HANDBOOK

ROAD STANDARDS FOR THE DESIGN OF THIN PAVEMENTS WITH SYNTHETIC BINDER

PLANNING AND CONSTRUCTION

NOVEMBER 2004

VEJREGLER

PREFACE

Background

In 2002, the Road Standards Secretariat decided to revise the current sections on for synthetic-bound surfacing in the tender and construction instructions for bridge surfacing on concrete bridges along with the associated design regulations contained in this book, as well as the section on thin pavements with synthetic binder in "Road standards for inspection of bitumen based waterproofing and bridge surfacing".

The audit headed by working group AG U.32 Waterproofing and bridge surfacing, which set up an ad hoc group to carry out the audit.

Terms of reference

1. Working group U.32 must register any need for audit of Tendering Regulations for Concrete Bridges section:
   - 10. Waterproofing
   - 11. Bridge surfacing.

2. Working Group U.32 must also register any need for audit in the following road standards:
   - "Design of bitumen-based waterproofing and bridge surfacing"
   - "Design of joints with soft sealant"
   - "Design of thin pavements with synthetic binder".

3. The working group must make proposals for the prioritisation of needs and prepare a basis for the Road Standard Secretariat's recommendation to the Road Standards Committee on how needs should be taken into account and to what extent the audit should be conducted in an ad hoc group. The working group must manage and coordinate any work of ad hoc groups. The working group must prepare a status and an action plan each year.

4. The working group is responsible for undertaking the following interface activities:
   a) Working group U.32 is responsible for reviewing their own documents in respect of interface in relevant working groups and subsequently to incorporate any review comments
   b) Working group U.32 must also carry out a review in respect of interface itself and provide comments to other working groups via roads standards administration in areas where AG U.32's work is assessed to impact on road standards maintained by other working groups.

5. In the context of the needs identification and preparation working group U.32 must:
   - take any new Danish and European acts, regulations and technical specifications, developments and new knowledge within working group U.32's area, which have an effect on the structure and maintenance of bridges into account
   - assess the environmental, safety, traffic flow and economic consequences of new and amended rules – Danish as well as European – within working group U.32's area.

6. In connection with the preparation of European technical specifications in CEN and EOTA, the working group must subject to on request assist the Danish negotiating missions.

7. Working group U.32 must subject to request assist in the consideration of interpretation issues within working group U.32's area.

8. The working group must, subject to agreement with the Road Standard Secretariat, ensure knowledge-sharing of the group's work by publishing articles in the specialist press and by taking part in meetings and seminars.

Composition:

1. Chairman: Vibeke Wegan, Danish Road Directorate
2. Secretary: H. Vagn Jensen, RAMBOLL
3. Members: Erik Stoltzner, Danish Road Directorate
   Otto Bach Ulstrup, BaneDanmark
   J. Blumensen, COWI
   Mikael Thau, LOTCON
   Pallet Bisballe, LMK-VEJ
   Mogens Bøhm, MB Projekt
   Erik Olesen, Tarco Vej
   K. Stovgård, Phønix Trelleborg A/S

The following expertise should be represented (possibly ad hoc):

- Sealants (cold/hot applied) - production and laying
- Thin pavements with synthetic binder - production and laying.

The current audit is conducted in an ad hoc group consisting of the following members:

Chairman: Jeanne Rosenberg, Tårnby Local Authority
Secretary: J. Blumensen, COWI
Members: Erik Stoltzner, Danish Road Directorate
Jørn Raaberg, Danish Road Directorate
Otto Bach Ulstrup, BaneDanmark
H. Vagn Jensen, RAMBOLL
Mogens Bøhm, MB Projekt
Erik Olesen, Tarco Vej
Niels Vangsted, Ulfcar

Approval

After being considered by working group, the ad hoc group's proposals were submitted by working group U.32 as a proposal for road standards for:

- Design of thin pavements with synthetic binder to the working group
- Tender and construction regulations for bridge surfacing – sections 11.7-11.8.

The Road Standards Committee considered the proposal on 17 November 2004 and approved the revised proposal for publication.

Road standards

Road standard for waterproofing and bridge surfacing includes:

- Road standard for the design of bitumen-based waterproofing and bridge surfacing
- Road standard for the design of thin pavements with synthetic binder
- Road standard for inspection of bitumen-based waterproofing and bridge surfacing.

Tender and construction specifications

The above road standards are subject to the following tender and construction specifications, General work specification (GWS):

- GWS for waterproofing (section 10)
- GWS for bridge surfacing (section 11)

- Sections 10 and 11 in paradigm for special work description for concrete bridges
- Sections 10 and 11 in paradigm for tender checking plans for concrete bridges
- Sections 10 and 11 in paradigm for tender and calculation basis for concrete bridges.

Information
Concrete bridge decks should be protected against degradation of both concrete and reinforcement by appropriate waterproofing and surfacing systems. Such a need has been proven by the extensive damage been observed in Denmark and in other European countries as well as in the USA on bridges with no or inadequate insulation.

At the beginning of the 1970s, conventional waterproofing of bridge decks in Denmark was made using bitumen sheets with protective concrete and covered with asphalt surfacing. On structures such as retaining walls and abutments, "bituminous thick coatings for waterproofing" was used on the side facing the ground. These waterproofing systems were described in the Danish Society of University Engineers' "Guideline on waterproofing concrete bridges".

In the period 1975-1980, GWS and design guidelines were prepared as part of the road standards for the design and planning of the following three waterproofing types:

- Bitumen sheets with protective concrete, termed type I
- Bitumen sheets with protective membrane, termed type II
- Mastic insulation, termed type III.

Waterproofing type I has since mainly been used for track-bearing bridges with ballast and bridges (tunnels) with soil cover or overpassing road substructure.

Waterproofing type II was type used the most in the late 1970s and 80s. It has been shown to be functional and durable.

Waterproofing type III has not been used since the late 1970s, when it led to a number of performance problems in terms of the establishment of a completely waterproof membrane. Type III was therefore discontinued in 1984.

At the beginning of the 1980s, adhesion problems were encountered in connection with the use of the traditional primer - Insulation: no. 0 - for bitumen sheets. This initiated a development project financed by the Danish Road Directorate, DSB and DTB, resulting in the development of a range of synthetic primers.

In parallel with this, waterproofing membranes with a coating mass of polymer-modified bitumen was developed.

Finally, good Danish experience with thin pavements with synthetic binder of acrylic and similar was recorded.

Following the audit, the road standards cover the following waterproofing:

Waterproofing type I to be used alone in the future for track-bearing bridges with overpassing ballast and soil-covered bridges or bridges with overpassing road substructure.

Waterproofing type II to be used on bridges exposed to heavy traffic, located in important areas of the road network, but the prescribed oxide bitumen sheets are no longer produced.

Waterproofing types IV a, IV b and IV c containing polymer-modified products are used differently depending on the traffic load on the bridges and their importance for traffic; type IV a can be used on the same bridges type II, while types IV b and IV c can be used on bridges of less importance or with less traffic load.

As an alternative to waterproofing types IV b and IV c, **thin pavements with synthetic binder** with binders of acrylic, epoxy and polyurethane polymers or combinations of these can also be used.

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1 PURPOSE

The design standards for thin pavements with synthetic binder provide a basis for designing and describing thin pavements with synthetic binder while taking into account:

- Prevailing influences (mechanical, thermal, physical-chemical)
- Properties of adjoining materials
- Common commercial products.

The design standards also provide a basis for understanding section 11.8, thin pavements with synthetic binder, in GWS for bridge surfacing and test methods for thin pavements with synthetic binder project and enabling designers to prepare Special Work Specifications.

2 TECHNICAL SCOPE

2.1 General information

This design standard is prepared for cycle track, road and track-bearing concrete bridge and tunnel decks without ballast. If the bridge should have a ballast, the top side of the thin pavements with synthetic binder should be mechanically protected using a synthetic geogrid in accordance with the client's s instructions. However, the rules can also be applied for other structures, such as parking decks etc., when the specific conditions of the area are taken into account.

With the appropriate modifications, the standards can also be used for thin pavements with synthetic binder on steel decks, e.g. decks on bascule bridges.

