performed on the six test fields in April and May 2008 (Figure 4.12). The test wheel runs had a total length of 8m, at 6m long sections the speed was constant. The test structures were instrumented with 72 sensors (strain gauges, inductive coils etc) for measurements of vertical pressure, deformations in the unbound and asphalt layers, strains in steel reinforcement, temperature and moisture. From this instrumentation it was possible to obtain response data under different load conditions, e.g. wheel load and tyre pressure. The readings were taken before, during and after the main test. The main test for each test field lasted for 2 weeks and the machine ran night and day 7 days a week with interruptions only for daily servicing. During the main test, cross profile measurements were carried out for calculations of rut depth propagation on the surface. It had been decided that the pavement temperature should be kept constant at 20 °C, and the wheel load would be 60 kN at the beginning of the tests, and then increased if necessary. The loading was performed in both directions, with a chosen lateral wander. The deformations measured in the gravel in test fields 1 and 2 are presented in Figure 4.8, and rut depth propagation at the surface of pavement is shown in Figure 4.9. It can be seen that the results match.

Cores were drilled from the asphalt pavement after the HVS testing and soil investigations were performed. The actual thicknesses of asphalt layer for test field 1 and 2 are presented in Table 4.10. From Table 4.10 and Figure 4.9 it can be seen that, in the case of test field 1, there is a clear dependence of the thickness of the asphalt layers on the depth of permanent deformation, whereas in the case of test field 2 all the permanent deformations are the same and do not depend on thickness. From these data it can be concluded there is some limit to which it is reasonable to go with the thickness of asphalt pavements. Of course, such a limit depends on the quality of the unbound layer beneath the

