Application of asphalt interlayers for road maintenance management

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Abstract

In recent years, asphalt interlayers have been used for repairs and reinforcements in road maintenance management in Switzerland. According to SN 670 259 EN 15381 these are geotextiles or related products which can be applied for road maintenance of bituminous road bases and wearing courses (SN 670 259 EN 15381, 2008). They are fitted in or between bituminous bearing courses and wearing courses to achieve an extension of road maintenance intervals. As a result, the life span of the pavement is increased and efforts for road maintenance are reduced.

So far, a Switzerland-wide overview regarding applications and experience with the effectiveness of asphalt interlayers in pavement maintenance management is largely missing. Due to the high relevance of the application of asphalt interlayers regarding maintenance management, a first research project (preliminary study) has been initiated in order to capture and analyse the products, the fundamentals for their application, and existing research and practical experience regarding asphalt interlayers. Based on the results and insights, the foundation for a tender for long term and object related research has been designed.

Keywords

Reinforced asphalt concrete - superstructure - road maintenance - road construction - pavement - asphalt interlayers

1. Introduction

In a first research project (preliminary study) which was carried out at the Institute for Transport Planning and Systems (IVT) at ETH Zurich and the Swiss Federal Laboratories for Materials Science and Technology (EMPA) in Dübendorf, currently missing knowledge about the use, experience and effectiveness of asphalt interlayers in bituminous bearing courses and wearing courses were collected, analysed and shown for Switzerland (Lindenmann et al., 2010).

In the preliminary study the basics and the level of knowledge to asphalt interlayers were compiled by means of a literature research. A simplified market research led to a systematisation of applied products in Switzerland according to material, structure and product manufacturers. Moreover, experiences with the use of asphalt interlayers for Switzerland were gathered by means of interviews with project managers from civil engineering firms, planners from communal engineering departments as well as product manufacturers.

Based on the findings of the conducted preliminary study, a concept for object related research has been formulated. The concept includes questions to be investigated, installation of test sections and establishment of a methodology for measurements and test methods in order to assess the effectiveness and life span of asphalt interlayers.

This paper is structured as follows. First, the layer system of the superstructure, the effective stresses as a result of traffic loads and the effectiveness of asphalt interlayers in the layer system are explained. Then, findings from the preliminary study regarding product systematisation, position of asphalt interlayers in the road superstructure, installation and dimension of maintenance with asphalt interlayers as well as experiences in the use of asphalt interlayers are described. Concluding, the further avenues of research in asphalt interlayers are compiled and the need for an object related research with field and laboratory analysis is shown. Finally the objective and the purpose, as well as the implementation of the object related research are discussed.

2. Basics of asphalt interlayers

2.1 Stress distribution in bituminous superstructure

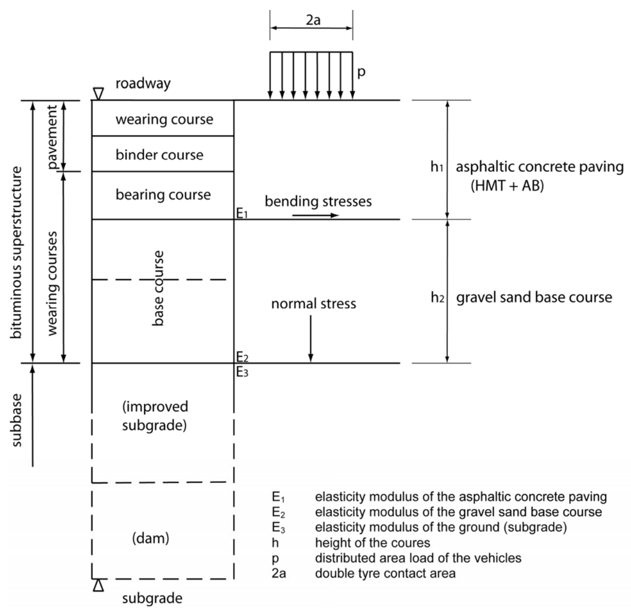
The application of asphalt interlayers as maintenance measure of asphalt pavements is done with the aim to improve the properties in comparison to classical bituminous construction maintanance.

The superstructure of roads basically consists of a layer system. The definitions and functions of the single layers of the superstructure are standardised for Switzerland in SN 640 302b (SN 640 302b, 2000).

There are two groups of layers, superstructure and subbase. The superstructure layers are divided into pavement and bearing courses and for the asphalt construction method the pavement that is, wearing course and binder course, is made of asphalt. In addition, the assembly of the uppermost ones of the defined bearing courses are mostly carried out with a bituminous mixture.