Until more experience is available, this surfacing type should be used on bridges with traffic volumes of typically 10,000 AADT or less. The surfacing structure must be designed in relation to traffic volume according to the guidelines/scope set out in GWS 11, section 11.8.1.

Advantages and disadvantages of thin pavements with synthetic binder compared with bituminous surfacing is summarised in the following table:

Advantages	Disadvantages:
Significantly less own weight	Shorter life
Small layer thickness/lower structural height	Less resistance to mechanical damage and intensive traffic
Simple flashing by curved/vertical/multiple surfaces	Greater requirements for base evenness
Easy in terms of gear required - no material space requirements	Limited possibility for levelling surfacing
No rutting/slipping	Highly climate sensitive
Easy to monitor for any damage	Health and safety measures during construction
Easy to repair/make joints	
Quick to make	
Cheaper in terms of construction costs	Test methods and acceptance criteria for crack bridging ability have yet to be defined

On an existing structure, the insignificant own weight can be used as bearing capacity reserve when replacing the conventional bridge surfacing with thin pavements with synthetic binder. The limited thickness may also be used for the repair of bridges, where improvement of the pavement crossfall is desired without increasing the edge beam height.

The key advantage is that the limited material consumption entails both substantial price and a time benefits compared to conventional bridge surfacing and that construction is flexible in terms of space as well as number, location and course of joints. However, the base must be very even so that any comfort requirements can be observed. Much stricter requirements are also in place for the climatic conditions during construction than for conventional bridge surfacing.

Past experience has shown that thin pavements with synthetic binder laid under optimum conditions and subsequently properly maintained have had an average lifespan of approx. 15 years. It is expected that the audit of this road standard and the corresponding tender regulation will lead to an increase in quality which will also result in a longer average lifespan.

At the time of the current audit, it has not been possible to introduce new test methods and acceptance criteria for the crack bridging ability of thin pavements with synthetic binder, meaning that the basis for the description still rely on experience with the properties of known structures and previously used test methods.

2.2 Terminology

This terminology overview serves as a complement to the road standard, Dictionary of Technical Road and Traffic terms.

Blinding material	Spreading of a blinding material to create better bonding of the newly applied binder course to subsequent surfacing.
BTU	The Committee for type approval of materials for waterproofing of concrete bridges.
Frictional material	Gravel aggregates used for covering/blinding wearing courses to ensure friction.
Interim approval	Provisional approval of system for waterproofing and surfacing on a concrete bridge, such approval being either limited in time or place (to a specific project), and where no type-approved system exists.
Synthetic materials	Multi-component materials which after mixing of the individual components via a chemical process – often without separating reaction products – harden to form a homogeneous material. The components are most commonly referred to as the binding and hardening components.
Thin pavements with synthetic binder	Thin surfacing on cycle tracks or road areas consisting of 2-3 layers. The binder in the surfacing usually consists of a synthetic material of epoxy, acrylic or polyurethane or combinations of these. Aggregate and frictional material in the surfacing consists of mineral-based gravel aggregates.

Thixotropic	Designation of specific flow properties for two-component materials. Thixotropy occurs by adding energy, e.g. by shaking or stirring the material, and reduces the viscosity of the material. This property is reversible, i.e., it will disappear over time.
Aggregate	Common term for sand and stones in thin pavements with synthetic binder, where the individual fractions may be naturally occurring, artificially produced or recycled.
Type-approval	Procedure for approval of waterproofing products and waterproofing structures. BaneDanmark and the Danish Road Directorate have initiated a scheme for "Type approval of materials for waterproofing of concrete bridges". The scheme is administered by a group appointed by BaneDanmark and the Danish Road Directorate, and the group refers to these agencies.

3 FUNCTIONAL REQUIREMENTS

3.1 General information

The background for establishing functional requirements is to avoid imposing one specific material on the contractor, for which specific requirements could otherwise be stipulated.

This is particularly relevant for thin pavements with synthetic binder involving many different chemical combinations in the various products.

In theory, thin pavements with synthetic binder can be tendered based on the functional requirements alone, but to ensure the quality of the work carried out, and thus avoid major warranty claims, where only replacement costs are covered by the contractor, while all traffic nuisances and costs must be carried by the road users, such requirements, particularly any execution requirements (see chapters 7 and 8), which must be applied even if they do not fully ensure that the functional requirements are observed, will normally be made.

Approval of specific thin pavements with synthetic binder is normally based on a type approval scheme, where the supplier can have a full system tested by an independent testing institute, usually the Danish Road Institute. The test results must be submitted to BTU (Committee for type approval of materials for waterproofing concrete constructions), which issues type approvals.

The type-approval scheme comprises thin pavements with synthetic binder with the prescribed structure, but non-prescribed structures may also under certain conditions be approved, provided that the observance of the functional requirements can be documented.

If type-approved products are not available, then approval of the surfacing can alternatively be required in accordance with interim conditions. Reference is made to the provisions set out for the type approval of products listed in GWS Concrete bridges, section 10, Waterproofing, item 10.1.1, as well as the guideline in SAB-P, item 11.8.1.1.

3.2 The background for the functional requirements

The functional requirements are set out in section 10 of "GWS for bridge surfacing", and, in the following, further details are provided on the background for the requirements.

Thin pavements with synthetic binder combine surfacing and waterproofing, and the functional requirements deal with both surfacing and waterproofing aspects.

With regard to the background for the functional requirements set out in for GWS, Concrete bridges, the following applies:

The three first functional requirements are **watertightness, mechanical stability and strength as well as resistance to cracking or layered separation**:

- Watertightness under all conditions. This also applies to all edges, endings and flashings, etc. throughout the surfacing area
- Mechanical stability and strength to withstand traffic impacts in the form of pressure and shearing forces, also in curves and during braking and acceleration
- Resistance to cracking or layered separation – including blistering – between all parts of the entire surfacing, including between the concrete and the primer. The requirements apply with regard to the traffic impacts and movements in the base and also in respect of the highest moisture content that can occur in the concrete.

Applies to all types of waterproofing and surfacing and therefore does not specifically relate to the fact that the surfacing and waterproofing materials in this case comprise thin pavements with synthetic binder.

In the last requirement it is specifically required that there is no separation between the thin pavements with synthetic binder and the concrete or, in other words that the surfacing must bond to the base. This is a key requirement, because otherwise rapid peeling of the thin pavements with synthetic binder will occur.

The fourth functional requirement for **preservation of watertightness and strength properties**:

- Preservation of watertightness and strength properties for an extended number of years under normal impacts from traffic, weather, slippiness chemicals, alkalis, waste oils and other degrading factors.

The requirement is also not specifically related to thin pavements with synthetic binder, but is nevertheless a key requirement for this type of surfacing and waterproofing, where a crack in the surfacing can easily affect the concrete and cause leakage.

The fifth requirement is **compatibility**:

- Compatibility between the individual constituent materials and the materials with which the surfacing is in contact.

This is not particularly related to thin pavements with synthetic binder.

The sixth functional requirement is that the **thin pavements with synthetic binder must not contain chemically unbound constituents**.

- Thin pavements with synthetic binder must not contain chemically unbound constituents which can migrate. The material must be free of solvents and bulking agents, which do not have a positive impact on the product properties.

This specifically relates to thin pavements with synthetic binder since any unbound constituents or solvents that have not evaporated before the next course is laid out may cause blistering in or soften subsequent courses.

The seventh functional requirement is that **thin pavements with synthetic binder must be able to be repaired**:
- Synthetic coatings must be able to be repaired. Subsequent courses must be permanently bonded to the preceding courses.

This specifically relates to thin pavements with synthetic binder, since one of the "strengths" is that spot repairs can easily be carried out. Similar requirements are usually made for surface dressing with paint.

4 DIVISION BY TYPE

Thin pavements with synthetic binder are divided into:
- Thin pavements with synthetic binder with prescribed structure:
  - 3-layer structures (primer, membrane and wearing course) based purely on binder
  - 3-layer structures (primer, membrane and wearing course), where the wearing course is based on a mortar mix of synthetic material and aggregate
- Thin pavements with synthetic binder without prescribed structure. Under this category, an infinite number of variants are available, of which the most frequently used are:
  - 2-layer structures (membrane and wearing course) based purely on binder
  - 2-layer structures (primer and combined membrane and wearing course), where coating mass is based on mortar mix of synthetic material and aggregate.

