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Use of Non-woven Fabrics, Grids and Composites in Asphalt Road Construction

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1. Introduction

This paper summarizes the current state of knowledge in the field of asphalt padding in Germany, by which the developments in the European Community and the European standards will also be considered. The aim of this working paper is to establish a basis for the further treatment of the products and construction methods, for example, to create service descriptions by immaculate technical definitions and descriptions of the products and their pavement and effectiveness based on present experience.

2. General

Since early 80's wadding is used in bound superstructure or undersurface treatment, with the aim to prolong the useful life of road fortifications. Essentially for this purpose known nonwovens and plastic structures of lattice are applied in earthworks. Initially, these products were often built according to the "Trial-and-error" method, with positive experiences from the original application transferred to asphalt road construction without careful review, and often basic technical principles are ignored.

For this reason, the Working Group 7 "Asphalt Roads" of the Research Society for Road and Transport prompted the "opinion on the use of nonwoven fabrics, mesh fabrics and grids in asphalt road construction in 1992, which basically warns against the uncritical application of products derived from the geotechnical field, a principle that is still true today. Since 1992, the use of nonwoven fabrics, mesh fabrics and grids was therefore no longer covered by the panels of activity within the Working Group 7, which deals with the creation of regulations for new construction with asphalt, so that none of these products are included in the road-specific rules in Germany.

In the last 10 years, different manufacturers have developed and tested products and pavement methods by taking into account the special requirements of the asphalt road construction.

As a result of this development, not at least because of significant success abroad - particularly in the superstructure of torn base [C-1.J-1, L-1, V-1] –'asphalt padding " has obtained a role in the restoration and maintenance of asphalt roads in Germany that can no longer be ignored. According to the manufacturer more than 20 million m^2 asphalt padding has been used in different construction so far.

In Austria and Switzerland technical regulations for the pavement of nonwovens have already been introduced [F-1, V-2].

Out of these reasons it was decided that the working group "Asphalt Roads" give further consideration to the asphalt padding. This working paper explains the effect of asphalt padding and steel grid, and describes characteristics necessary for various applications. The working paper contains directions for exploration, status detection and tables with possibility of application of asphalt padding, depending on road condition, with Installation and pavement Instructions. In addition, guidance is offered for recycling.

3. Terms

Definitions below were consistent with the definitions for asphalt road construction in accordance with the ZTV BEA-StB and RStO, as well as the definitions of geosynthetics according to ISO 10318, the TL Geok E-StB and the "fact sheet for the application of geosynthetics in road earthworks"(M Geok E) matched.

The steel mesh plays a special role, because their application has so far been reserved for a few special cases with unusual problems. The various fields of application for steel grid padding was investigated and described in the European-funded research program REFLEX with the participation of the Technical University of Munich and the German Institute for concrete reinforcement [N-1]. In addition, there're assessment theoretical investigations in the United States [E-1]

Raw Material: Asphalt paddings provided for road construction are made of different materials and their combinations. Usually there're synthetic raw materials such as aramid (AR), polyethylene terephthalate (PET), polypropylene (PP), polyvinyl alcohol (PVA), polyethylene (PE) and natural substances (e.g. coal and glass fibers). These are processed into nonwoven fabrics, grids and composites.

Non-woven fabrics resulting from the consolidation of blankets (fleece) from surface-wise on each other piled, irregularly arranged filaments (endless threads) - "filament nonwovens" - or 3 to 15 cm long fibers (staple fibers) - "staple fiber nonwovens". The consolidation can be mechanical (for instance by needling or sewing) and / or adhesive (e.g. binder) or cohesive (e.g. by thermal effects).

Grids are made of synthetic or natural fibers / bundles, or manufactured from extruded polymer grid structures with different node structures and pave opening widths. There is a distinction to woven and rustled, stretched and laid grids:

- **Woven Grid** consisting of two perpendicular intersecting thread systems. The intersection is fixed by an additional thread in case of rustled grids. Because of the similarity of both being manufactured with the textile technology the term woven mesh is used for both grids in this paper.
- **Stretched Grid**: Stretched grids are either produced with punched plastic sheets and by pulling (stretching) of the hole grid structures embrasure, or with hole grid structures extruded and then stretched.
- **Laid grid**: For laid grids plastic or fabric strips are crosswise laid and connected to each other at the contact points.
- **Steel grids** are made of steel wire or thin grids produced with concrete steel. The nodes can be welded like welded mesh. Another method is to manufacture grid structure as in a chain-link fence.

Composites consist of surface-linked surface structures (e.g. grid with nonwovens).

- **Grid with pavement assistance**: Grids for the facilitation of pavement are combined with auxiliary materials (thin non-woven fabric or plastic sheeting).
- **Grid with Nonwovens**: The non-woven fabric simplifies the pavement and make up a sealing layer together with the binder.

Cleading: Grids or composites may be coated with polymers or bitumen.
Reinforcement: Reinforcement is conceived as the use of asphalt padding, which due to their properties is able to absorb tensile stresses.
Effective Asphalt Thickness: This is marked by the thickness of the cracked asphalt in cross section.
Binders: Bitumen and bituminous binders (bitumen emulsion, polymer modified bitumen and polymer modified bitumen emulsion).
Anchorage: Length of the asphalt padding outside the load application area.
Asphalt Padding: Products that in combination with asphalt build a layer system.
SAML: Stress Absorbing Membrane Interlayer is thin layer of viscoelastic materials that could reduce stress.

4. Application principles

For the success of a measure is the selection of appropriate materials and material combinations crucial. The desired objective, the related requirements and the existing boundary conditions play a role in the selection. It is important to note that the asphalt padding, depending on the type of raw materials can have very different properties and therefore are not freely interchangeable. Literature: [F-1, V-1].

Objectives of the application of asphalt padding are:
- Extension of the repair interval
- Reduce the maintenance effort
- Extending the use life of the street.

The asphalt padding can perform the following tasks:
- Sealing effect
- Function even layer adhesion
- Delay of reflection-crack
- Reinforcement effect

In the application of asphalt padding, the existing boundary conditions must be observed:
- Type and condition of the existing road fixing, capacity
- Type and condition of the existing road surface
- Nature and composition of the new roadway surface or ceiling
- Binding agents used
- Traffic congestion and importance of the road (transport mode, road type, each with associated construction class.