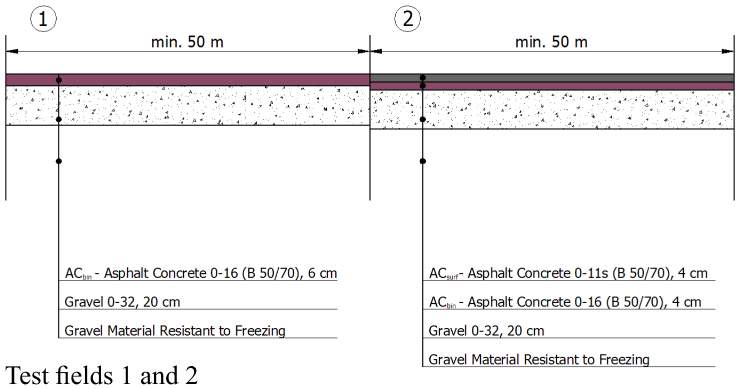


Figure 4.5 Test fields 1 and 2

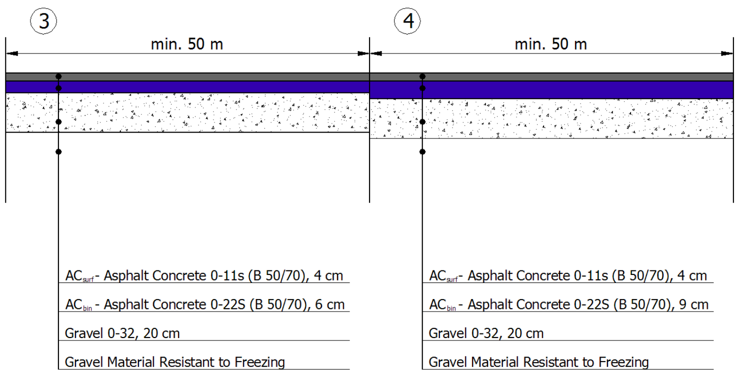


Figure 4.6 Test fields 3 and 4

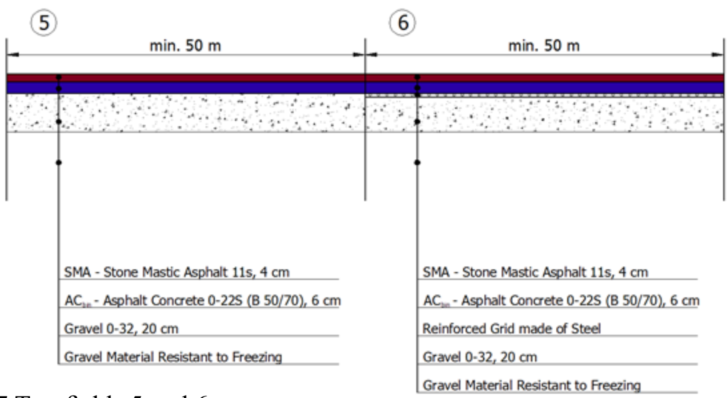


Figure 4.7 Test fields 5 and 6

asphalt pavement, and on the applied loads.

The final outcomes are presented in D16 'Guidelines for the selection of the most convenient upgrading systems based on the results of heavy vehicle simulator tests and cost-benefit analyses of field trials'.

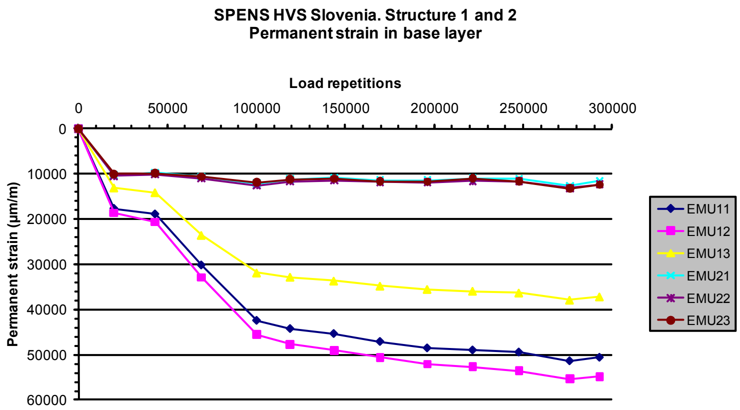


Figure 4.8 Propagation of permanent deflections in the unbound gravel layer.

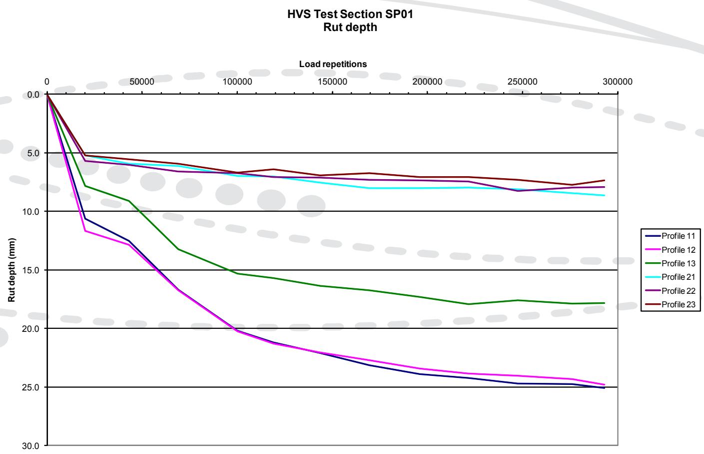


Figure 4.9 Propagation of permanent deformation (rutting) on the surface of test fields 1 and 2

Test field / measuring position	Asphalt thickness (cm)	Test field / measuring position	Asphalt thickness (cm)
No 1 - 1	6,2	No 2 - 1	9,6
No 1 - 2	5,7	No 2 - 2	10,6
No 1 - 3	7,1	No 2 - 3	11,1

Table 4.10 Total thickness of the asphalt layers

Figure 4.11 Local road in Dragučova before the construction of test fields

Figure 4.12 HVS testing in April 2008

WP4 Conclusions

The research performed within WP 4 contributes to standards indirectly. The test results provide a technical background for the relevant standardization committees.