The above-mentioned types all have frictional materials on the top side. The main differences between the above mentioned thin pavements with synthetic binder are partly the use of mortar mixes and partly the omission of primer. The use of mortar mixes requires careful attention to the crack bridging ability of the materials – especially for 2-layer structures, since this surfacing type does not contain an actual impermeable layer (membrane layer). Surfacing types without a primer require careful attention to the quality of the base.

The above types of thin pavements with synthetic binder are based on binders such as:
- epoxy
- acrylic
- polyurethane (PU)
- other synthetic materials or combinations of the above such as polyurethane-modified epoxy types etc.

The main differences between systems based on the three common types of binder are characterised in the table below. It should be emphasised that the table is simplified, and that binders exist which combine good properties for two different binder types, e.g. systems based on a binder of epoxy-modified polyurethane.

Characteristics of the various systems for thin pavements with synthetic binder

Binder attribute / **property**	**acrylic**	**epoxy**	**polyurethane (PU)**
Surfacing materials before and during hardening			
Hardening Time	+	+++	+++
Sensitive to low temp.	+	+++	+++
Sensitive to high temp.	+++	++	++
Sensitive to moisture	++	+++	+++
Dangerous in connection with contact	+++	+++	+++
Dangerous if inhaled	+++	+	+
Surfacing materials after hardening			
Minimum interval between repainting	+	++	++
Maximum interval before repainting	-	+	+
Roughen for repair	-	++	++

- None/not applicable
+ Small or short
++ To some extent, some
+++ To a large extent, longer

The following sections 5-9 set out more detailed information on the properties of the different binding agents.

Earlier (between around 1970-1999) thin pavements with synthetic binder with an epoxy tar binder were laid in one/two layers on a number of bridge facilities, but for health and safety reasons, this surfacing type is now no longer used.

5 REQUIREMENTS FOR CONCRETE BASE

The properties of the concrete base are of great importance for water-proofing and surfacing. For thin pavements with synthetic binder, the requirements for the base are mainly the same as for bitumen sheet insulation and reference is therefore made to "Road standard for the design of bitumen-based waterproofing and bridge surfacing", Chapter 2, "Requirements for concrete surfaces".

In addition, special requirements must be imposed in terms of evenness, texture, strength and moisture content, for concrete surfaces which will later be covered by thin pavements with synthetic binder.

If the concrete surface does not fulfil the evenness requirement, then small depressions and unevenness (up to 1.5 mm) must be levelled at a very early stage in connection the laying of thin pavements with synthetic binder. Uneven areas larger than this must be levelled by repairing the base with materials that are compatible with adjoining materials in the thin pavement with synthetic binder.

The evenness requirement can be difficult to observe, because only a small number of levelling actions can be made (see section 8.5) by means of increasing the layer thickness in the actual surfacing, and the evenness requirement in respect of the concrete surface must therefore be the same as the requirement for evenness of the final surfacing, see Chapter 6. Necessary levelling of the base should be carried out in accordance with the guidelines set out in section 8.5.

The evenness requirement is put in relation to driving speed. Concrete surfaces for long bridges (L > approx. 20 m) outside urban areas with higher permissible speeds will therefore be very difficult to realise with-out the use of special equipment for even regulation of the top of the concrete deck. It should be noted that the friction requirement increases, see GWS, item 11.8.1.2, when the permitted speed is > 80 km/h.

That is why thin pavements with synthetic binder should normally not be prescribed for long concrete bridges outside urban areas, and where they are used in exceptional cases, GWS section 8, Concrete, will normally require more specialised and expensive regulation.

The tender documents usually prescribe that the surfacing contractor must inspect the finished concrete surface, before any waterproofing and surfacing.

With regard to thin pavements with synthetic binder, the surfacing con-tractor must, in connection with this inspection, be careful that the even-ness requirements are observed, see chapter 6.

In addition to the above-mentioned evenness requirement, the normal requirements for the dimensional tolerances of the concrete surface must be observed, see section 8 of the "GWS for Concrete Bridges", and it is particularly important that depressions do not occur at all and that geometrics ensure effective water drainage.

The concrete surface texture (as measured by the sand patch test method) is vital to thin pavements with synthetic binder. A coarse texture with many protruding pebble grains will result in the surfacing/membrane locally not attaining the appropriate layer thickness with the ensuing risk of later moisture penetration and erosion of the surfacing.

Normally, the texture depth must not be greater than 1.5 mm, and surfacing suppliers must be able to take account of this when submitting their tenders.

For repair work where the texture depth cannot be determined in advance, special rules should be prepared for additional use of synthetic material where the texture is coarser.

Conversely, concrete surfaces should not be too smooth as it will prevent proper adhesion. The requirement stated in "GWS for Concrete bridges", section 8, concerning shot-blasting or high-pressure blasting of surfaces which are to be insulated with bitumen sheets must therefore also be made in respect of surfaces that are to receive a thin pavement with synthetic binder, and which must then be stated in the concrete description.

Accordingly, the texture depth must not be less than 0.5 mm.

Requirements for concrete base strength are not usually a problem for new bridges during construction. However, in the case of repair work, a minimum tensile strength is often required. 2.0 MPa for new concrete and 1.5 MPa for old concrete structures are often required. If the tensile strength of concrete is lower than 1.2 MPa, the concrete will normally be cut or milled. The values must be obtained by carrying out a peel test on Ø 75 mm or Ø 50 mm cores; see DS/EN 1542. For bridges intended for vehicles, it is essential that the specified concrete strength is achieved before traffic is allowed on them.

Concrete moisture content is crucial for the bonding of the thin pavement with synthetic binder to the concrete.

Concrete minimum age in connection with construction is based on the supplier's instructions, as required in the tender documents.

6 REQUIREMENTS FOR THE FINISHED COATING SURFACE

The tender documents normally details requirements relating to friction, evenness, profile and appearance of the top side of the surfacing.

6.1 Friction

The mean friction coefficient for a new surfacing (within the defects liability period) must be ≥ 0.40 measured at 60 km/h on clean, wet surfacing using ROAR.

This requirement can normally always be observed with thin pavements with synthetic binder where relatively sharp grains, which are resistant to polishing are scattered in the upper course, such as calcinated bauxite grain, see GWS 11.8.2.3, which sets out requirements for increasing the polished stone value depending on traffic intensity.

If measurements using ROAR are not practicable – due to either the length of the structure or speed restrictions – substitute measurements can be performed by combining texture measurements and pendulum testing. However, the basis for the acceptance criteria as listed in SWS-P are based on limited experience.

6.2 Evenness

The GWS for bridge surfacing sets out requirements for the evenness of thin pavements with synthetic binder in connection with straightedge measurements. The acceptance criteria entail a minor tightening in relation to GWS for hot mix asphalt for a wearing course with a desired speed of ≤ 80 km/h, but are metrologically much more operational.

The SWS-P sets out proposals for a tightening if the desired speed is greater than 80 km/h.

Technically it can be difficult to produce a concrete surface, which complies correctly with the above-mentioned evenness requirement over a longer distance, and since any major levelling of the actual surfacing is not allowed, the evenness of the concrete surface will be crucial to the evenness of the surfacing. Therefore the requirements of the road standard may be relaxed. Despite these relaxed requirements, however, a need for mechanical concrete surface regulation should be expected for long sections, e.g. by using a slip-form paver.

In the case of short bridges (L < 20 m) and bridges in urban areas with a lower speed, greater levels of roughness than those stated above may be accepted.

6.3 Cross section

The surfacing cross section will normally be in order if the requirements for crossfall deviation of the top side of the concrete surface comply with the tolerances specified in GWS concrete bridges, section 8.3.1.

6.4 Appearance

The surfacing must have a uniform appearance. Spreading of frictional material on top of the surfacing must take place in a manner and at a time so that the optimum immersion of the frictional material takes place at the same time as a uniform appearance is ensured. Areas with poor graining, which can cause stones to break loose, and other aspects associated with poor appearance must not occur.

Sometimes, the special work description (SWS) requires that the contractor to sets up a test field outside the bridge. Once this has been approved by supervision, the field can be used as a reference field.