In order to fulfill the tasks, the properties of the asphalt padding, materials and systems of each building project and the temperature-dependent viscoelastic properties of the asphalt have to be adjusted.

Asphalt changes its properties with temperature and rate of loading to a much greater extent than the properties of the asphalt padding at the same temperature range changing. This has the consequence that the system characteristics of the combination of asphalt mixture and asphalt padding also change with temperature and rate of loading. Temperature-independent values can not be given for the system characteristics.

Recent work deals with the behavior modeling of asphalt padding in asphalt layer. The applied calculation models based on the multi-layer theory on isotropic elastic half-space, or elastic supports, as well as the use of 2- or 3-dimensional finite-element models show good agreement with the experiences from laboratory studies and in practical use [B-1, B-2, N-1].

But because of the complexities and many influence factors the calculation models must be confirmed by further field trials [C-3, E-1] before they can be regarded as secured, so that application is still largely relied on practical experience.

These experiences were reflected in the following sections.

5. General Effect

Recent findings on the effects of asphalt padding are to be summarized below. Three fundamentally different effect mechanisms are to be considered, which in practice do not occur in its pure form, but overlap in most cases.

5.1 Sealing effect

The sealing effect of bituminous coatings has been known since antiquity. Then as now, they are used to seal water pipes, pipes, storage tanks, etc. In building bridge and by roof waterproofing people take advantage of the sealing effect of bituminous layers through the application of bitumen sheets of carrier system.

In asphalt road construction nonwovens create a sealing layer in conjunction with bitumen. The binder layer acts as a sealing of the base against the ingress of water and atmospheric oxygen. Thus, the aging of binder due to oxidation and the formation of embrittling crack in the existing asphalt pavement is slowed.

Note: Regarding the assessment of the tightness against water and water vapor it should be noted that pure bitumen films are too thin to warranty a long term sealing effect. For example, in DIN 18195 "building waterproofing" pure bitumen coatings are no longer permitted as a seal against soil moisture on the basement walls. According to DIN 4108-4 "Thermal insulation and energy saving in buildings - Part 4: Heat and moisture prevention technical characteristics" only casting asphalt layer with a thickness of 15 mm is regarded as water-vapor-tight.

A sealing effect reduces the penetration of surface water; thereby the frost resistance can also be improved. An additional damage caused by water frozen in the layers (Explosion, forming of ice lens, soaking in the thawing period) is largely prevented. In frost-sensitive layer without binder, the sustainability of the road fixing is indirectly improved. The risk of water penetrated through the surface of due to detachment of binder film in the bound layers (stripping) is delayed.

5.2 Stress relaxation effect through "flexible composite"

Bitumen shows visco-elastic behavior in the use temperature. This means that with a load of binder film three different strain responses take place:

- **Elastic Deformation** is directly related to the load and immediately and completely reset again (reversible) after the removal of the load.
- **Delayed-elastic Deformation** takes place with a time lag and approaches a limit that is dependant on load size. The deformation is completely halted after the removal of the load after a certain time (reversible).
- **Viscous Deformation** is performed with a constant speed as long as the load is applied (flow); the deformation is not postponed again after the removal of stress (irreversible).

The delayed elastic and viscous properties of the bitumen are responsible for the voltage-depleting effect.

The loading of the binder film can be caused by traffic loads, namely the triggered pressure, tensile and shear stresses, deformations of the substrate, or by deflections and / or temperature-conditioned strains. The load generated in the binder film tensions that lead to flow processes [SAMI] as a result of the viscous component in "inner" of the binder film.

Tensile cracks from the shore movements of the surface will be largely eliminated within the bituminous layer through viscous flow. Should the crack edge movement not or in a weakened form passed to the overlying asphalt layer, there will be no tension surpassing the tensile strength of the asphalt on the underside of it. In fracture mechanics this is characterized as the diminution of notch stress [J-1].

At the same time, the adhesion of the bitumen ensures that the binder layer has a good bond with the base and the overlying asphalt layer.

Because of the good connection and viscous deformation ability this system is called a "flexible composite.

The nonwoven fabric acts as binder storage and allows the production of larger and more uniform thickness, as if they were possible with pure bitumen.

In addition, the nonwoven fibers increase the viscosity of the whole bitumen nonwoven fabric, so that a "swimming" of the overlying layer is avoided, while still allowing a reduction in tension in the bitumen layer.

5.3 Reinforcement effect through absorption of tensile tension

Multi-layered asphalt system can be reinforced if it succeeds in bracing padding in the asphalt, so that it is able to absorb tensile forces.

For the absorption of tensile stress by padding the following requirements must be met:

- The padding must be located in the field of tensile stresses.
- Through frictional interconnection the stresses can be transferred from one building material to another.

The force transmission from the asphalt to the reinforcement is achieved through different mechanisms [B-2]:

- **Adhesion** - it is achieved by the surface structure of the padding and the application of special coatings (e.g. bitumen coatings). As an analogy ribbed concrete steel is to be mentioned.
- **Bracing**- it is done through the arrangement of "slats". It determines the nature of the connection between longitudinal and transverse reinforcement, just as the design of the intersection determines the measure of the transferable force. As an analogy, welded cross bars should be mentioned in the case of steel grids.

The introduction of force by asphalt in the reinforcement can either be made through longitudinal (adhesive or additional bituminous adhesive layers) and/or through the transverse reinforcement by "tightening" of the aggregates in the lattice (aggregate interlock).

Other anchorages arise from the gauge length, defined as length of reinforcement outside the load entry region and bound by adhesive forces.

The fatigue resistance of a reinforced layer of asphalt is higher than that of an unreinforced [C-1, B-1J.

The effect of some grids in the asphalt has been demonstrated in practice through years of testing [B-2, C-2, L-1, V-1] and confirmed in laboratory experiments [B-1, E-2, J-1]. Work in theoretical approaches is underway to take account of the reinforcement effect in assessment models (see Chapter 4). The problem however is that, depending on the boundary conditions, such as temperature gradient or location of the padding in the system, the reinforcing effect is very different.

Three examples will illustrate this:

Example 1: Location of the reinforcement under the top layer of cracked asphalt surface

The reinforcement is not in the tension zone, although they're able to absorb tensile stresses. In this case these tensile stresses don't result from the tension variation due to traffic congestion, but from the opening of a crack or a gap in the base in cooling off.