At the layer borders load dependent stresses occur. Figure 1 shows, simplified, the stress distribution as a result of plane distributed loads. The most important horizontally working bending stresses and the vertically normal stresses are shown. The display of the different shear stresses was omitted for reasons of the clarity.

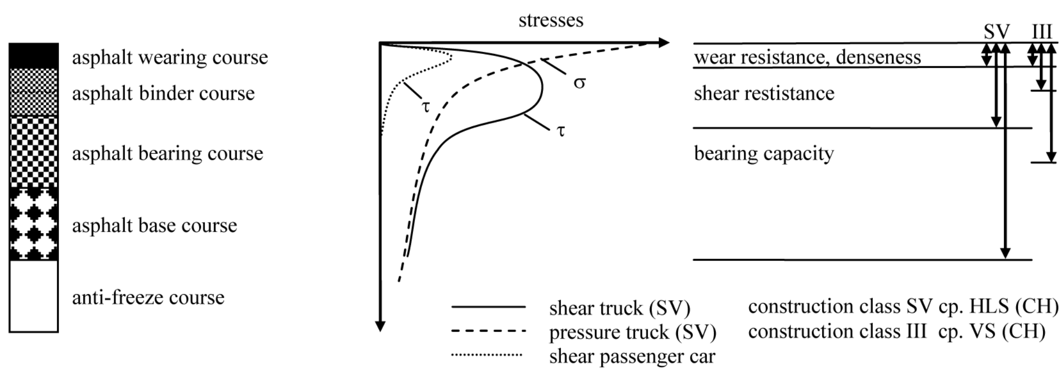
Figure 1 Typical layer construction of a road body with load dependent stresses (simplified) on layer borders



(Lindenmann et al., 2010)

Glet (Glet, in 1999) illustrates the principles of the layer construction by the comparison of qualitative property requirements, shear stresses and compressive stresses as a function of the layer thickness and thus shows the functions of the layers. Moreover, he found that although the forces decrease from top to bottom in the superstructure, shearing stresses reach their maximum in the depth of 4-8 cm their maximum (Figure 2).

Figure 2 Representation of the shear stresses and compressive stress as a function of the layer depth and the resulting functions of the layers (conceptually)



(Glet, in 1999)

2.2 Effectiveness of asphalt interlayers in the layer system (interlayer bond)

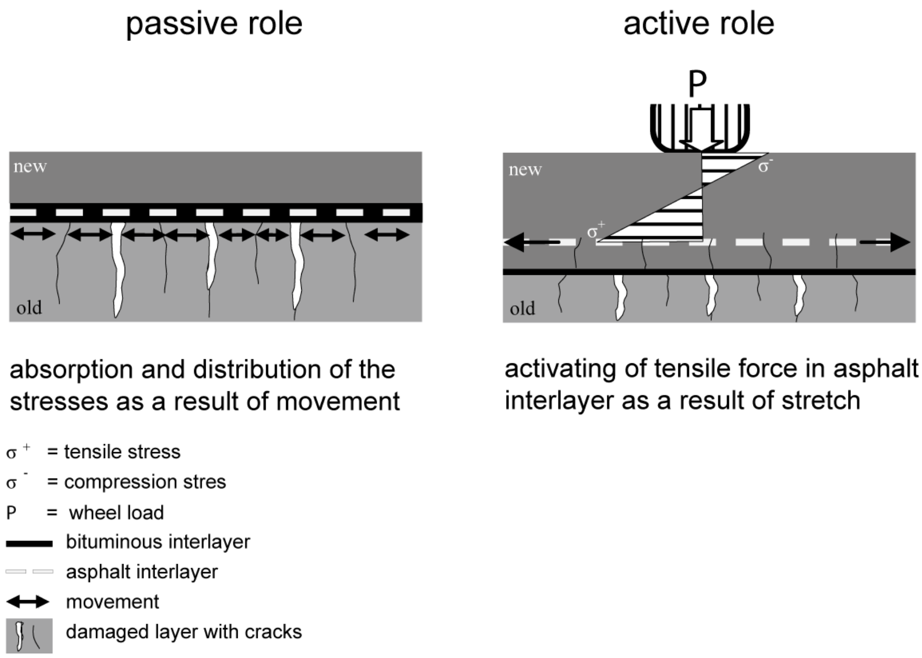
The asphalt interlayer is laid in area under stress for stress relief. In the literature the stress relief is explained by two mechanisms.

- Creep
- Reinforcement

The term „creep“ is described according to Rüegger (Rüegger et al., 1988) as a process of viscous deformations of nonwoven geotextile, reducing stress peaks. Under stress the asphalt interlayer (nonwoven geotextile) stretches and thus may contribute to crack bridging (passive role) (Figure 3).