7 STRUCTURE AND MATERIALS

7.1 General information

Thin pavements with synthetic binder with the prescribed structure consist of the following layers:

- Primer
- Membrane
- Wearing course, chips.
- Any sealing.

The thickness of the wearing course as well as the grain size and polishing resistance of the frictional material must be specified by the supplier within the limits set out in the type approval document, corresponding to the expected traffic load expressed as AADT in the relevant operating period.

It should be noted that the layer thicknesses stated in GWS are measured as clean binder for primer and membrane. The layer thickness for wearing courses is measured to include aggregate and frictional material. As a rule, the wearing course thickness can rarely be laid out thinner than about twice the maximum grain size. Blinding using quartz is used for footbridges and bridges with little traffic load, typically in fractions of 0.5 - 1.2 mm, while more durable grains of calcinated bauxite, etc. are used for bridges with a higher traffic load in fractions typically between 1.5 and 2.5 mm.

The primer must create a strong bond between concrete base and the membrane. It must be thin enough to seep into the concrete pores. The surface finish must allow adequate adhesion of the membrane. Too little (or no) primer may cause bonding failure between the membrane and the base.

The membrane is the actual impermeable layer. It must be elastic enough to absorb movements of any small cracks in the base without being damaged. The strength must be sufficient to transfer the forces from traffic to the concrete.

The wearing course must be very strong because it is exposed to direct forces from the traffic. The wearing course should be somewhat less elastic than the membrane, but it must be able to withstand impacts from traffic and the base without cracking. It must be able to provide good bonding to the membrane and be able to keep the chips in place

The wearing course can sometimes also be effected with a mortar mix of synthetic bonding agent and aggregates, usually quartz sand. However, mortar wearing courses are often less flexible than wearing courses based purely on a bonding agent of the same type which is chocked with chips.

Friction chips must ensure a proper friction and protect the wearing course against excessive wear. They must be strong and resistant to polishing. Stone size must be adapted to wearing course thickness and traffic level. Usually, 0.5/1 mm, 1/3 mm or 3/5 mm crushed chips are used, which must be clean-separated and oven-dried, see GWS. The greater the traffic density, the greater the stone polishing resistance is required. To ensure that frictional material is retained, the surface can be sealed. Sealing is done after any excess frictional material has been removed.

Chips used for blinding is available in many different materials and qualities with variations in wearing resistance and appearance, and in addition to different coloured natural products, dyed products are also available. In connection with dyed products, it should be ensured that the quality may be different – in terms of durability of colour and hue.

Thin pavements with synthetic binder can also be used for pedestrian area and cycle tracks. The thickness of primer and membrane is the same as that used for carriageway areas, but the wearing course can be made a bit thinner.

7.2 Acrylic surfacing

The binder consists of polymerised acrylic acid and/or acrylic esters. The vast majority are normally methyl methacrylate. A syrupy mass is used for surfacing, which consists of a mixture of polymer dissolved in monomer, which helps achieve a viscosity suitable for laying. The mass also contains a catalyst, usually in the form of a tertiary amine, as well as a very small quantity of paraffin wax, which after laying rises to the surface and prevents the oxygen in the air form accessing the material, which would otherwise prevent proper hardening.

Immediately before use an initiator (hardener) is added to start a polymerisation of the monomer. The initiator is usually a peroxide, usually benzoyl peroxide. The polymerisation process develops heat (up to 70°C), so as to accelerate the process further and complete the hardening process in a short time, i.e. about one hour under favourable conditions. Indicative characteristics such as the processing time and ability to withstand traffic are specified in section 8.1.

Acrylic surfacing are laid in two layers on a primer:

- A highly elastic membrane to ensure surface tightness. The membrane must therefore have the greatest possible elongation at rupture, which is provided by excluding any addition of aggregate
- An elastic wearing course (possibly with added aggregate in the form of quartz sand) to protect the membrane and provide the friction required by traffic. The wearing course is covered with frictional material according to the type approval. This material can be quartz, calcinated bauxite or similar.

Through a suitable choice of starting materials and controlling the polymerisation processes in the desired way, an acrylic binder with the desired hardness from hard and brittle to soft and rubbery material can be made.

For acrylic surfacing, a relatively soft and elastic material is used as the lower layer and a somewhat harder and stronger material for the wearing course.

The acrylic-based wearing course binds chemically to the membrane. The membrane therefore does not need to be covered with chips/roughened if work must be interrupted for a period of time due to weather. The same effect may to a certain extent be used for a top layer on top of new or maintenance of old, cleaned acrylic-based wearing courses.

7.3 Epoxy coatings

The binder is a 2-component material. The one component is made up of partially polymerized epoxy resin (binder), the other of hardener, plasticizer and possibly other additives.

The hardener is normally an amine, but may also be an alcohol or other hydroxyl compound.

Epoxy surfacing is laid in two layers on a primer:

- A highly elastic membrane to ensure surface tightness. The membrane must therefore have the greatest possible elongation at rupture, which is provided by excluding any addition of aggregate
- An elastic wearing course (possibly with added aggregate in the form of quartz sand) to protect the membrane and provide the necessary friction for traffic. The wearing course is covered with frictional material according to the type approval. This material can be quartz, calcinated bauxite or similar.

The plasticizer is added to improve the crack bridging ability, which generally does not react with the epoxy resin. For thin pavements with synthetic binder, it can also be beneficial to use an "integrated" plasticizer, since it is possible to combine hardeners with polyurethane, which following reaction with epoxy resin produces a material, which is significantly more elastic than an epoxy-based binder without plasticizer.

Mixing a binder and hardener produces a number of reactions, which result in growth of and anchoring between the molecules, which in turn creates a strong material, where the hardness and elasticity depends on the starting materials and hardening conditions.

Indicative properties such as the processing time and ability to withstand traffic etc. are specified in section 8.1

Epoxy surfacing is laid in two layers, a relatively elastic "membrane", into which a small amount of uniform-sized grain may be added after some hardening, so that the sand fastens to the epoxy resin material without sinking to the bottom. The membrane does not contain any aggregate.

The wearing course must be laid on the membrane, as soon as the membrane can be accessed. In this way it is possible to obtain a modest chemical bond between the two layers. If the wearing course not laid until the next day or later than specified in the type approval document, measures must be taken to ensure the bond between the layers, e.g. by means of blinding.

7.4 Polyurethane surfacing

The binder is a 2-component material. The one component consists of partial polymerisates and naphtha (crude oils), the second of a hardener, usually an isocyanate.

Mixing of binder and hardener produces a number of reactions, which result in growth of and anchoring between the molecules, which in turn creates a strong material, the hardness and elasticity of which depends on the starting materials.

For polyurethane surfacing, a relatively soft and elastic material such is used for the membrane and a flexible, somewhat harder and stronger material is sued for the wearing course.

The polyurethane coatings are laid in two layers on a primer
- A highly elastic membrane to ensure the surfacing tightness and which must therefore have the greatest possible elongation at rupture
- A sand-saturated, elastic wearing course to protect the membrane and provide the required friction for traffic. The wearing course is covered with frictional material according to the type approval. This material can be quartz, calcinated bauxite or similar.

The wearing course must be laid on the membrane, as soon as the membrane can be accessed. In this way it is possible to obtain a modest chemical bond between the two layers. If the wearing course is not laid until later than specified in the type approval document, measures must be taken to ensure the bond between the layers, e.g. by means of blinding.

Indicative properties such as the processing time and ability to withstand traffic etc. are specified in section 8.1.

8 EXECUTION

8.1 General

During the laying of thin pavements with synthetic binder, many factors impact on the final result:
- Correct temperature
- Correct moisture conditions
- Correct mixture ratio and mixing time
- Observance of processing time
- Observance of reapplication intervals.

It is important that the above conditions have been checked and found to be in order.

Application of thin pavements with synthetic binder should not begin until reliable weather forecasts have been obtained that render it probable that the material will be sufficiently hardened before they are exposed to harmful climatic impacts, such as moisture/rain, high/low temperatures or dust from winds. If there is no prospect of favourable weather conditions, work must be postponed or measures to protect against the weather must be taken.