The horizontal movement of the crack edges or fusion face takes place directly beneath the asphalt padding. Provided a good bond with the top layer, the movement of the base will be not or only partly transferred to the upper layer, because the asphalt padding only partially joins in the stretching movements due to its rigidity. As a result, a localized horizontal movement occurs in the bond connection, which uncouples horizontally the top layer from the substrate with a very narrow range: i.e. seperate. This horizontal movement, in conjunction with the absorption of tensile stress from the following crack edge movement prevented the pass-through of the crack in the asphalt layer and thus the occurring of reflection crack.

The reinforcement prevents the opening of the crack. This effect makes it possible that the crack surface not separate so far apart from each other, that there is no transmission at all (Gapping crack), but only so much that the crack surfaces come into contact again after a short vertical displacement and thus transverse forces can be transferred. Compared to an unreinforced system the reinforced system has therefore a better sustainability. Further degradation is slowed down, the use life increases despite an existing crack [B-2].

Example 2: Location of the reinforcement on torn base with multi-layer asphalt pavement

The reinforcement is located in the tension zone and assumes some of the existing traffic-determined tensile stresses. The tensile stress absorption of the reinforcement leads to a large dimensional distribution of traffic loads and thus relieves pressure on the binder in the asphalt. According to present knowledge this large-scale tension distribution doesn't determine the rigidity of the entire system but prevents or delays the formation of traffic-determined cracks.

Note: The traffic-determined deflection remains with or without reinforcement up to the forming of crack, but the widths of the cracks are limited by the reinforcement and thus the stiffness of the overall system remains at a higher level over a longer period.

Also a part of the tensile stresses resulting from the opening of a crack or a gap in the substrate during cooling is absorbed by the reinforcement.

Example 3: Location of the reinforcement on the underside of the asphalt base course

By this mainly in Scandinavian countries used form of reinforcement steel bars are normally used. The filler layer is disposed in the tension zone, i.e. on the underside of the asphalt base course and assumes some of the existing tensile stresses there. As evidenced by analysis and shown by finite element programs, compared to a non-reinforced building the elastic indentation on the top layer of the surface at a 22 cm thick, steel reinforced system of equal thickness reduces by approximately 16%. It was concluded by the elastic sinking to stiffness and demonstrated through calculations that the load capacity could be improved through the ordering the steel mesh on the underside of the asphalt base [N-1].

In light of the complexities the application of asphalt padding for reinforcement requires details of the boundary conditions and the functions, which goals are to be achieved.

5.4 Combined Effect

In the application of composite materials, such as grids of high tensile fiber or grids connected with nonwovens or embedded in binder layer, sealing (see Section 5.1), tension-degrading (see Section 5.2) and reinforcement effects (see Chapter 5.3) could overlap.

Depending on the position of the reinforcement, the condition of existing road mounting, thickness of the asphalt layers to be newly installed and interaction of building materials in the composite different effects combinations happen.

6. Nonwovens

Literature: [C-1, J-1, Section 4.3].

6.1 System Description

Nonwoven fabrics are to be laid on the binders previously transferred to the existing road surface, and then they are overbuilt with a surface treatment or an asphalt layer.

By spraying the surface, the subsequent rolling up or pavement of the non-woven and the superstructure the nonwoven fabric is impregnated with the binder.

6.2 Effects

Non-woven, impregnated with a binder, can simultaneously produce sealing and tension-depleting effect (see Chapter 5.1 and 5.2). The non-woven impregnated with binder creates a composite with uniform thickness, which is able to glue the layers [J-1, Section 4.3].

The viability of the existing road superstructure is not increased by non-woven fabrics, but may indirectly improve the frost resistance and load capacity of the road fastening by the sealing effect. A reinforcing effect is not achieved [F-1, Section 3.1].

6.3 Characteristics, test methods and guidelines for nonwovens

The standard values of Table 6.3 should be followed. The values are recommended and have achieved positive experiences in recent years.

Table 6.3: Characteristics, testing and benchmarks for nonwovens

No	Property	Testing Method	Unit	Guidelines
1	mass per unit area	DIN EN ISO 9864	g/m^2	≥140
2	thickness	DIN EN ISO 9863-1 and 2	mm	0.5 to 5
3	Tensile strength	EN ISO 10319	kN/m	≥9
4	Breaking Extention	DIN EN ISO 10319	%	55
5	Extrusion Behavior	DIN EN ISO 12236	kN	-
6	Dielectric Behavior	DIN EN 918	mm	-
7	Damage during construction	DIN EN ISO 10722-1	%	-
8	Bitumen absorption	prEN 15381:2005, Appendix C	g/m^2	1.1
9	Weather resistance	DIN EN 12224, Annex B1	%	≥60
10	alkali resistance	ISO / TR 12,960, DIN EN 14030	%	≥50
11	Melting point	EN ISO 3146	° C	≥160
12	layers composite	ALPA-StB, Part 4	kN	≥ 10
13	Environment harmlessness	M Geok E, 2005 Edition, Sections 3.1, 6.28 and 7.6		

Remarks:

1) The test is required by European standards, but there are no requirements.

2) The test is required by European standards. Currently, testing for various applications are developed, there are no requirements.

3) There are no requirements.

7. Grid

7.1 System Description

Grids are laid on the existing road surface and fixed in their position, enabling the superstructure. Some grids are embedded in a binder layer and then overbuilt with asphalt. Other grids are simply stuck on the tarmac or at the gate with an adhesive layer (e.g. molten bitumen) and immediately covered with asphalt.

7.2 Effect

Literature: [B-1].

Through the incorporation of tensile stresses a reinforcement effect can be achieved with grid (see Section 5.3).

The reinforcement effect of grids depends on the mechanical properties of the product and the condition of the product in the entire road fixing. A reinforcement effect only starts by friction-locked bond.

The asphalt fortified with grid forms a composite system, which is in a position to delay the pass-through of cracks from the surface to the overlying layers and keep the asphalt thickness effective longer than without reinforcement.

The viability of the existing road superstructure is not increased by grids; however due to the absorption of tensile stress of the asphalt padding the load generated by redevelopment will be held at a higher level over a longer period (e.g. delay of cracking). A sealing does not occur.

7.3 Properties, methods of testing and guidelines for grid

The standard values of Table 7.3 should be followed. The values are recommended and have achieved positive experiences in recent years.