The stress relief by reinforcement is reached according to FGSV AP 69 (FSGV AP 69, 2006) by a local horizontal movement and tensile stress take-up by reinforcement elements. Asphalt interlayers in the form of geogrid are, other than nonwoven geotextile, able to absorb tensile force and thus may contribute to crack prevention (active role) (Figure 3).

Figure 3 Effectiveness of asphalt interlayer, different between active and passive role



(Lindenmann et al., 2010)

According to SN 670 259 EN 15381 (SN 670 259 EN 15381, 2008) „ the stress relief is created by a road construction material (nonwoven geotextile or material combination) which - if probably installed between a street surface and asphalt wearing course – allows for light differential movements between two layers. The propagation of breaks in the wearing course is thereby delayed or limited“.

The comparison of the aspects of stress relief by nonwoven geotextile and geogrids is shown in Table 1.

Table 1 Comparison of asphalt interlayer nonwoven geotextile and geogrid

asphalt interlayer / comparision aspect	nonwoven geotextile	geogrid
function of asphalt interlayer	asphaltic road binder	absorb tensile force
mechanism during stress relief	compensation of deformations by viscosity of the asphaltic road binder	force transferred to geogrid with limited horizontal movement
material property	viscosity breaking elongation	extentional stiffness
problems with asphalt interlayer	susceptible for shear forces interlayer bond	non-positive interlayer bond

(Lindenmann et al., 2010)

A sufficient interlayer bond between the parts of the layer construction is prerequisite for the appropriate function of the construction. The shear-proof bond of the asphalt interlayer in the layer system is critical for the functions of the asphalt interlayer to be fulfilled.

Findings of investigation reports and journal articles regarding the aspects of layer bond and reinforcement mechanics are described in the following.

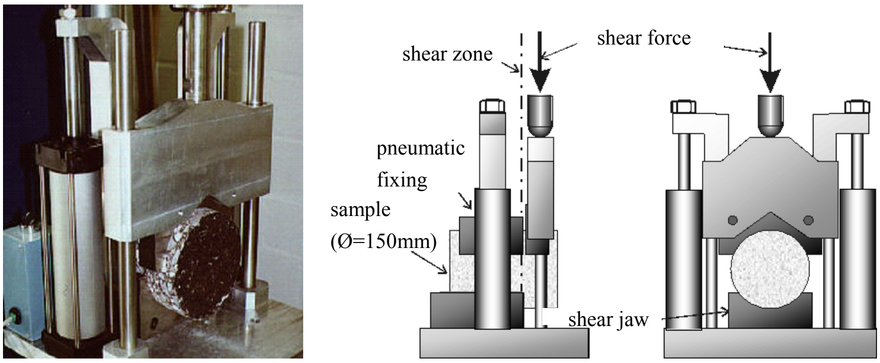
2.3 Research in Switzerland

The following is based on research projects of the Swiss Federal Laboratories for Materials Science and Technology (EMPA) in Dübendorf on the interlayer bond and reinforcement mechanics are listed.

- Effects of geotextiles on the interlayer bond with bituminous replacement on concrete roads (Raab, 2007)
- Important aspects of interlayer bond in overlays (Raab und Partl, 2004)
- Laboratory analysis in differently reinforced asphalt layers (Sokolov, 2007)
- Experimental analysis of fibre reinforced asphalt composites with four point bending test (Kim et al., 2009a) and (Kim et al., 2009b)

The interlayer bond was determined using drilling cores according to the SN 670 461 (SN 670 461, 2000) at pre-determined temperatures. The examination apparatus is shown in Figure 4.

Figure 4 Layer-Parallel Direct Shear Device (LPDS)

