



Bridge Decks

Waterproofing and Wearing Course





**Norwegian Public Roads
Administration**

Bridge Decks

Waterproofing and Wearing Course

Guidelines

January 1997

Norwegian Public Roads Administration Handbooks

This is one of a series of handbooks prepared and issued by the Norwegian Public Roads Administration - a collection of consecutively numbered books which are primarily written for use within the Administration.

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Bridge Decks Waterproofing and Wearing Course

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Preface

The present document is a translation of the original handbook written in Norwegian in 1997. The handbook has been of great value to engineers in Norway, and it is hoped that this English edition will reach a much wider audience.

Finally, tribute must be paid to Mr. Torbjørn Brudeseth, who was responsible for the translation, and to several colleagues at NPRA who quality controlled the document.

Preface to the Norwegian Edition

Handbook 145, Bridge Decks - Waterproofing and Wearing Course, is now published for the first time in the Public Roads Administration's handbook series.

The handbook replaces the following:

Internal Report no. 1275:
Concrete Bridge Decks: Waterproofing and Wearing Course -
Guidelines.
Revised May 1986,
Road Research Laboratory.

Guidelines: Evenness Requirements for Bridge Wearing Courses, NA-Circular no. 89/37.

To provide basic materials for later revisions it is desirable that experiences and information relevant to such revisions are being sent to:

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1 Introduction

These guidelines for protection of bridge decks, shall be used in design and construction of bridges and in maintenance of such where wear from traffic, or where the use of salt in winter maintenance necessitate the protection of structural elements from damage.

The handbook contains both **standards and guidelines**, *the latter indicated with cursive types*.

Damage to structures can be avoided if they can be kept away from direct contact with traffic, water and salt. Experience shows that establishing efficient protection of bridge decks is costly. It is therefore important that the concrete is as resistant as possible and the numbers of vulnerable spots are kept to a minimum. These guidelines give no directions regarding bridge deck construction, design and quality. Such information should be obtained from current standards. Neither do the guidelines provide complete directions for maintenance or repaving of existing bridges with larger or lesser damages, or bridges which were built according to specifications different from current ones, because such situations require individual assessments and possibly individual investigations.

Applicability

The standards contained in the guidelines shall apply unless special circumstances indicate otherwise. Special investigations of bridge deck conditions may provide a basis for other approaches to paving than specified by the guidelines. Such considerations shall be presented to the department in charge.

The guideline text contains advice and textbook material.

New materials and bridge deck waterproofing methods are continually being introduced. General application of these shall be made only after controlled testing. Such testing shall result in a classification of pavement types according to Chapter 2.1 and 3.

Historical Overview

The initial guidelines for bridge deck waterproofing and wearing course were published in 1976 by the Norwegian Association of Professional Engineers, "Guidelines for Waterproof Pavement on Concrete Bridge Decks".

Revisions of these guidelines were performed by the former Road Research Laboratory in 1985-86. The guidelines were then published as Internal Report no.1275 "Concrete Bridge Decks: Waterproofing and Wearing Course", Road Research Laboratory 1986.

Document Overview

Bridge deck paving shall be designed and undertaken in accordance with the following documents:

Design Rules for Bridges
Handbook 185, Public Roads Administration

Load Regulations for Bridges and Ferry Quays
in the Public Road Network
Handbook 184, Public Roads Administration

Bridge Handbook Parts 1 - 16
Handbook 100, Public Roads Administration

Bridges - Safety and Technical Standards
Handbook 150, Public Roads Administration

Quality Assurance - Main part (Level A)
Handbook 144, Public Roads Administration

Management, Operation and Maintenance of Bridges
Handbook 147, Public Roads Administration

Road Construction
Handbook 018, Public Roads Administration

Process Code 1
Handbook 025, Public Roads Administration

Process Code 2
Handbook 026, Public Roads Administration

Laboratory Investigations
Handbook 014, Public Roads Administration

Field Investigations
Handbook 015, Public Roads Administration

ASPHALT - Guidelines
Norsk Teknisk Forlag

Concrete Decks
Handbook 179, Public Roads Administration

Inspection, Sampling and Testing Methods for Asphalt Decks
Internal Report 1741
Road Research Laboratory
(New control system is being prepared)

Guidelines for Milling of Bridge Decks
Directorate of Public Roads, 1985

If these documents contain contradictory directions, the documents have priority in the sequence indicated in the tender documents.