The aim of the research work has also been the widening of the implementation of the existing EU standards in the New Member States. The results of tests performed according to the EU standards can be compared with the national specified tests, formerly used in the New Member States. A by-product of the project could be the preparation of recommendations for laboratory or field tests, as well as methodologies to reduce deviations in standardized and commonly used procedures.

The field trials with accelerated load tests on different road upgrading layers will lead to innovative road upgrading techniques. Systematically planned laboratory tests on different modified bitumen and asphalt mixes containing such bitumen will deepen existing knowledge about performance-related laboratory tests. In the field of high modulus asphalt mixes, the goal is not only the transfer of technology, but also the further development of similar materials.

WP5 Assessment of the impact of roads on the environment

Figure 5.1: The VTI circular road simulator

Work Package 5 was concerned with methods to investigate the impact of pavement choice on the environment especially for European New Member States (NMS). The common goal of partners of old and New Member States alike was to achieve a common understanding of suitable pavements and the associated procedures and methods to assess and manage their environmental properties. Within the broad scope of environmental impacts the WP5 partners selected air pollution by particulate matter and noise emission as their main investigation targets. The partners from NMS provided information on the general legislative situation in their countries, the methods and procedures currently applied concerning the selection of road pavements and on the actual use and distribution of pavement types within their countries. A first insight gained by all partners was that the differences were less present in the pavement types actually used, which would be considered quite standard pavements in the old member states, but more in the procedures and methodologies. The use of advanced low noise pavements like porous asphalts is not likely to be found in NMS, but the same is true for quite a lot of the EU-15 countries.

The experimental programme of WP 5 focused on investigations of the most common pavement types in the participating NMS partner countries, which were found to be asphalt concrete (AC) and stone mastic asphalt (SMA) varieties. Some of the investigations also included measurements on concrete pavements, as they play a significant role in some motorway networks. The investigation programme contained measurements of the particle emission of typical pavements with hard (Czech Republic) and soft (Slovenia) stone material on the VTI road simulator combined with a chemical analysis of the particles, in-situ dust fall measurements of PM emissions in the Czech republic and Slovakia and SPB (ISO 11819-1) and CPX (ISO/CD 11819-2) measurements in all three NMS partner countries. The experiments showed some interesting results both for the pavements themselves and the applied methodology.

The final recommendations were derived from the experimental results and previous knowledge to help road administrations manage environmental effects influenced by road construction and maintenance.

The recommendations for air pollution from tyre-pavement interaction point to the importance of investigating the pavement contribution to PM emissions in road and street environments where the EU PM10 limit values are exceeded. If harder stone material is chosen for the pavement, it will generate less overall PM and is more resistant to the applied torque from speed changes. However, a part of the results indicates that harder stone material tends to have a higher emission of small-size particles below 1µm which are more dangerous than the larger particle diameters. Winter tyres will produce more PM than summer tyres no matter which kind of road surface is present. Results from CDV indicate that asphalt concrete pavements are less resistant to abrasion than cement concrete pavements and produce more particulate matter. However, the highest attention should go to the fraction with diameters below 1 µm, as they penetrate very deeply into the lungs. The share of this fraction was found to be high in locations with stone mastic asphalt. The results of dust fall measurements in tunnels are in accordance with measurements of PM in ambient air. In any case it can be stated that the effect of tyre and pavement abrasion on PM present in the air can be very difficult to determine due to the many possible background sources.

The recommendations for noise emission show that the noise emission from NMS road surfaces is very comparable to that of standard road surfaces in the rest of the EU. Asphalt concrete and SMA surfaces dominate, and problems are usually due to the use of old types of concrete surfaces or bad maintenance condition. SMA pavements with small chippings sizes of e.g. 8 mm are considered the most silent pavements already in use. The future may see the introduction of more open-graded road surfaces and porous asphalt surfaces to improve the noise emission situation.