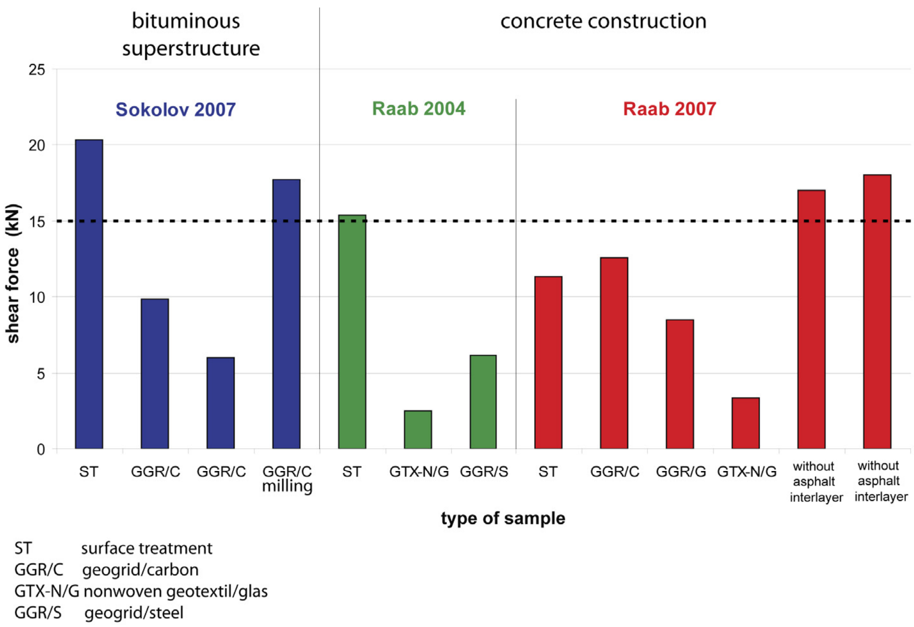


(Raab, 2007)

It was found that asphalt interlayers can reduce the interlayer bond. The analyses of Raab (Raab und Partl, 2004) und Raab (Raab, 2007) has been carried out on a concrete base. The required shear force of 15 kN was reached with no sample with asphalt interlayer. In the analysis described by Sokolov (Sokolov, 2007) the necessary shear force (15 kN) was reached only with milled samples with carbon grid. What contributes the reduction of the shear forces was not explained in detail in the research reports.

The results of shear trials carried out with different samples of Raab (Raab und Partl, 2004), Raab (Raab, 2007) and Sokolov (Sokolov, 2007) can be seen in Figure 5.

Figure 5 Overview of measured shear forces according to Leutner in different analysis



(Raab, 2007; Raab und Partl, 2004; Sokolov, 2007)

Testing interlayer bonds trials conditions during analysis of Sokolov (Sokolov, 2007), Raab (Raab und Partl, 2004) und Raab (Raab, 2007) differ. Differences can be seen in the experimental set up, e.g. the material of the base (bituminous superstructure or concrete superstructure) and in the composition of the wearing course mixture (SMA 11, AC 8 S, AC 11), the treatment of the base (milling yes/no) and the position of asphalt interlayer in the layer system. Furthermore, trial conditions vary during testing of the interlayer bond, for example the examination temperature. Therefore comparability of results is limited. However, it seems that the position of the asphalt interlayer (tension zone) and the character of the base (milled) which is provided with a new layer asphalt interlayer play an important role.

Kim (Kim et al., 2009a) considered the reinforcement mechanics at 4 point bending samples and found, that geogrid reforcing has a positive effect on the structural behaviour, in particular it influences the crack distribution. Here, the bending behaviour could be described well with a bilinear fracture model under the use of visco-elastic theory.

A Swiss test series investigating products of several manufactures by an independent research institution does not exist yet. Therefore, objective short and long-time analysis should be carried out to test, analyse and estimate the behaviour of the layers of the whole road body in the composite material with asphalt interlayers in regard to changes in terms of crack formation. The conditions and set up of experiments have to be chose so that results are comparable to each other.

Within the framework of the RILEM Technical Committees TC 206 ATB Advanced Testing and Evaluation of Bituminous Materials Task Group TG 4 Pavement Performance Prediction and Evaluation managed by EMPA, a comparative test is currently organized in Italy, where different reinforcements are built into a street with high traffic volume. The aim is to evaluate samples which are produced by different laboratories parallely.

In summary, there is still no objective Swiss-wide overview of comparable analyses by independent research institutions. Especially uniform assessment criteria and test criteria for the behaviour of asphalt interlayers in layer systems are missing. Here is a need for further research and development. First useful hints are found some in laboratory analysis already carried out.

3. Preliminary study of asphalt interlayers for Switzerland

The objective of the preliminary study was to develop a Swiss-wide overview regarding applications and experience with the effectiveness of asphalt interlayers in pavement maintenance management.

The analysis of the basics should provide results and knowledges about the different applications of asphalt interlayers in road maintenance management, identify gaps in knowledge and point out where certain field testing and analysis seem to be necessary.