2 Pavement Selection

2.1 Pavement Classes

Relevant pavement types for new bridges are divided into the following classes:

- A 1 Asphalt wearing course directly on the bridge deck
- A 2 Asphalt wearing course with simplified bridge deck waterproofing
- A 3 Asphalt wearing course with full bridge deck waterproofing
- B 1 Concrete wearing course cast monolithic with the structural concrete
- B 2 Concrete overlay wearing course bonded to the structural concrete

The term bridge deck is here meant to include travelled way, sidewalk or pedestrian/bicycle lanes, medians etc. and bridge decks for separate pedestrian/bicycle bridges. For medians etc. wearing elements may be replaced with other types of material. For areas with pedestrian/bicycle traffic, wearing elements may be reduced, see Chapter 2.2.

The pavement types listed are also relevant when paving older bridges, but must then be individually assessed. An individual paving solution is described for older bridges with low load carrying capacity:

- C 1 Combined waterproofing/wearing course

On older bridges with worn spots and rutting, restoration with special cement based mortar, with or without subsequent waterproofing, is a relevant method.

2.2 Pavement Design Loads

Steel bridge decks shall, prior to paving, be given surface treatment in accordance with Handbook 185, Design Rules for Bridges. Surface treatment is not considered part of the pavement design load.

Concrete bridge decks shall have a reinforced cover in accordance with requirements in Handbook 185, Design Rules for Bridges. The cover shall protect structural reinforcement and at the same time constitute a part of the load carrying structure. Therefore, only thickness beyond the cover requirements mentioned can be utilized as wearing course and be included in the pavement load.

According to Handbook 184 "Load Regulations for Bridges" bridge decks shall be designed for loads of **minimum 2 kN/m²** beyond that of the structural load carrying cross-section.

When selecting design loads several factors must be considered such as bridge type, span length, type of bridge deck, traffic volume, maintenance and economy.

Table 1 is a simple guide in the selection of pavement design loads for new bridge design for various span lengths and AADT for bridge decks in steel and concrete.

Table 1 Recommended Pavement Design Loads for Concrete and Steel Bridge Decks

AADT	Span Length Range (m)			
	$l < 10$	$10 < l < 35$	$35 < l < 200$	$l > 200$
< 2000	5.0 kN/m ² (200 mm)	2.5 kN/m ² (100 mm)	2.0 kN/m ² (80 mm)	2.0 kN/m ² (80 mm)
≥ 2000		3.0 kN/m ² (120 mm)	2.5 kN/m ² (100 mm)	2.0 kN/m ² (80 mm)

The Public Roads Administration may approve wearing course loads of less than 2 kN/m² (80 mm) for large and complicated bridges if:

- The costs of the bridge will be large with wearing course greater than 2 kN/m² and
- future pavement maintenance problems are acceptable when considering traffic volume, salting, etc.

For bridge types or construction methods known to give large variations in deck evenness, increasing the pavement thickness in Table 1 should be considered. Similarly, deck thickness in Table 1 may be reduced with high evenness, as with steel decks, but not below the minimum requirement (80 mm), see above.

Generally, Table 1 reflects that with minor bridges, pavement shall be subordinated that of adjoining roads.

On main roads minor bridges such as culverts should be provided with traversing base course, see Bridge Handbook -1, Structures in Embankments - Cast-in-place Culverts, and Handbook 018, Road Construction. Such bridges are designed for the base course and the design loads in Table 1.

With large traffic volumes Table 1 suggests the selection of thicker pavement. This ensures greater safety as the pavement wears down and allows for postponement of repaving, as well as lessening the risk of damage to waterproofing materials.

Sidewalks, pedestrian/bicycle lanes and separate pedestrian/bicycle bridges should as a minimum be designed for 1.5 kN/m² (60 mm).

Chapter 3 describes pavement classes with associated pavement types along with the conditions for their application.