Table 7.3: Characteristics, Testing Method and Guidelines for Grids

No	Property	Testing Method	Unit	Guidelines
1	mass per unit area	DIN EN ISO 9864	g / m²	≥200
2	Knitting width/grid opening width	TL Geok E-StB 05, Sec 2	mm	≥10
3	Tensile strength MD / CD	DIN EN ISO 10319	kN / m	≥20/20
4	Breaking Extension	DIN EN ISO 10319	%	≤15
5	damage during pavement	DIN EN ISO 10722-1	%	-
6	Layers bond/ Shearing behavior	ALPA-StB, Part 4	kN	≥ 10
7	Weather resistance	DIN EN 12224, Annex B1	%	≥60
8	alkali resistance	ISO / TR 12,960, DIN EN 14,030	%	≥50
9	Melting point	EN ISO 3146	°c	≥160
10	Environmental harmlessness	M Geok E, 2005 Edition, Sections 3.1, 6.28 and 7.6		

Remarks:

1) The test is called for in European standards. Currently, testing for various applications are developed, there are no requirements.
2) When applying melted asphalt separate proof is required.

8. Composites

8.1 Grid with Pavement assistance

8.1.1 System Description

Grid with pavement is applied on or in the binder brought in advance on the existing road fastening according to construction, or melted on the surface under heat. Subsequently, the redevelopment is done with asphalt.

8.1.2 Effect

Grid with pavement assistance has exclusive reinforcement effect. Binder (thin non-woven fabrics) or plastic sheeting melting under heat serves as pavement assistance.

The effects of the grid with pavement assistance correspond to Chapter 7.2.

The pavement assistance secures the position of the grid during installation and by the areal coverage of the sprayed surface the sticking of the laid product to the truck tires, wheels or tracks of the paver could be prevented. For grid that is not melted on the unsprayed base, the location fixation is secured by bonding with the substrate.

The viability of the existing road superstructure is not increased by grids with pavement assistance, however due to the absorption of tensile stress of the asphalt padding the load generated by redevelopment will be held at a higher level over a longer period (e.g. delay of cracking). A sealing does not occur.

8.1.3 Guidelines

The standard values of Table 8.3 should be followed.

8.2 Grid with Nonwoven

Literature: [B-1].

8.2.1 System Description

Grid with non-woven fabrics is applied in the binder that’s brought on the existing road in advance. Subsequently, the redevelopment is done with asphalt.

8.2.2 Effect

Grid with non-woven fabrics can combine the sealing, tension-relieving and reinforcing properties of grids and nonwoven fabrics (see Section 5.4).

The effect of the nonwoven soaked with binder would correspond to Chapters 5.1 and 5.2 just as grid to chapter 5.3.

A reinforcement effect only starts by friction-locked bond.

The viability of the existing road superstructure is not increased by grids with pavement assistance, however due to the absorption of tensile stress of the asphalt padding the load generated by redevelopment will be held at a higher level over a longer period (e.g. delay of cracking). Through the sealing effect the frost resistance and sustainability of road fastening can also be indirectly improved.

8.2.3 Properties, test methods and guidelines for composites

The values are recommended and have achieved positive experiences in recent years.

Table 8.3: Characteristics, Testing Method and Guidelines for Composites

No	Property	Testing Method	Unit	Guidelines
1	mass per unit area	DIN EN ISO 9864	g/m^2	≥200
2	thickness	DIN EN ISO 9863-1 and -2	mm	1 to 2
3	Knitting width/grid opening width	TL Geok E-StB 05, Sec 2	mm	≥10
4	Tensile strength MD / CD	DIN EN ISO 10319	kN / m	≥20/20
5	Breaking Extension	DIN EN ISO 10319	%	≥ 2 and ≤15
6	Extrusion Behavior	DIN EN ISO 12236	kN	
7	Dielectric Behavior	DIN EN 918	mm	
8	Damage during construction	DIN EN ISO 10722-1	%	
9	Bitumen absorption	prEN 15381:2005, Annex C	g/m^2	1,1
10	Weather resistance	DIN EN 12224, Annex B1	%	≥ 60
11	alkali resistance	ISO / TR 12,960, DIN EN 14,030	%	≥ 50
12	Melting point	EN ISO 3146	° C	≥160
13	layers composite/ Shearing behavior	ALPA-StB, Part 4	kN	≥ 10
14	Environment harmlessness	M Geok E, 2005 Edition, Sections 3.1, 6.28 and 7.6		

Remarks:

1) The test is required by European standards, but there are no requirements.

2) The test is required by European standards. Currently, testing for various applications are developed, there are no requirements.

3) There are no requirements.

9. Exploration

Since the non-woven fabrics, grids and composites are mainly used for structural maintenance of asphalt roads, the application requires a careful analysis of the damage and causes, which shall not be limited to a visual assessment of the damage pattern (visual status survey), but e.g. statements about layer thicknesses, asphalt composition and thickness of the frost-proofing superstructure by core sample drawing should be allowed (metrological status survey). The aim of state detection is to optimize the remedial design based on detailed knowledge of the causes of damage. These damage patterns are interpreted, causes recognized and e.g. different remediation areas are determined.

The procedure for the exploration is summarized in Appendix 2.

An essential component of state detection is the analysis and evaluation of cracks. Possibilities of cracks appearing in street fixtures are shown in Appendix 3.
Based on the findings from the state assessment, selection can be made of the physical measure for the rehabilitation. Then it must be considered, whether and to what extent asphalt padding can be introduced.

10. Selection of the Constructional Method

After evaluating the state detection of defective asphalt fastening there're usually several ways for remediation. From a technical point of view various construction method and procedures are available, which are mostly different in terms of economy.

Through an objective description of the costs and the sustainability of the rehabilitation the builder or/ and the planner could make an informed decision regarding the selection of appropriate structural measures. For financial as well as traffic-related reasons, this could well be the preferred methods for remediation, which has a shorter useful life compared to the basic term or renewal in the high and deep construction, but can carry the traffic quickly and without undue influence.

Through the application of asphalt padding it could be built directly onto the existing, damaged road surface in many cases.

In Appendix 4, the application possibility of asphalt padding depending on the type of damage and the structural measures are presented.

11. Mounting and Installation Instructions

11.1 General Principles / System Concept

Literature: [F-1, V-2].

The goal of using different systems is to create a constructive component that acts together, in which the positive qualities of the individual components are used, which shows an advantage for the use and life of the whole construction in the sum.

Information provided by the manufacturer must be observed in installation and its feasibility in the construction practice has to be examined.