Concerning the methodology, all partners recognized the value of performing SPB and CPX measurements to assess the noise performance of road surfaces. The following general recommendations were derived:

- When choosing new pavements for road construction the existing information on noise emission should be considered. Optimally a noise classification system should exist which details the noise emission performance with regard to a known reference surface and is supported by a statistically significant number of measurements.
- The preferred measurement methods for classification of pavements are the SPB method (ISO 11819-1) and the CPX method (ISO/CD 11819-2). For the basic classification of road surfaces at least SPB measurements are necessary.
- For conformity of production testing and monitoring CPX measurements are most suitable.
- The SILVIA project (http://www.trl.co.uk/silvia/) and the associated handbook make a good proposal for a possible noise classification system for road surfaces.
- In general the acoustic performance of road pavements tends to decrease over time, leading to increased noise emission levels. Therefore the end of the acoustically viable working life can be expected to arrive before the end of its working life from a purely mechanical point of view.
- The noise reduction performance of any type of road surface can be compromised by the presence of road surface discontinuities, cracking and ravelling, potholes and any irregularity introducing step changes in the road surface level. For this reason regular maintenance of road surfaces does not only keep them in good condition, but also keeps them silent.
- No general recommendation for asphalt or concrete surfaces in terms of noise emission can be given. The most silent road surfaces today are found among the porous asphalt pavements, which usually show a shorter effective working life than most other pavements. However, also durable and sufficiently quiet

Figure 5.2: Pavements in the road simulator: Czech diorite (top) and Slovenian limestone (bottom)

concrete pavements are available e.g. in the form of exposed aggregate concrete road surfaces. The loudest road surfaces are usually old concrete road surfaces with unfavourable surface treatments like transverse brushing and block pavements.

- A complete system for the management of the noise emission of road surfaces would include a classification system compatible with the noise immission calculation scheme, conformity of production checks and a regular monitoring programme.

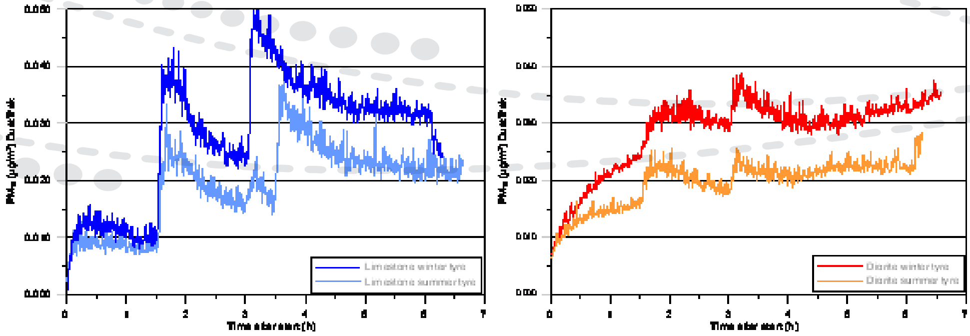


Figure 5.3: PM10 concentration during test with the two pavements

The results of SPENS WP 5 were presented in a workshop on the 7th of May, 2009, in Bled, Slovenia. They also form the basis of SPENS deliverable D17 ' Guidelines for the environmental assessment of various pavement types including recommendations to road authorities in New Member States', which aims at providing recommendations and guidance on the environmental assessment of pavements and on useful and cost-effective techniques and procedures to keep their environmental impact at acceptable levels.