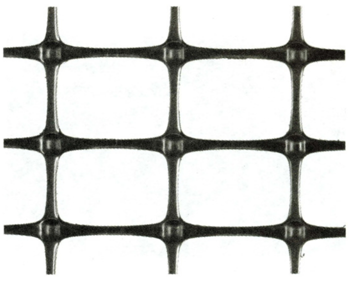
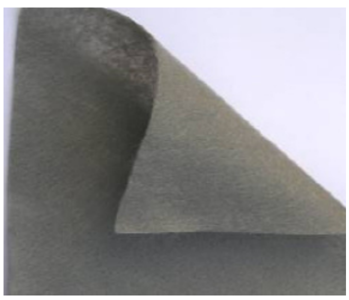
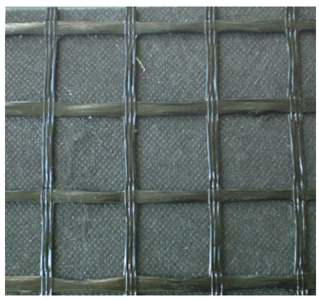
The results of material and structure, the product systematisation, position of asphalt interlayers in the road superstructure, assembly and dimension of maintenance are described below.

3.1 Material and structure of asphalt interlayers

Asphalt interlayers can be produced from synthetic or natural polymer material. In the asphalt road construction, synthetic is used as a synthetic material and as natural materials glass and carbon are used. Beside the synthetic and natural materials, asphalt interlayers can be made from steel. The materials plastic, glass and carbon are processed to fibers or web. The configuration of the fibres and webs and the steel wire in the asphalt interlayer results in the following different structures (Figure 6):

- lattice shaped
- plane
- lattice shaped and plane

Figure 6 left) geogrid - lattice shaped, middle) nonwoven geotextile - plane, right) geocomposite - lattice shaped plane

(Asphalt Academy, 2008; Müller-Rochholz, 2008; Rüegger und Hufenus, 2003)

3.2 Product systematisation for Switzerland

In the preliminary study, the products which are offered on the Swiss market are discussed, as well as which combination of material and structure is used most often. To compile an overview of the products, a simplified market research was carried out with manufacturers.

The simplified market research for Switzerland found that eight manufacturers offer products, made of different materials and structures (Table 2).

Table 2 Product overview of asphalt interlayers for Switzerland (Lindenmann et al., 2010)

structure	material	S&P Reinforcement	SYTEC Bausysteme AG	TenCate Geosynthetics AG	Fritz Landolt AG	Tensar International GmbH	Huesker/ Schoellkopf	REHAU AG	Bekaert
GTX-N	PP			PGM					
GGR	PET						Hatelit		
	C/G	Carbophalt G							
	G	Glasphalt G	Glasgrid					ARM-APAL G	
		Glasphalt bit						ARM-APAL GL	
	S								Mesh-Track
GCO	PP/C	Garbophalt GS							
	PP/G	Glasphalt GS		PGM-G	Landobit	Glastex		ARM-APAL plus	
		Glasphalt GV				Tensar Crack Stop			
	PP/PP					Tensar AR-G			

GTX-N nonwoven geotextile PP polypropylene C carbon fiber
GGR geogrid PET polyester S steel
GCO geocomposites G glas fiber

Concerning the structure Table 1 shows that of in total 18 products the choice of composite materials is, with nine products, the biggest. Eight products with a geogrid shaped structure (grid) and only one plane (nonwoven geotextiles) are available.

Considering of the materials of which the grids and nonwoven geotextiles are produced, it can be seen that the number of fibreglass asphalt interlayers is, with five products the highest. Two products made out of synthetics are available and only one from carbon fibres and steel. Synthetics are mainly used for composite materials.

3.3 Position, dimensions and installation of asphalt interlayers

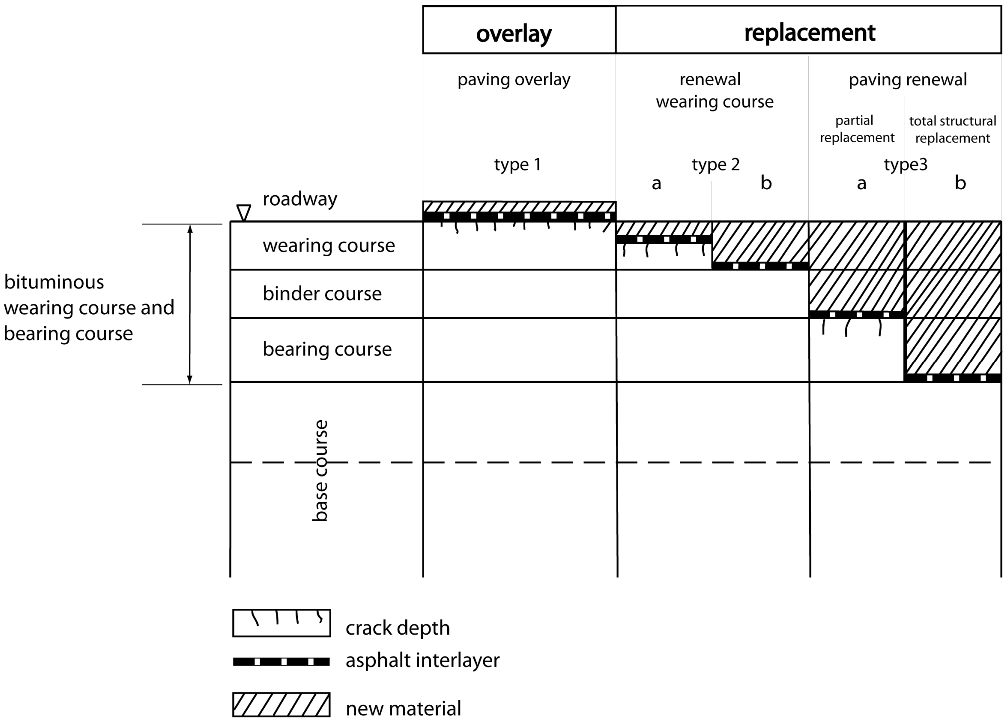
In the interviews with project managers from civil engineering firms, planners from communal engineering departments and product manufacturers, information and data were collected using a questionnaire.