- The installation of reinforcement and / or sealing padding in the asphalt pavement construction requires very great care and experience. The remainder of the old road, binders, asphalt padding, and redevelopment must be coordinated. The installation therefore should be carried out by specialist companies that are proved to be familiar with the systems and their combinations.

The binder quantity should be attuned, so that

- Asphalt padding can be navigated with construction vehicles without having the binder rising too strongly to the surface and sticking to the tires of construction vehicles, if necessary, the surface must be sprinkled with clean, dry, coarse aggregates,
- enough binder is available, so that the sticking to the superstructure is reached
- No binder surplus arises, which rises by installation of the asphalt mix.

The installation of asphalt padding should be carried out immediately after application of the binder.

In the superstructure of joints with vertical movement of the flanks the cause of the vertical movement should be eliminated (e.g. press down concrete slabs).
For the installation of non-woven fabrics, meshes and composite materials the base must be free of loose constituents, clean, dry and smooth. Depressions in some places in the form of potholes, gapping cracks, joints or the like must be filled in before the superstructure.

Great mismatch in roadway, for example transition from asphalt to concrete, must be removed (e.g. balancing with suitable asphalt or milling). In case of strong roughness the application of a leveling layer is necessary.

The full-surface contact of the asphalt padding with the base must be guaranteed. The binding agent should not significantly exceed the surface of the asphalt padding. Folding and distortion must be avoided.

If folding occurs in installation, they should be cut and glued on spot, and overlapped. Cuts should be made in curves to allow for proper overlap or collision without folding; alternatively the installation could be carried out in the form of polygon.

It is recommended to increase the amount of binding agent according to the given increased bitumen capacity in this area in case of impact of overlapping.

Intense shunting, acceleration and braking should be avoided on the asphalt padding during the construction, in order not to damage the installed area. The drivers of the mixture transport vehicle, road paver and the rolls should be advised on characteristics of the construction.

11.2 Superstructure with Asphalt

Asphalt padding can be overbuilt with all asphalt types and grades in accordance with ZTV Asphalt-StB. Information on temperature limits of the manufacturer must be observed. The asphalt paving is in accordance with the rules of technology. The following instructions must be observed:

- It has been proven right not to build one up to 20 cm wide strip of asphalt padding in the half-build of the first paver road at first, in order to form the longitudinal joint or the overlap. The longitudinal joint or the overlap is not under the longitudinal seam in the asphalt layer too.
- The asphalt padding should stop about 10 cm before the outer edges of the overlying asphalt layer.
- The overlying asphalt layer is usually at least 4 centimeters in thickness, so that a sufficient heat capacity for the melting of the binder is available. This is the prerequisite for adhesion of the asphalt liner with the superstructure. Currently there’s no insufficient experience for thinner asphalt assessment.
- In sealing the appropriate changes in shear sensitivity of the bitumen/ Asphalt padding location should be taken into account. The temperature of the surface on the compression and the device (roller weight) should be adapted.

11.3 Superstructure with surface treatments (OB)

Mechanically solidified nonwovens have proved for the superstructure with OB. The required amount of binder results from the binding capacity of the nonwoven fabric and the friction-locked bon with the base.

Both the surface treatment with simple sprinkle of delivery grits 5 / 8 and the double surface treatment with the delivery grits of 5 / 8 and 2 / 5 have proven themselves for redevelopment.

The installation of the OB is done in the usual manner by meeting the requirements of ZTV BEA-StB.

Currently there is no experience for the redevelopment of composites and grids with OB.

11.4 Binders

The nature and quantity of the binder must be based on the condition of the existing road fixing and to be coordinated with the asphalt padding and the nature of the superstructure.

Choosing the right binder type as spatter-dashing medium influences the effect of the asphalt padding significantly. The type and amount of spatter-dashing medium shall be designed in a way that for example no binder drains and no bumps are formed by a binder pools when using bitumen emulsions by the gradient of the road.

The binder must be dosed accurately and is in principle put about with a ramp sprayer mechanically. According to current experience, Polymer modified bitumen emulsions or polymer modified bitumen are used for the installation of non-woven fabrics, grids, and bond materials.

It is recommended to establish requirements similar to the "Technical Conditions for ready-made polymer modified binder for surface treatment with bituminous binders (TL PmOB). Provisionally polymer modified bitumen emulsion type CU 70 K has proven itself, but with a softening point in the ring and ball extracted binder from 41 to 46 ° C and a breaking point of maximum -15 ° C. The elastic recovery should be at least 20%. Quick-cracking bitumen emulsions are preferably used with a fracturing behavior of <130according to DIN 52047-1.

In special cases, heat processable polymer modified binders are used, by which 65 PmB A or PmB 40/100-65 H is suitable according to the "Technical Specifications for ready-made polymer modified bitumen" (TL PmB). It should be noted that because of the indirectly introduced adhesion effect for a binder to be hot processed the installation could be significantly more difficult than the use of a bitumen emulsion.

12. Aging Resistance

The currently used raw materials can be expected from the aging resistance under conditions of constructional appropriate use, which is sufficient for the appropriate use. For example, materials such as steel or corrosion-alkali-glass fibers could be effectively protected by coating, coatings or embedding in bituminous mortars.

Asphalt padding from non-alkali raw materials can not be built in direct contact with concrete. When used with limestone aggregates, the alkali resistance of these products must be detected.

The aging process of the products is determined by various factors, such as corrosion in steel mesh, embrittlement, oxygen accumulation (for example, with PP and PE), chemical aggression, hydrolysis for polyester in the presence of water, fatigue, therefore a generally applicable statement can not be made.
In individual cases, the information from the manufacturers, especially in the CE accompanying document should be noted.

13. Recycling

The process of dismantling and recycling of asphalt layers, which contain the non-woven fabrics, mesh or composites, should be described by the provider at tender submission under the respective technical standard so sufficient that, the results can feed into the required economy consideration. The provisions of the recycling and waste laws (KrW-/AbfG) should be taken into account.