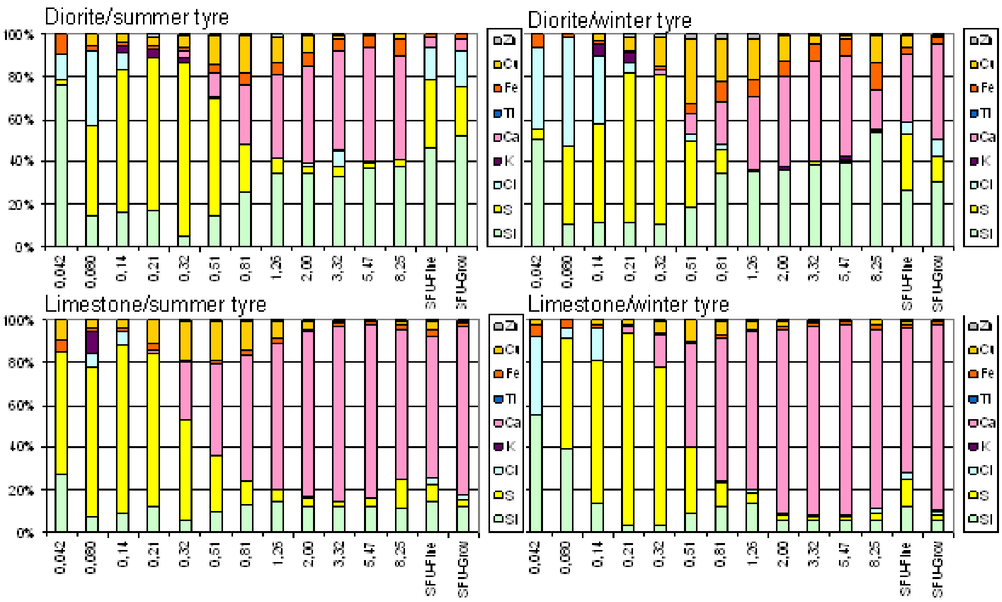


Figure 5.4 Elemental analysis (PIXE) of SDI particle sampling.