Factors such as moisture, temperature and time factors may lead to surfacing being laid under a tent and at a controlled temperature. In this case, it should be specified in the design documentation.

The supplier's instructions, as set out in the type approval document, must be carefully observed under all circumstances.

Indicative properties characterising the most common types of binder in thin pavements with synthetic binder are listed in the following table.

Binder / Characteristic	Acrylic	Epoxy	Polyurethane
Processing Time	10-15 min	15-25 min	15-45 min
Min. reapplication interval	1 hour	8 hours	6 hours
Max. reapplication interval	-	16 hours	48 hours
Moisture sensitivity after laying	1 hour	5-8 hours	10-20 hours
Can withstand traffic	2-3 hours	1-4 days	1-4 days
Fully hardened	2-3 hours	7 days	7 days

Data provided in the table indicate typical times for binders at 15 to 20°C and without the addition of an accelerator or other additives which are not used in the "normal situation". At other temperatures, the properties change; see the product data sheet.

It is possible to reduce the specified waiting times, if an accelerator is added, but it may have a negative impact on quality.

During project preparation, the designer should be aware of special circumstances that apply in the following situations: Possibility of covering, requirements for commissioning or environmental restrictions, which must be incorporated into the project. Such conditions may have an impact on whether all types of binder can be accepted for the project in question. For example, any requirements for quick hardening – either because covering is not possible or because quick commissioning is desired – can mean that acrylic-based surfacing is prescribed for some projects.

8.2 Temperature conditions

In order to ensure proper and quick hardening of the various surfacing layers, the surface temperature should preferably be 15 - 20°C and must under no circumstances be below 5°C. These temperature conditions must be provided immediately before laying. If there is a prospect of conditions with lower temperatures, the surfacing should not be laid.

Epoxy and polyurethane-based binders can take several days to harden at low temperatures and should therefore only be used for surface temperatures between 10°C and 30°C, unless specific measures are taken such as covering/heating. Acrylic-based binders with appropriate hardener additives will, in most cases, have formed a bond in the course of an hour, even at low temperatures.

Low temperatures may lead to slow/interrupted hardening and thereby damage as a result of moisture or dust on unhardened binders. Corrective action usually consists of relaying or repairing according to the manufacturer's instructions.

On the other hand, the surface temperature should not be too high (not more than 30°C). Synthetic surfacing should not be laid in conditions with direct, strong solar heat. Work site should in such cases be carried out in the shade.

High temperatures can cause unintended fast hardening and thus lack adhesion/durability. The damage is seen in the form of discolouration or blistering. Corrective action usually consists of relaying.

For all synthetic surfacing types, priming and membrane laying on concrete surfaces should not be performed if the surface temperature in-creases rapidly. The reason for this is that sun and heat can cause evaporation of moisture from pores in the concrete base which can cause blistering in the unhardened primer or membrane. Reference is made to the Danish Road Institute's internal memo no. 3 "Blistering in membranes for bridge insulation" for a detailed description of the phenomenon as well as measures to cope with such damage. The key measures are covering (establishment of shade) or performance of the work at odd hours.

In connection with blistering, proper temperature conditions should be awaited before the damage may be remedied by repeating the priming.

8.3 Moisture conditions

The thin pavements with synthetic binder are moisture sensitive during the first stages of hardening. They must therefore be protected against rain, dewfall or fog during this period, i.e. in practice until the material seems hardened to the touch, but hardening time varies greatly depending on binder type and ambient temperature.

If there is a risk of rain, it is important to know how quickly the materials will be able to withstand the first moisture impact, and it must be ensured that the treated areas can be covered quickly.

The following indicative times can be set for when the most frequently used binder types for thin pavements with synthetic binder can be exposed to moisture without deteriorating the material properties:
For acrylic, the time is one hour, for epoxy it is 5-8 hours and for polyurethane it is 10-20 hours.

The supplier's instructions, as set out in the type approval document, must be carefully observed under all circumstances.

The surface temperature of the base must be 3°C or more above the air dew point temperature when thin pavements with synthetic binder are laid and its hardening. If this is not observed, condensation may occur on the surface and thus cause moisture on unhardened binders.

Moisture on surfacing during laying often leads to one or more of the following characteristics:
- Uneven appearance/discolouration
- Inability to adhere to the base or subsequent layer
- Uneven hardening
- Blistering or foam formation
- Deterioration of the material

Corrective action usually consists of relaying of damaged areas.

8.4 Preparing the surface

In order to ensure proper adhesion of the primer to the concrete base, the base must be completely clean of soil, cement sludge, oil and grease stains, and free of any loose or weak parts. Gentle shot blasting and subsequent vacuuming are one of the most effective means of cleaning.

Such shot blasting will normally be prescribed for the concrete work. If not, it should be included in the surfacing contract.

Cleaning criteria should be clearly defined in the tender documents for the purpose of negotiations between surfacing and concrete contractors in connection with the previously mentioned inspection.

Contaminated areas should always be remedied, since contaminants entail a significant risk to adhesion failure. Remedying may consist in relaying or chemical/mechanical cleaning.

It is also vital for the lifespan of the thin pavements with synthetic binder that the concrete moisture content is appropriately low, when laying is performed. This means that it is crucial to determine the concrete moisture content before the laying of synthetic membranes. Two different measurements must be made:

1. a measurement of the concrete moisture content in the drilled core and
2. a measurement of concrete moisture content at the surface.

Re 1
The moisture content of the concrete core at depth must be determined, since too high a moisture content can impact the long-term adhesion of the membrane to the concrete surface. Moisture content is measured in a pressure cabinet from the drilled core and should normally not exceed a capillary water saturation level of 90% RH or an absolute moisture content of 5,0% of the core weight.

Re 2
Concrete moisture on surface must also be determined, since a moisture content which is too high can impact the hardening and adhesion ability of the primer. Moisture content can be determined by using e.g. resistance measurement on the surface or gas measurement on a sample taken from the concrete surface.

It is important that both measurements comply with the requirements. In cases where the core moisture level is equal to or below the limit, and surface moisture is above the limit - usually as a consequence of heavy rain on the concrete surface - this can often be resolved by rapid warming of the surface. Conversely, measurements carried out after strong solar heating typically result in an acceptable surface moisture measurement, whereas core moisture levels are not affected directly by the heat of the sun.

For measurements, where moisture content values are above the acceptance criterion, the work must be suspended, or the manufacturer must be consulted, before work continues.

8.5 Levelling

If the actual requirements for the concrete surface in chapter 5 with regard to evenness and depressions are not met, then levelling can be performed.

Such levelling can be performed in several ways, the most important of which include:

Extensive and deep levelling (5- 20 mm) is usually performed by casting a layer of cement-based special mortar (with proper adhesion properties and little waste).

Minor local areas (≤ 1 m²) can be levelled using synthetic mortar. This should be limited as much as possible to minimise the risk of adhesion failure between concrete and levelling materials and any ensuing scaling.

It is important to be aware that the synthetic mortar in question does not have an expansion coefficient that is too large, and that it can absorb the dynamic movements of the bridge deck. Synthetic mortar should thus be flexible enough to absorb the differences in movement between the mortar and the concrete.

In case of a thinner graduation of texture depth of 1.5-5 mm, this should be done using a liquid mortar of synthetic material with bulking agent. This is known as scrape levelling. The primer for the bridge surfacing is normally used as binder. Blinding material may need to be used to ensure adhesion to the next layer.

Widespread thin levelling of layers (including depressions) of 0.5-5 mm is commonly carried out using a durable mortar that also has the primer as its base.

The limited levelling permitted by the thin pavements with synthetic binder must be taken into consideration (max. 1.5 mm).

Unevenness exceeding 1.5 mm, levelling exceeding 1 m 2 and levelling of cross fall and longitudinal section must be made in the base, as indicated above as well as in accordance with the additional guidelines detailed in the "Road standard for the design of bitumen-based waterproofing and bridge surfacing", Chapter 2, "Requirements for concrete surfaces".

Thin pavements with synthetic binder should adhere to levelled areas, and the contractor should therefore guarantee that the prescribed levelling will not impact quality. In connection with type approval, it should also be specified to which other materials the thin pavements with synthetic binder adhere.