In processes of dismantling and recycling the details of the product manufacturer should be observed. Some general guidelines are summarized as follows:

- The gaining of asphalt layer with as halt padding from non-woven fabrics, grids or composite materials can be done by milling.
- When milling it should be noted that the asphalt padding loop around the milling drum, and can hinder the milling process when a large area is milled in the plane of asphalt padding.
- In special cases, such as steel bars, the padding is separated from the reclaimed asphalt and disposed separately.
- Remnants of asphalt padding in the reclaimed asphalt should be as small as possible as and not greater than the maximum. It is necessary to examine to what extent these proportions affect the ability of future recycling in asphalt base layers have concerning asphalt mixture production (Temperature requirement) and asphalt mixture properties (compressibility).
- The possibilities of hot recycling of asphalt padding are to be checked with experimental mixture when in doubt.
- If the installation process and the corroboration are not disturbed, recycling in hydraulically bound layers is possible.
- In all cases of the recycling of asphalt granules with asphalt padding a targeted aptitude test must be created.

***Note**: The above restrictions on the recycling of asphalt granules must also be included in the view of economy.*

14. Environmental Sustainability

The producers of nonwovens, grids and composites should prove that their products are environmentally sustainable when used in asphalt layers - installation, service life, recovery and recycling.

The manufacturer shall provide evidence that the materials used during installation or after an eventual recovery, or by a possible landfill won’t contain environmentally hazardous substances or secrete.

A corresponding proof is to be produced tender submission but not later than the construction.

15. Open questions

Although the effect of asphalt padding in practice has been demonstrated in many cases, a verified theory to describe the relationships and mechanisms of effects is still missing.

This is also the reason for the lack of design procedures. With the existing, mostly on elastic behavior of layer model based method, the influence of thin films can not be satisfactorily modeled. Approaches with finite element programs have produced promising results, but it still lacks procedures for measurement models used today. As long as the exact effects of asphalt padding in tension and stretching distribution within a system is still unknown, no basic dimensioning of fatigue functions could be established for the bond system.

Currently it also lacks meaningful examination and testing procedures, which allow a direct comparison of different asphalt padding. One approach to this is performance-related-tests, such as dynamic crack bridging experiment that is still under development.

Appendix

Appendix 1: References

Appendix 2: Exploration

Appendix 3: Types of cracks

Appendix 4: Constructional method with the application of asphalt padding

Appendix 5: Technical Rules and Regulations

Appendix 1
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Appendix 2
Exploration

1. Generals

Reason: In Chapter 4 of RStO 01 the state detection and assessment apply for the renewal of road high installation in conjunction with the BEA ZTV-StB. With the application of asphalt padding other objectives are pursued, therefore, a separate schedule is established for the state detection and assessment.

Objective: Optimization of remediation measures for approaches in repair based on detailed knowledge of the causes of damage (damage patterns, identify the causes, determine different redevelopment areas), for actions in the renewal and expansion of the roadways.

The exploration is divided into several steps. First it is a visual state detection. After evaluating the results, areas that require further investigation by metrological state detection are identified.

The exploration should be carried out by experienced professionals and laboratories. It is recommended only to authorize verifiers that are demonstrably related to exploration and familiar with the interpretation of the results.

2. Characteristics and properties of the layers in road pavement

To describe the state certain characteristics and properties of the layers of pavement are used.

Superstructure:

Asphalt: skid resistance, flatness, composite layers, layer thickness, external appearance, maximum grain size, grain size distribution, binder content, binder properties, degree of compaction, (Cause of deformations such as rutting and / or wave formation), possibly containing tar / pitch

Concrete: grip, flatness, thickness, if necessary bond between layers, external appearance, openness, compressive strength, hollow site, joint condition, joint movements (horizontally, vertically)

Strain hardening: thickness, external appearance, compressive strength Layers Without

binder: layer thickness, particle distribution (type of aggregates: crushing, round grain, recycling material), external appearance, frost resistance, density, permeability, (water), using the ZTV SoB-StB

Foundation：

Strain hardening: thickness, external appearance, compressive strength，crack image

Layers Without Binder: layer thickness, particle distribution (type of aggregates: crushing and round grain, recycling material), external appearance, frost resistance, density, permeability, (water-proof), deformation module EV_2 or EV_{dyn} taking ZTV SoB-StB as a basis.

Underground: designation of soil and determine the thickness of individual layers, insofar as they affect the structural performance of the road fixing; determine the particle size distribution, blowdown-able shares; determine the frost sensitivity class in accordance with ZTV E-StB, deformation module Ev_2 or EV_{dyn}

3. Visual status detection

The visual state detection is the first classification and definition of future action.

4. Metrological state detection;

4.1 Measurement of the surface geometry

Measurement of transverse and longitudinal profile, e.g. Rutting or shear waves, longitudinal and horizontal inclination of the banquets, for example, by leveling or with the 4-m-slat *

Surface deformation, subsidence and sacking in the restructuring plan could, happen, for example based on the drainage and the mass flow: Influence on transverse and longitudinal gradients, necessary thickness of layers for profile compensation

4.2 Determination of the structure and viability of the layers without binders

Trenching, core drilling, core drilling, penetration test, determination of the density of construction test, determination of the deformation module, e.g. static and / or dynamic plate load test, impulse radar.

4.3 Determine the viability of road construction on road surface

Measurement of the depression of bonded layers with Benkelman beam or drop weight device (Fading Weight Deflectometer, FWD), measurements with the impulse hammer, use of (fast-) running measuring systems.

4.4 detection of cracks and crack edge movement

In the bound layers, there are many different types of cracks (see **Appendix 3**), which differ in cause and effect on the serviceability of the road. This has impact on the selection of remedial measures (see **Appendix 4**).

Detection of cracks:

- Visually: type, width, length, depth, history, crack width (e.g. in m2), location in the roadway, single cracks, cracks network, parallel repeated cracks, a crack system to recognize (E.g. edge parallel cracks, regularly recurring cracks over joints in the building, etc.)
- Simple measurement of width und length with tape measure or crack width gauge
- By measuring the depth with gauge (rarely possible), e.g. by secure cores, concrete by ultrasound or impact technical procedure.
- Measurement of vertically crack edge movement by Benkelman beam, FWD or measuring pedestal with electrical position encoder.
- Measurement of crack edge movement Horizontal: stress-measuring extensometer to gauge length, electronic distance sensor for long-term measurements and measurement of the movement under load
- Impact on sustainability: Benkelman beam or FWD as compared to non-cracked cut.

---

1. With impulse radar determination of the thickness and the continuous expansion of the layers in the longitudinal and transverse directions, as well as the anomalies in road fixing - on the basis of the results of the impulse radar places are identified, where conventional explanations are made to calibrate the impulse radar measure result. This allows a line-oriented continuous statement about the nature, characteristics and thicknesses of the materials available.