The evaluation of the questionnaires yielded four typical fields in maintenance where asphalt interlayers are used.

- New wearing course (reinforcements) overlay (type 1)
- Renewal wearing course (type 2)
- Partial replacement (wearing course, binder course and/or bearing course) (type 3), total structural replacement (wearing course, binder course, bearing course and/or base course) (type 3)
- Repairs and renewal of segments of pavement (as broadening the road cross-section, trenching)

Figure 7 shows the position of asphalt interlayers after maintenance.

Figure 7 Systematisation of the position of asphalt interlayers in the superstructure in road maintenance



(Lindenmann et al., 2010)

Type 1 asphalt interlayers are applied as overlay reinforcements. The asphalt interlayer is applied on the slightly damaged wearing course and is built over with a new wearing course. Type 2 and 3 asphalt interlayers are used for replacement. Type 2 asphalt interlayers are used for renewal of the wearing course. In type 2a, the wearing course is milled down to slight damages. The asphalt interlayer is laid on it and a new wearing course is built over it. In type 2b, the asphalt interlayer lays between the binder course and wearing course. Asphalt interlayers are used for partial replacement and total structural replacement in type 3. In type 3a, the wearing and binder course removed up to the slightly damaged part of the bearing course. The asphalt interlayer is laid on the slightly damaged bearing course and is overlaid with a new wearing and binder course. In type 3b the whole bituminous superstructure is broken up and overlaid with new bituminous material.

With suitable analysis, the usage of asphalt interlayers may be optimised, in particular regarding the usage of asphalt interlayers between wearing course and binder course (type 2b) and the binder course and bearing course (type 3a).

The results of the extent of the maintenance work are described below. A distinction was made between local and plane maintenance measures.

Plane measures are those, in which the asphalt interlayer was applied laminary on both sides.

Plane measures are:

- Plane asphalt layers for the purpose crack prevention

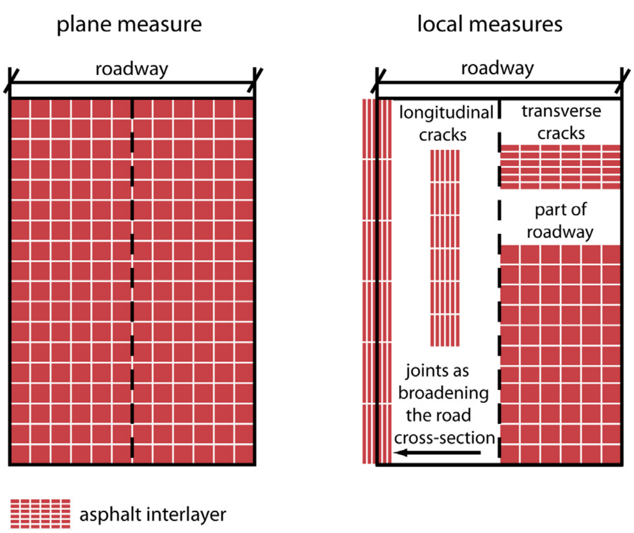
In local measures, the asphalt interlayers were used for bridging local damages. The asphalt interlayers were used on damaged sections, stripe-wise with longitudinal cracks and transverse cracks or on joints that are a result of different adjoining superstructure constructions.

Local measures are:

- Asphalt interlayers for reinforcement of patches
- Asphalt interlayers for repair of special crack patterns
- Asphalt interlayers to improve border area of the roadway

Figure 8 shows the different between local and plane application of asphalt interlayers for road maintenance measures.