8.6 Transport and storage of materials

All materials must be transported and stored in accordance with authority regulations. The same applies to transport and, possibly destruction of empty packaging.

Moreover, the materials must be transported and stored in accordance with the supplier's instructions, so that the materials are not damaged due to cold, heat, leaking packaging, etc. If such instructions are not available, they must be furnished by the supervision. Conditions should normally be printed on the packaging. Manufacturing date and use-by before date should appear on the packaging. Reference must also be made to the description of packaging, transport and storage in GWS, item 11.8.4.

The material must be stored so that any current fire and environmental requirements are observed.

It should be ensured that the materials are used before the use-by date stated on the packaging.

If materials are stored under conditions which are contrary to the manufacturer's instructions, the supplier is to be notified of this circumstance. Additional identification tests may need to be carried out.

8.7 Mixture of materials

During mixture, the following three conditions, amongst others, must be ensured:
1. Stirring of settled materials
2. Proper mixing ratio
3. Complete mixing of the various components.

Re 1
The constituent parts must be stirred with a slow-moving agitator before they are mixed together. Too quick stirring will stir air into the material which will usually result in a more void-filled surfacing and negative changes in material characteristics.

Accidental sedimentation or crystallisation must be treated in accordance with the supplier's instructions.

Re 2
The proper mix ratio is normally ensured by adjusting the liquid components so that a container containing one of the materials must be mixed with a container containing the other material to achieve the proper mixing ratio. If this is not the case, the contractor must specify in what way he ensures that the mixing ratio observed. If the quantity of hardener is temperature-dependent, it can be measured by means of a measuring cup or by weighing.

Re 3
Mixing should normally be carried using a machine with a special mixing unit. If, in exceptional cases, mixing is carried out manually, it must be carried out in a different container than the one that has contained the materials and by using slow moving agitators so as not to mix air into the material.

During mixing, the products should be decanted often to ensure a homogeneous material.

The mixture should only be made under the temperature conditions specified in section 8.2.

Where materials are to be laid on steep slopes or vertical surfaces, thixotropic agents should be added according to the supplier's instructions.

More material than will be laid out should not be mixed too long before the processing time expires. All products generate reaction heat to a greater or lesser extent, which means that batch sizes should be limited for safety reasons.

Material that is not fully homogenised during stirring or mixed in the wrong ratio will remain non-homogeneous and will not harden properly and should normally always be discarded.

8.8 Laying

Primer
For all thin pavements with synthetic binder, the low-viscosity primer must be applied suing cross-rolling ("paint rollers").

The primer can also be applied with a brush or with a combination of a rubber scraper and a brush.

Polyurethane surfaces may be rolled with a spiked roller to minimise the amount of trapped air.

It is important to ensure the surface is saturated; however, the primer must not be laid too thick.

Most primers are based on epoxy and are therefore often blinded.

Membrane
The membrane is applied normally using a toothed trowel. In this context, care should be exercised in relation to the trowel slope and any wear on it. Quantity control should therefore always be performed by comparing the used quantity of synthetic material with the area on which it has been laid.

The membrane can also be applied by using a brush or a paint roller.

The material viscosity must be properly adjusted, so that the material does not flow out, but it must still remain self-levelling. On very sloping and vertical surfaces, a thixotropic agent may need to be added.

If blinding material is to be applied to ensure adhesion between the layers, the timing of the application of the grain is very important (if the layer has become too hard, then the grains will not become bonded, and if the layer is not sufficiently hard, the grains will sink to the bottom). Where appropriate, a small test area must be established next to laying area, so that grain application can be checked regularly.

The type approval document specifies to what extent blinding should be performed on both primer and membrane.

Wearing course
The wearing course is usually a toothed trowel or other suitable tool.

The material viscosity must be properly adjusted, so that the material does not flow out, but it must still remain self-levelling. On very sloping and vertical surfaces, a thixotropic agent may need to be added.

Frictional material
Application of frictional material on top of the wearing course is usually done manually ("thrown in the air"). It is important that a suitable quantity of stone is added at the right time, so that the frictional material is properly "immersed" and appears to be evenly distributed on the surface.

Control of laying
Immediately before and during work, a number of control measures must be launched in addition to the actual material testing. Reference is generally made to GWS and the specific provisions that may be specified in the type approval document and related annexes concerning the specific details of these control measures. This can be summarised as follows:

Registration of external conditions:
Air temperature, base temperature, the material temperature and humidity are measured at intervals as specified in GWS.

The results must be recorded in a control logbook.

Measurement and calculation of required values:
In connection with execution of the work, a number of measurements must be carried out with a view to documenting that the requirements are met.

The concrete surface roughness is measured to provide a supplement to the layer thickness, so that the layer thickness requirement is observed across the grain heads.

The concrete base moisture content, core moisture as well as surface moisture is determined as specified in the type approval document.

Wet film thickness is measured with a comb measurement device or a depth gauge, which can be read visually.

The reapplication interval is determined on the basis of registration of the external conditions - primarily the temperature – and the type approval document.

The levels of adhesion of thin pavements with synthetic binder can be measured using the method specified in GWS (peel test).

Material quality
Material samples are produced which can be used for reference in cases where doubt can arise as to the satisfactory condition of the material. It is therefore important that the samples harden under the same external conditions as the laid thin pavement with synthetic binder.

The quantity should always be checked where the quantity of synthetic material used is compared with the area on which it has been used.

8.9 Hardening

Re-application intervals
When laying individual layers of surfacing, the minimum and maximum re-application intervals provided by the supplier must be observed, i.e. when the next layer can be applied at the earliest, and also the maximum time that can pass before the next layer *must* be applied.

These intervals can be very different for acrylic, epoxy and polyurethane coatings and dependent on e.g. temperature.

The following indicative time intervals for thin pavements with synthetic binder can be used:
- For acrylic surfacing, the re-application interval is no earlier than one hour, while there is no fixed time limit for the maximum time for re-application
- For epoxy surfacing, the re-application interval is not earlier than eight hours and not later than 16 hours - longer, however, if blinding material is used
- For polyurethane surfacing, the re-application interval is not earlier than six hours and not later than 48 hours – longer, however, if blinding material has been used.

Traffic
Thin pavements with synthetic binder can be exposed to traffic when the surfacing is sufficiently hardened.

The following indicative time intervals can be set for when thin pavements with synthetic binder can be exposed to traffic based on the most frequently used binder types:
- Acrylic surfacing can usually be opened to traffic after 2-3 hours
- Epoxy and polyurethane surfacing can be opened to traffic after 1-4 days after completion.

In all cases, it must be considered as an advantage, if more time can pass before the road is opened to traffic.

The supplier's instructions must be observed in all circumstances.

8.10 Environmental conditions

Attention is drawn to the fact that all products used for thin pavements with synthetic binder will mean that all project partners: Client, consultant and contractor each, in each of the various phases of a project, must be aware of their obligations in accordance with regulatory requirements.

The material components contain substances that can be harmful to the skin. Volatile substances in the materials may pose health hazard if inhaled.

The designer must clearly specify in the tender documents that hazardous substances are used.

The specific project must provide a description of the relevant regulatory requirements with respect to the Safety and Health Plan, how they are observed and who is responsible for and obliged to ensure compliance with regulatory requirements.

The tender documents must usually specify that the contractor is charged with obtaining the necessary authorisation of the Danish Working Environment Authority and other authorities regarding the planned working methods and products. In this connection, it should be pointed out that in the past the authorities have issued a general prohibition against the application of synthetic-bound materials by spraying unless it is done on industrial plants.

The contractor must ensure that requirements for the training of operators and staff, as well as waste management, are observed.

After working hours, the contractor must ensure that the materials are inaccessible to unauthorized persons – this applies to both material storages as well as laid unhardened materials – through marking and barriers.

9 EDGES AND OTHER DETAILS

Edges etc. can normally be performed quite easily.

In the case of edge beams, where the surfacing ends on a vertical surface, it is an advantage to take the surfacing into a recess to improve adhesion see figures 9.1 and 9.2. It should be ensured that the minimum layer thickness of the membrane is achieved – including on vertical surfaces – since any waste in thin layers may cause loss of adhesion. However, the wearing course can be made thinner or possibly be omitted provided that membrane layer is UV resistant. Where possible, the surfacing must be taken to a horizontal surface in the most appropriate manner, ensuring gradients away from the edge.