Appendix 3
Types of cracks

Preliminary

The following compilation is to facilitate the assignment of crack forming into certain causes of loss in the course of state detection. The compilation does not claim its completeness. It is recommended to explore the concrete conditions on site according to the method described in **Appendix 2**.

As for the possibilities of application of asphalt padding in connection with the damage forming, the relevant section of the working paper and the table in **Appendix 4** are to be referred to.

In this context, it is pointed out again that exploration, interpretation of test results and the development of rescue proposals by applying asphalt padding should only by done with experienced professionals and laboratories, who are familiar with the peculiarities of the construction with asphalt padding.

1. Cracks with horizontal movements

Cracks, mainly caused by horizontal stresses or movements due to temperature changes occur in the following forms:

A: Cracks in the longitudinal and transverse directions in asphalt binder with too little content, too hard or after-cured binder on sustainable and deformation perpetual surface (**Fig. 1**).

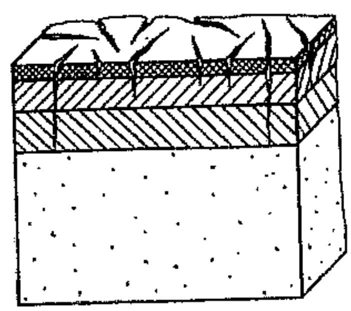

Figure 1: Cracks in the longitudinal and transverse directions in asphalt pavements

B: Dielectric end cracks (reflection cracks):

- Over cracked hydraulically bound base layers or soil reinforcement with hydraulically binders with too high strength (**Fig. 2**), over cracked or brittle asphalt binder, Asphalt base course.

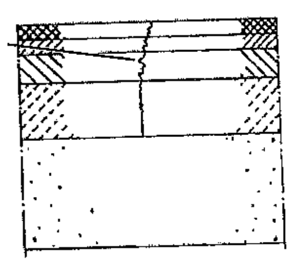

Figure 2: Reflection on cracked base layers with hydraulic binders

- Over blunt pounded seams in asphalt binder and asphalt base course,

- The replacement of stepwise milling by asphalt layers or through excavation outside (**Fig. 3**).

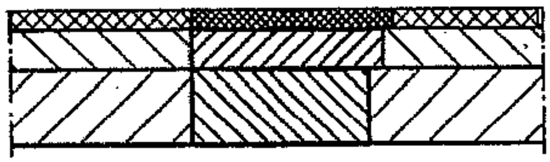

Figure 3: Reflection cracking over offsets by stepwise milling

- through joints in concrete floors or in built-up base layers with hydraulic binders.

C: Opening of longitudinal and transverse joints and seams of work.

2. Cracks with vertical movements

Cracks, the edge of which to move vertically or horizontally and vertically appear in the following forms:

D: “Bottoming Out” of joints and cracks in concrete pavement layers (" fluttering "of the concrete slabs) and load layer with hydraulic binders in the asphalt built-up layers.

E: Single cracks and fissures in the surface layers of reticular asphalt fastening, the capacity of which is significantly reduced (e.g. by a binder in the asphalt binder layer delamination, embrittlement of the binder, large deflections due to low traffic-carrying capacity of the subsoil).

3. Cracks in horizontal and vertical movement

Cracks in horizontal and vertical movement occur in the following forms:

F: reticulate cracks in a thin asphalt surface over an inadequate total frost building.

G: Crack accumulation in the rolling track of the asphalt pavement by insufficient sustainability of the underlying layers without binders and / or due to high traffic loads.

H: cracks in fragile ground.

4. Structurally induced cracks

Structurally related cracks, which are usually produced simultaneously by both horizontal movement as well as vertical motions, occur in the following forms:

I: longitudinal cracks due to road widening.

The cracks caused by:

- Changes in the constructional structure (e.g., external edge of an old rough-stone pitching,
- Jump in the thickness of the frost superstructure,
- Jump in the stiffness / load between the old consolidated government structure and the widening or through
- The cultivation of an additional lane on a new embankment fill.

J: longitudinal cracks in superstructure of concrete edge strips, tram lines and excavation of all kinds

Appendix 4

Road condition and structural measures with asphalt padding

Table 1: material defects, evenness defects and cracks

No	road condition Status Description	Status Image	Conclusion (Appendix 2)	Causes	Construction method/according to according to ZTV BEA-StB	possibilities of using asphalt padding	Purpose/Goals
1.1	Substance Defects Thinning Grain outbreaks Loss of substance Porosity	-rough or porous surface -Outbreaks of coarse aggregates	-Mortar loss or loss of chippings by inspection -Prolonged moist state after rain -The study of development samples or counter samples	-Materials Properties -Mixture compounding -Installation Error -Scaling -Mechanical –influences -Large void content	-surface treatment -partially where appropriate, -Bituminous or sludge pore-filling bulk according to TL Sbil	-Surface treatment(OB) with non-woven fabric, when sealing is to be achieved -Bituminous sludge on non-woven fabric, if sealing is to be achieved	-the sealing of existing street fixtures -Extension of the duration of use of OB and sludge
1.2	Lack of evenness, deformations	-change in horizontal or longitudinal profile , mainly in sub-base or underground, z. B. in the range of backfills, embankments, broadening	-Insufficient water flow -Profile measurement -Evenness control -Investigation of development samples -Investigation of counter samples -Include the profile shifts -Investigation of layers without binders -Identifying the soundness of the substructure	-Lower assessment of the grain structure -Surface and underground Influences -Influences coming from layers without binders or carrying layers with hydraulic binders -Influences of asphalt layer -Drainage deficiency -Material Fatigue	-Rutting Compensation - Profile compensation -Renewal (high installation, deep installation or combination of both)	-Installation of one or more asphalt layer on composite substances or grid on existing road fastening -Steel reinforcement in or under the asphalt base course	-equalizing the set tongues -Reduction of outlet
1.3	Single cracks	-individual fine to gaping holes in one or more layers of bonded superstructure	-visually recognizable -mark by moisture -Load carry investigation -Crack edge movement horizontal / vertical	-cracks / joints in underlay -Mechanical and thermal overload -Overloading the periphery -Movement of the substrate -Inadequate drainage -Frost heave -Lack of bond between layers -Building material properties	-Filling in or molding with cold or hot processable joints, possibly after cutting or milling see the HSR	-Surface treatment with non-woven fabric - Also in part to destruction of the crack after -Stripwise milling and paving of asphalt on nonwoven fabric, composite material or grid	-Longer service life than pure filling-in or molding with joint compound -Improving the skid resistance