Figure 8 Overview of the differences between local and plane measures



(Lindenmann et al., 2010)

For the local measures, good experiences exist. With plane measures, experiences are missing regarding the effectiveness and longevity of the asphalt interlayers. Hence, the usefulness of the application of asphalt interlayers is very interesting for plane measures.

Following the installation of asphalt interlayers is described. Before the asphalt interlayer is fitted in the bituminous overlay, the cleaning and drying of the base takes place. The bond between asphalt interlayers and higher lying and underlying layers is established with a bonding agent. The bonding agent and asphalt interlayer are adjusted to each other, in which the manufacturer of the asphalt interlayer and the manufacturer of the bonding agent (bituminous emulsion) work closely together.

The bonding agent is distributed on the damaged area and afterwards the asphalt interlayer is laid on the top of it (Figure 9).

Figure 9 Installation of asphalt interlayers

(Lindenmann et al., 2010)

3.4 Research findings

The research and survey in Switzerland showed that manufacturer-specific product descriptions and applications recommendations exist. However, analysis and scientifically established results of independent research institutes regarding the effectiveness and life span are largely missing so far. Moreover, scientific knowledge hardly exists regarding the following aspects:

- Long-term behaviour of asphaltic interlayers with bituminous courses of the pavement (interlayer bond)
- Performance in different layers
- Prevention of cracking (reflective cracking)
- Increase of load bearing capacity

Most results of the survey are based on test applications, where asphalt interlayers were used for maintenance projects where was evaluation of this measure. Analyses are carried out less systematic and uncoordinated, thus conclusive findings for the success of emplacement of an asphalt interlayers cannot be derived.

For this reason an object related research should investigate the questions regarding the concrete area of application and purpose, the interactions with the neighboring layers as well as behaviour in local, but especially plane applications, as well as life span. Therefore, suitable short and long time analysis in the field and in the laboratory in an object related research is necessary.

4. Concept for object related research

Based on the findings of the conducted preliminary study, a concept for object related research has been formulated. Following, objectives and purposes, as well as the analyses and examination methods are explained.

4.1 Objectives and purpose

The object related research includes the installation of test segments and the execution of short term and long term analysis in the field and laboratory. With the analysis, the behaviour of the layers of the whole road body in combination with the asphalt interlayer should be analysed and evaluated concerning changes with regard to cracking and life span. Furthermore, the questions of the suitable application extent (locally, plane), the effect on damaged roadway surfaces and the application limits of the different products should be tested.

The following questions regarding application and effectiveness of asphalt interlayers for maintenance remain unanswered and are therefore of great interest for the research project to be designed:

- Bridging (penetration of cracks, progress over time)
- Crack pattern (distribution, crack size, etc.)
- Shear/adhesion (forces and effects, progress over time)
- Rigidity/deformation
- Moisture at crack area (water intrusion)

An emphasis shall be placed on the following areas:

- Grid shaped asphalt interlayers (glass and carbon)
- Plane maintenance measures
- Fitting type 3a (between road base and base course)

In addition to these key aspects further application of different materials should be considered, if possible.

The aim is to find the most important measures and applicable ranges there of, which allow for an estimation of functionality of any asphalt interlayer product in a given case. Also, requirements with regard to impact and durability of a product used in sustainment procedure should be shown.

With the newly-developed systematic test methods, new products may be validated directly by themselves, so that uncertainties concerning the basic suitability in introduction of new and innovative systems are lifted. Furthermore, mistakes in the installation of the asphalt interlayers may be avoided through decision support.

4.2 Analysis procedure

The object related research is divided in two phases and each phase has five work packages. The results and findings of the first phase are to be summarised into an interim report. The second phase of the analysis will be based on the findings of the interim report. Following, the work packages of the first and second phase are described.

Phase one should begin directly after the installation of products in the bituminous road superstructure and stretch over a time frame of one year after installation. Phase one can be subdivided as follows:

a. field trials under real conditions on objects (test sections)

b. parallel laboratory analysis on samples (drilling cores)

c. laboratory analysis of products used in field trials

d. simulation of long term analysis in the laboratory

e. derivation of results

The second phase should begin five years after installation of the asphalt interlayers in the same test section of phase one. With it the long time effect from asphalt interlayers under real traffic should be tested. The second phase can be subdivided as follows.