In case the surfacing ends by edge beams, where the thin pavement with synthetic binder is usually taken a little way up the inside of the edge beam, it should be ensured that moisture does not penetrate through the concrete behind the thin pavement. This can often be prevented by sealing the surface – using only the membrane layer – of the upper part of the edge beam, by taking this sealing down by the inside of the edge beam and over the thin pavement with synthetic binder – this requires that the membrane is resistant to UV radiation. See an example of such flashing in figure 9.3. Plinths for equipment are also covered according to the same principles, see figure 9.4.

At bridge ends, the surfacing ended by taking it towards an edge on an embedded section, which creates a transition to the surfacing outside the bridge. If there is nothing to hold it back, then the surfacing will break off. If there are greater expansions than one bitumen joint can handle, an asphaltic plug joint or a mechanical joint construction must be established. Figures 9.5, 9.6, 9.7, and 9.8 show solutions with coverage of both mechanical and asphaltic plug joints as well as joint openings.

Coverage of this type must be provided along any kerbstones to prevent water ingress between the stones.

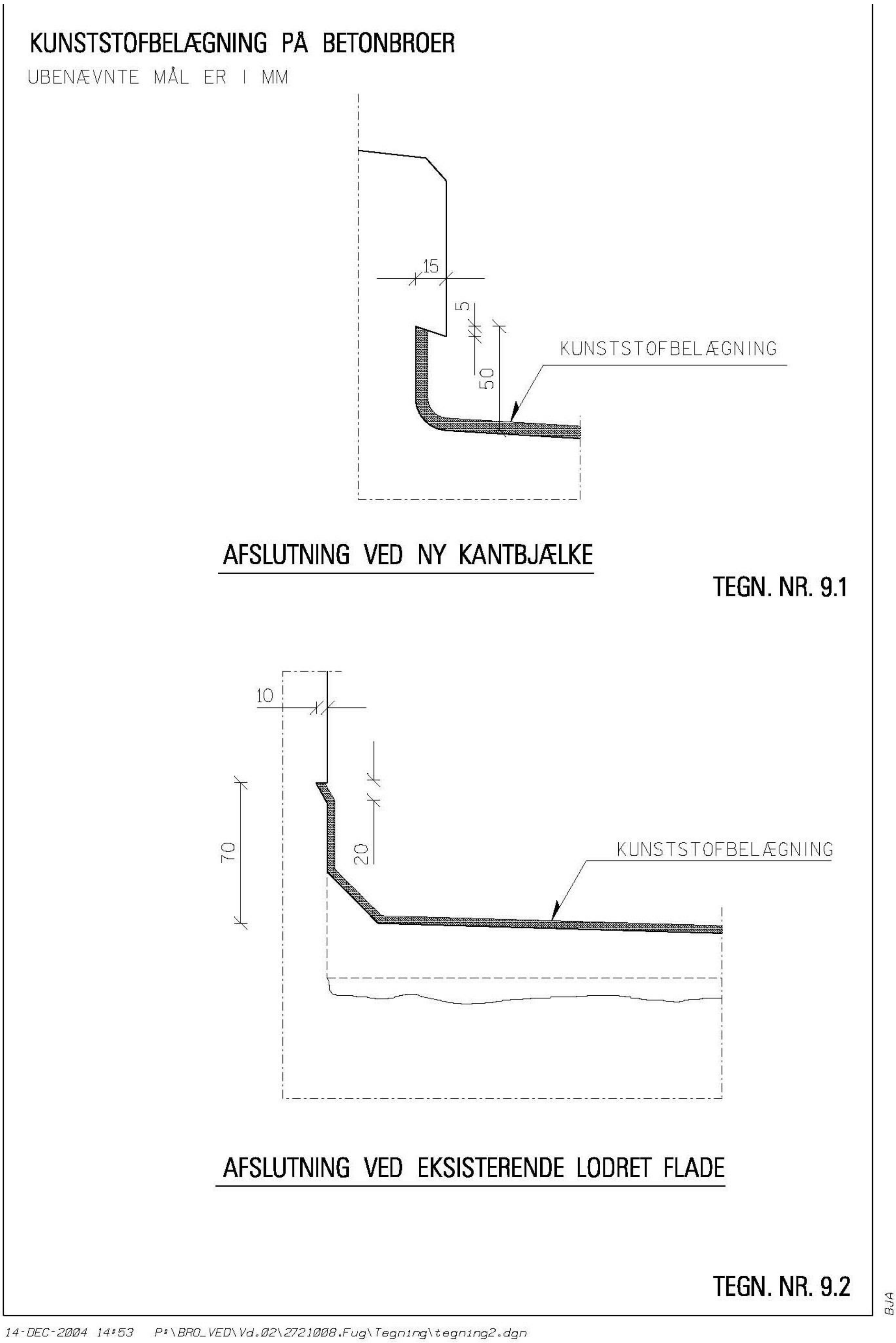
Corners between horizontal and vertical surfaces are normally filled with groove. Special profile sections are used for this purpose.

In areas where the surfacing ends, special attention must be given to the following conditions:

- Compatibility with adjoining materials (the current materials must appear from the project together with any requirements for documentation of compatibility)
- That edges are drained effectively
- Visual effect of edge
- Maintenance conditions (cleaning, winter maintenance, vandalism).

Examples of flashing and edges are shown on the following pages.