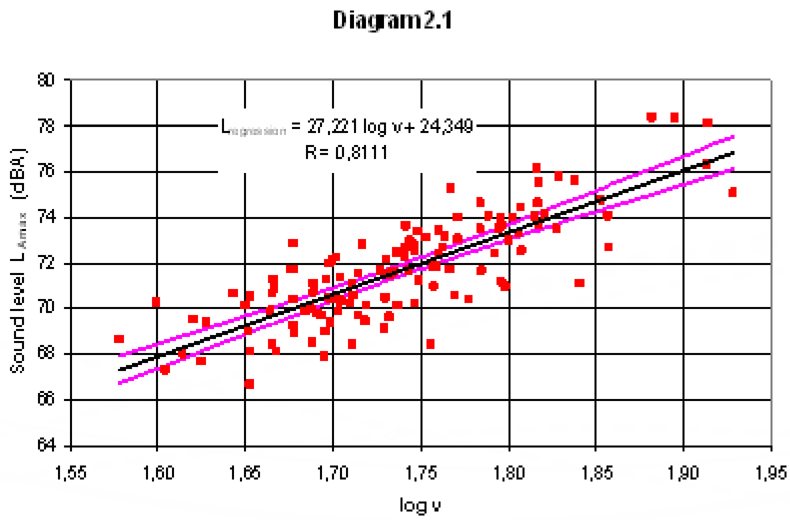


Figure 5.5 SPB measurement results for SMA 8s at Domžale

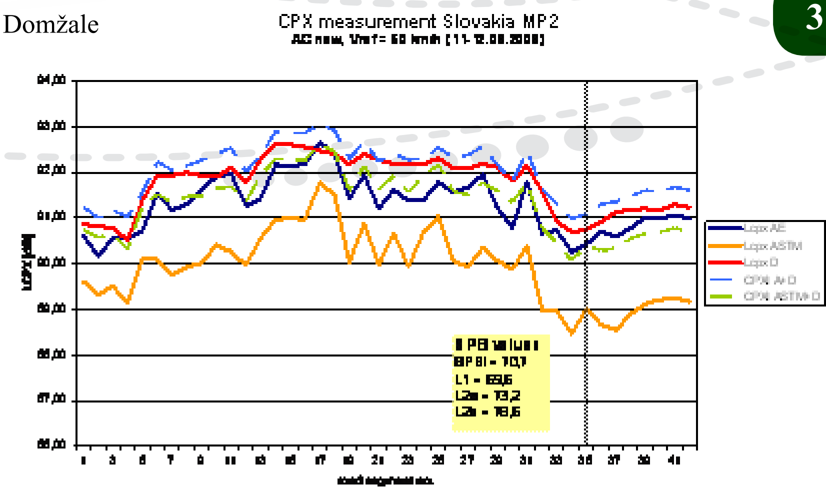


Figure 5.6 CPX measurement results for Slovakian AC

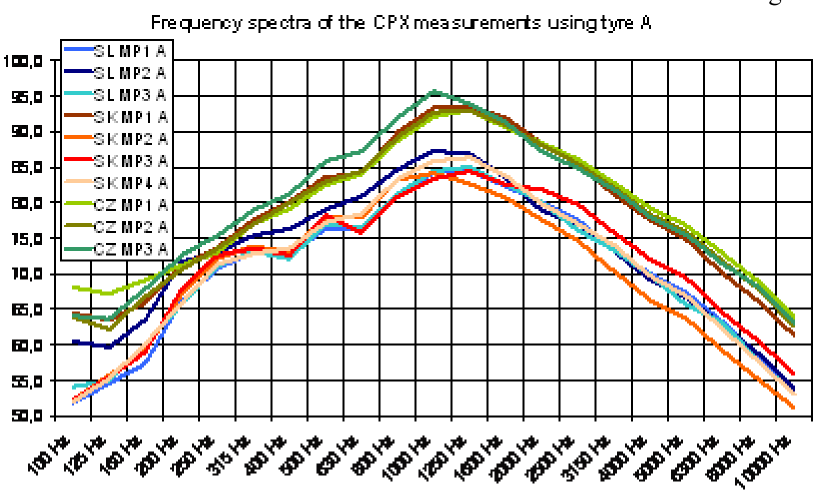


Figure 5.7 Spectra of CPX measurement results

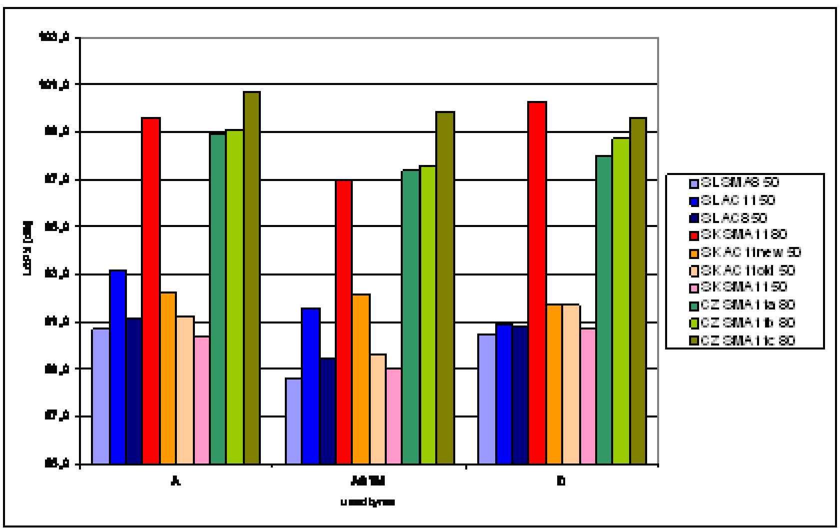


Figure 5.8 CPX levels for the ten measured sites using tyre A, ASTM and D

FOR MORE INFORMATION

FEHRL

FEHRL - Blvd. de la Woluwe, 42
1200 Brussels - Belgium
Phone: +32 2 775 82 45
Fax: +32 2 775 82 54
E-mail: info@fehrl.org
http://spens.fehrl..org

ZAG - Slovenia

Ferriere Nord - Italy

AIT - Austria

DDC - Slovenia

IBDIM - Poland

KTI - Hungary

CDV - Czech Republic

VTI - Sweden

TUZA - Slovakia

IGH - Croatia

IP - Serbia

Tecer - Esto

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