a. field trials under real conditions on objects (test sections)

c. laboratory analysis of products used in field trials

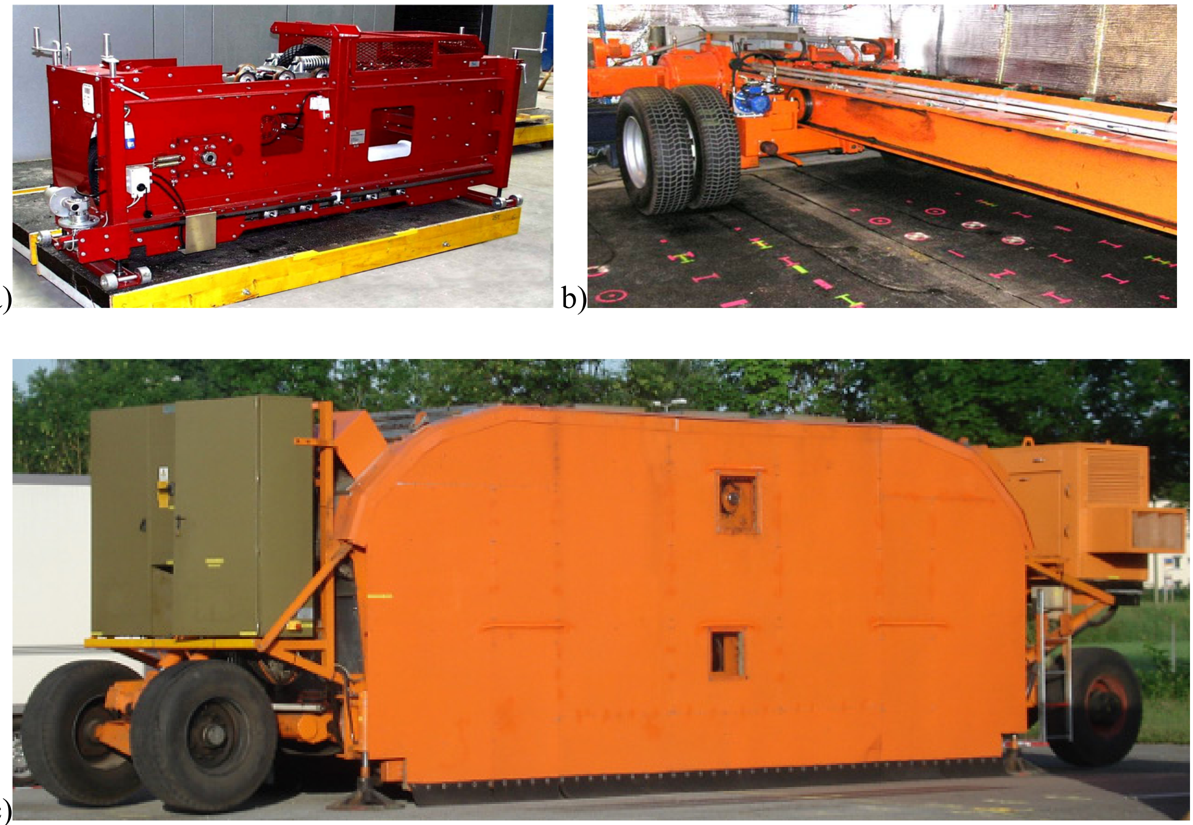
e. derivation of results

4.3 Examination methodology

For the simulation of traffic loads, the traffic load simulators MMLS3 (EMPA) and hall Fosse (EPFL) for laboratory analysis and MLS 10 (EMPA) for field analysis are available. The traffic load simulator is shown in Figure 10. The behavior at low temperatures can be analysed with the Joint Movement Simulator JMS at EMPA.

With the traffic load simulator MMLS3 quick evaluation of pavements is possible. Furthermore, it is used for the determination of mechanical properties under wheel load, in particular the investigation of rutting in wearing courses. The MMLS3 consists of a stiff steel frame with four adjustable feet. The load is applied with four wheels (30 cm diameter) which move in the same direction along a circulation rail.

Figure 10 a) MMLS3 EMPA, b) hall Fosse EPFL, c) MLS10 EMPA



a) b)

c)

(Lindenmann et al., 2010)

4.4 Conclusion

The pilot study showed that there is a need for further research on the application of asphalt interlayers for road maintenance management. Because of this, the Institute for Transport Planning and Systems (IVT) at ETH Zurich, the Swiss Federal Laboratories for Materials Science and Technology (EMPA) in Dübendorf and the Traffic Facilities Laboratory (LAVOC) at the EPFL are going to conduct out field studies and laboratory research to gain more knowledge of the application and effect of asphalt layers when considering types of different damage of bearing courses and wearing courses. The application of asphalt layers for measures in the area of maintenance management is promising and shows potential for the future. Research should show that with asphalt layers, an optimisation of repair and reinforcement in road maintenance management can be reached.

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