10 DRAWINGS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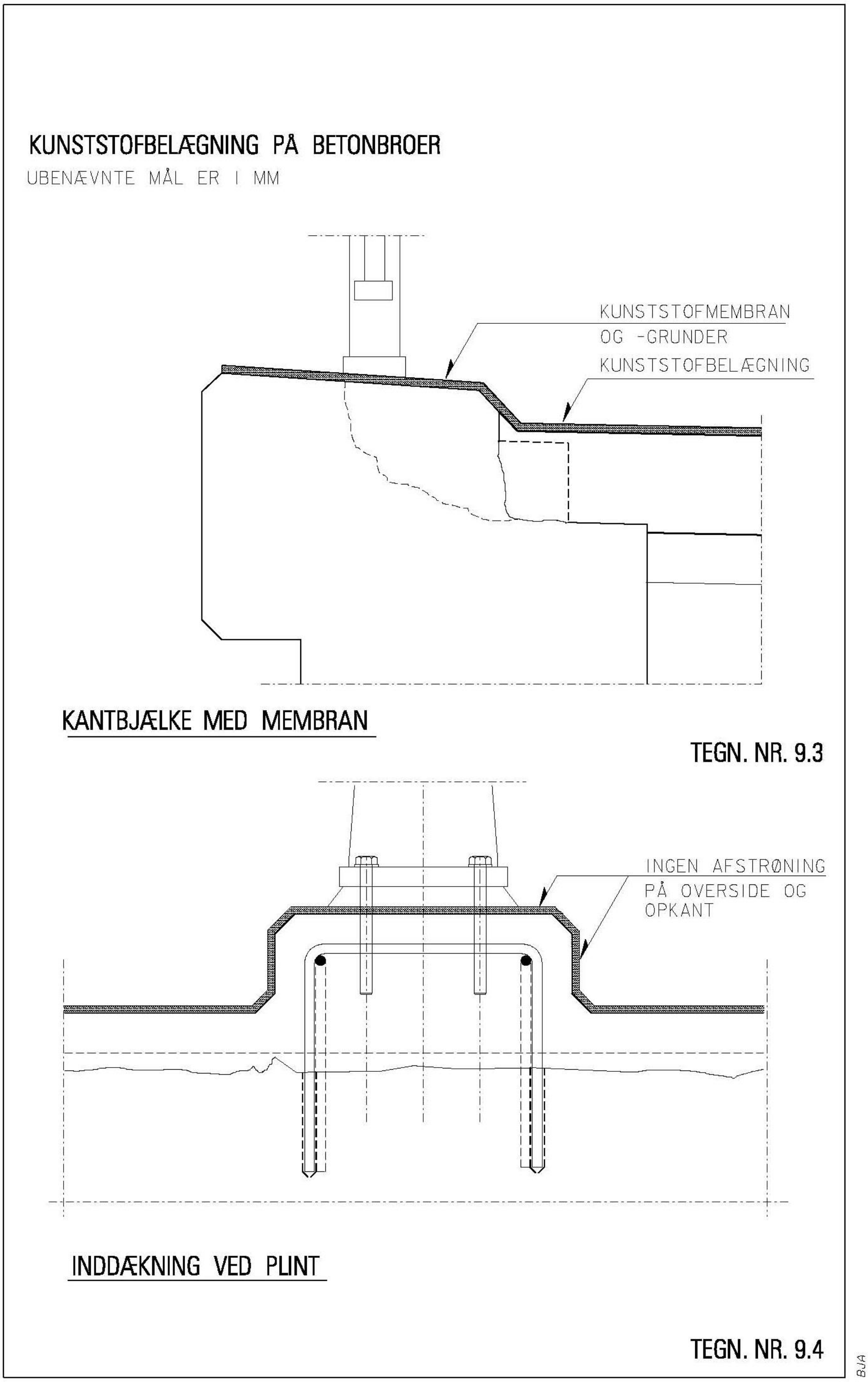

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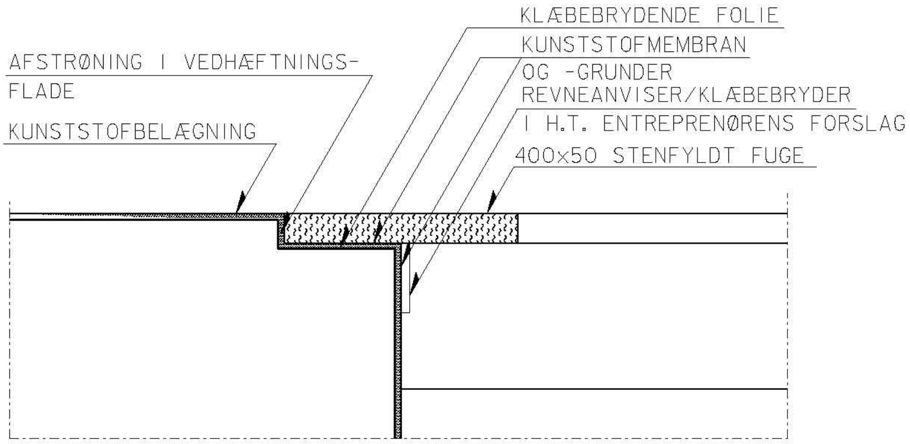

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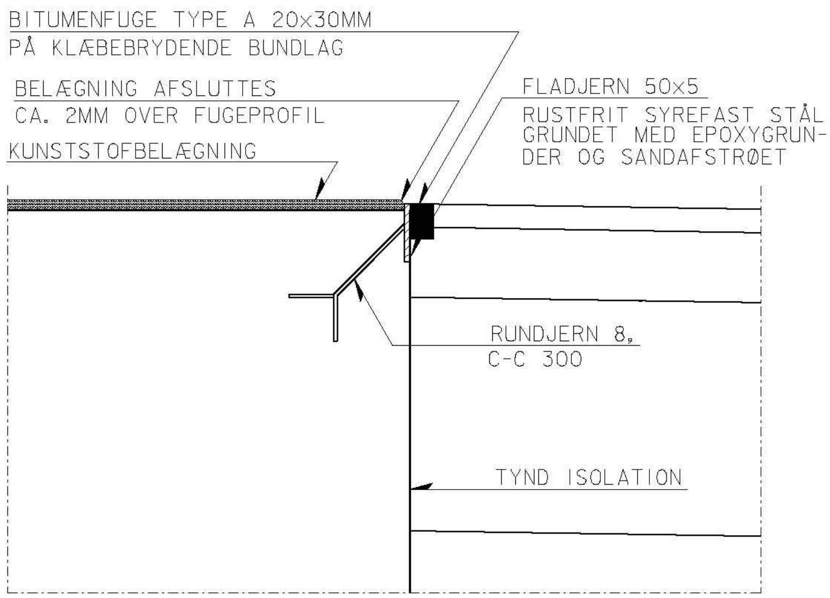

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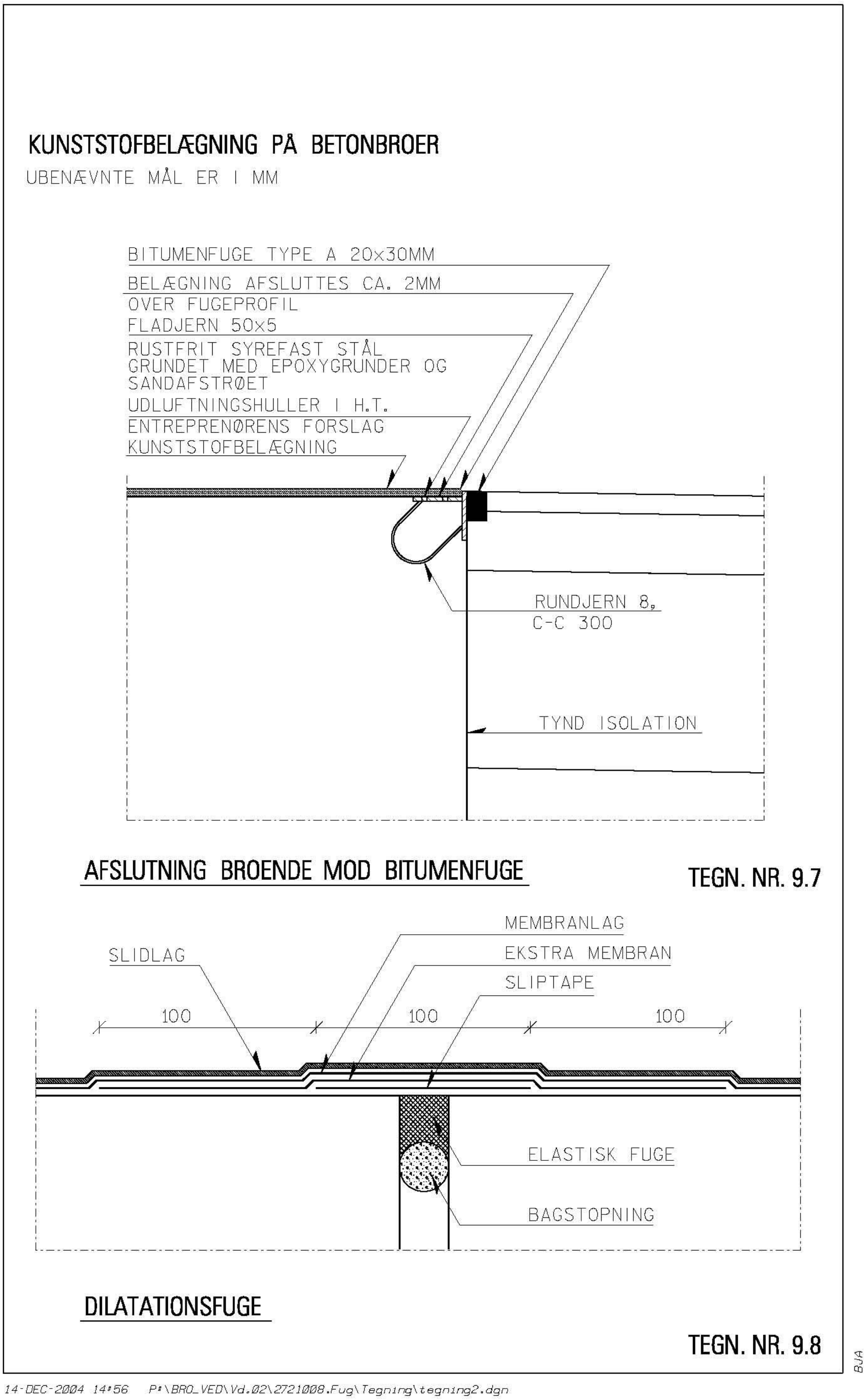
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Vejdirektoratet

Niels Juels Gade 13
Postboks 9018
1022 København K
Telefon 7244 3333

vd@vd.dk
vejdirektoratet.dk

vejregler@vd.dk
vejregler.dk

EAN: 9788793248489

Transportministeriet