Continuation of Table 1: material defects, evenness defects and cracks

No	road condition Status Description	Status Image	Conclusion (Appendix 2)	Causes	Construction method/according to according to ZTV BEA-StB	possibilities of using asphalt padding	Purpose/Goals
1.4	cracks without bearing capacity deficiencies	-accumulation of unidirectional cracks -Net-like crack image with deformation	-visually recognizable -Marking by moisture -Maximum load calculation -Investigation of the layers without binders, as well as the substructure or substrate -Investigate installation sample and/or counter samples	-Materials Properties -Mixture configuration -Installation Error -Lack of layer bond -asphalt layer that's too thin -Embrittlement	**Maintenance:** -Surface treatment -sludge **Renewal:** -High construction, deep construction and replacement of the upper layers of asphalt layer	-Non-woven fabric and application of sludge -Partial surface treatment with non-woven fabric -Asphalt layers on non-woven fabric, laminated fabric or grid	-delay of the penetration of cracks -With fabric and composites sealing of the substrate -Extension of the use life
1.5	cracks with bearing capacity deficiencies	-accumulation of unidirectional cracks -Net-like crack image with deformation(waves, depressions, ruts)	-visually recognizable -Marking by moisture -Maximum load calculation -Investigation of the layers without binders, as well as the substructure or substrate -Investigate installation sample and/or counter samples -Evenness in horizontal and vertical profile	-Materials Properties -Mixture configuration -Installation Error -Lack of layer bond -asphalt layer that's too thin -Overload due to traffic -Inadequate capacity of lower layers -Frost sensitiveness of lower layers -Fatigue, brittleness	**Maintenance:** -Surface treatment **Renewal:** -High construction, deep construction and replacement of the upper layers of asphalt layer	-Surface treatment with nonwoven fabric (also partially) for sealing as a temporary measure to delay the damage progress -Asphalt layers to increase the sustainability of non-woven fabric, laminated fabric or lattice	

Table 2: superstructure of damaged concrete and asphalt pavements

No.	road condition Status Description	Status Image	Conclusion(Appendix 2)	Construction method/according to according to ZTV BEA-StB	possibilities of using asphalt padding	Purpose/Goals
2	Renewal needed road fastening from concrete / asphalt	-seams, joints, cracks (e.g. notches in HGT) - Other surfaces damage	-Bearing capacity investigation -Crack width and depth -crack edge movement horizontal/vertical	-superstructure with asphalt layer	-superstructure with asphalt layer/s on partially on seam / joint / crack laid non-woven fabric, laminated fabric or lattice -Superstructure with asphalt layer / s the entire surface of nonwoven fabric, laminated fabric or grid	-Depavement or preventing the crack forming due to the penetration of seams, joints, cracks

Table 3: Road widening

No.	Measures	Status	Conclusion(Appendix 2)	Construction method/Procedure	possibilities of using asphalt padding	Purpose/Goals
3	Road broadening	-Free edge of an asphalt or concrete road	-Appearance and sustainability of the adjoining base -Maximum load determination on the existing roadway	-construction of multilevel of asphalt pavements	-Laminated fabric or lattice in the transition area	-Delay or prevent the crack forming due to the different compression behavior between existing and new construction

Appendix 5

Technical regulations

DIN [1)]	DIN 52047-1	Bitumen and bituminous binders - Part 1: Determination of the crushing behavior of emulsions - Cationic Bitumen Emulsion
	DIN EN 918	Geo-textile and geo-textile-related products - Dynamic penetration test (cone test)
	DIN EN 12224	Geo-textile and geo-textile-related products –determination of resistance to acids and alkaline liquids
	DIN EN 14030	Geo-textile and geo-textile-related products -choosing method for determine the resistance against acid and alkaline liquid
	DIN EN ISO 9863-1	Geosynthetics - Determining the thickness under specified pressure-Part 1: individual layers
	DIN EN ISO 9863-2	Geotextiles and geotextile related products - Determination of thickness under specified pressures - Part 2: Procedures for determining the thickness of individual layers of multilayer products
	DIN EN ISO 9864	Geosynthetics - Test method for determining the space-oriented mass of geotextiles and geotextile related products
	DIN EN ISO 10318	Geosynthetics - Geotextiles, geotextile products, geomembranes and geosynthetic clay liners- terms and their definitions
	DIN EN ISO 10319	Geotextiles; wide strip tensile test
	DIN EN ISO 10722-1	Geosynthetics - Procedure for simulating damage occurring during installation - Part 1: Installation in granular materials
	DIN EN ISO 12236	Geotextiles and geotextile-related products, stamp pushing-through test (CBR test)
	prEN 15381 2005	Geotextiles and geotextile-related products -properties that are required for the construction of road surfaces from asphalt
	ISO / TR 12,960	Test method for determination of resistance to liquids
FGSV[2)]	ZTV Asphalt-StB	Additional technical specifications and guidelines for the construction of asphalt pavements (FGSV 799)
	ZTV BEA-StB	Additional technical specifications and guidelines for the maintenance of traffic Construction - asphalt construction (FGSV 798)
	ZTV e-StB	Additional technical specifications and guidelines for earthmoving in road construction (FGSV 599)
	ZTV SoB-StB	Additional technical specifications and guidelines for the construction of layers without binders (FGSV 698)
	TL Geok E-StB	Technical delivery conditions for geosynthetics in earthworks of the road (FGSV 549)

FGSV[2)]	TL PmB TL PmOB	Technical delivery conditions for ready-polymer modified bitumen (FGSV 748) Technical delivery conditions for ready ¬ polymer modified binders for surface treatments (with bitu-sion binders) (FGSV 753)
	TL Sbit	Technical delivery conditions for regeneration and bitumen-based pore-filling bulk (FGSV 785)
	RStO	guidelines for the standardization of the superstructure of traffic area (FGSV 499)
	ALP A-StB, Part 4	Work Manual for testing asphalt, Part 4: Examination of the composite layers by people (FGSV 787 / 4)
	M E Geok	fact sheet on the application of geosynthetics in earthworks of the road (FGSV 535)
	HSR	Information for the closing and rehabilitation of cracks and defective joints and connections in the traffic areas of asphalt (FGSV 777)

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