2.3 Selection of Pavement Classes

Before a bridge is provided with special pavement, the need for such pavement must be assessed. The main function of the bridge pavement is to prevent damage to the bridge deck structure. This is done by waterproofing the bridge deck to prevent disintegration of concrete and corrosion of steel, as well as protecting the bridge deck against wear from traffic. The use of salt in winter maintenance and the bridge deck wear are the most important aspects to be considered. As a rule both these types of wear are directly related to the road's AADT.

Salt is used in winter maintenance to improve road surface friction. Salt is used to prevent frost, snow and ice to adhere to the roadway to facilitate easier snow removal. Salt is also used as an additive to sand to prevent sand from freezing in storage. Salt (NaCl) is applied on roads with AADT above 1500 where the climate warrants. Based on traffic volumes and climatic conditions, it is determined which road sections to be salted. In addition to decisions on routes to be salted for the entire winter season, determinations are also made on which routes shall be salted in spring and fall to ensure safe conditions also during these transitional periods. Spring and fall salting is also performed on certain sections with traffic volumes below 1500 AADT.

Salting may be carried out according to three methods, with dry salt, moistened salt or brine. Dry and moistened salt can be used under all weather conditions, while brine is not used during precipitation. Brine is therefore used primarily in spring and fall to prevent slippery roads as a result of frost, freezing rain or water that freezes etc.

The amount of salt used varies from 10 to 30 g per m² during each application. With brine smaller quantities are being used than when applying dry or moistened salt. The total consumption of salt during one winter season depends on weather conditions, temperature and precipitation. On two lane roads typically 6000 - 8000 kg salt is used per km of two-lane road during a winter season.

The use of brine contributes to a reduced overall salt consumption. Brine will force its way into openings, cracks, fractures and other damaged areas quicker and more easily than salt. The total detrimental effect on the structure is therefore anticipated to be greater with the use of brine than with dry or moistened salt.

The amount of salt mixed in is normally 30 - 50 kg per m³ sand. This corresponds to 6 - 10 g salt per m² roadway. With inexact salt dosages or the spreading of excessive amounts of sand, the detrimental effect to the roadway may be greater than with the use of salt only.

Recently alternative ice melting agents have been developed for use in winter maintenance, such as CMA (calcium-magnesium-acetate). Such materials may prove to have a different deteriorating effect on bridge decks than common salt (NaCl).

The wearing effect to the bridge deck wearing courses is primarily determined by traffic volumes and the use of studded tires. Wear from studded tires is normally what causes the need for repaving roads with traffic above 3000 AADT where pavement type and material qualities are in accordance with the standards given by Handbook 018 Road Construction. High speeds, sharp curves, acceleration and braking will result in increased wear. Narrow lanes on bridges often result in excessive rutting. This may also be caused by the confining effect of high bridge railings as compared to road sections that might even be without guardrails.

On **steel bridge decks** pavement class A3 shall always be used.

On **concrete bridge decks** pavement classes in accordance with Table 2 shall be used. In addition to the use of salt and extent of wear, consideration shall be given to whether pre-stressed or conventional steel bar reinforcement is being used, see explanation in Table 2.

On sidewalks and pedestrian/bicycle lanes, pavement classes are determined by conditions on approaching lanes and Table 2.

Table 2 Selection of Pavement Classes

Wear from Studded Tires	Salting in Winter Maintenance	AADT (Design Volume)	Conventionally Reinforced Concrete Bridge Deck	Pre-stressed Bridge Deck and Steel Bridge with Concrete Deck	Steel Decks
Little Wear	No Salting	< 1000	A1 A2 B1 ≥ 30 mm ¹⁾ B2 ≥ 60 mm ¹⁾	A2 A3 B1 ≥ 30 mm ¹⁾ B2 ≥ 60 mm ¹⁾	A3
	Limited Salting	< 2000	A2 A3 B1 ≥ 30 mm ¹⁾ B2 ≥ 60 mm ¹⁾	A3 B1 ≥ 30 mm ¹⁾	
Extensive Wear		Heavy Salting	≥ 2000	A3 B1 ≥ 40 mm ^{1) 2)} B2 ≥ 60 mm ^{1) 2)}	

¹⁾ mm indicates concrete wearing course thickness

²⁾ Applies to minor bridges on roads with concrete deck

For B1 the design loads in Table 1 it is allowed additional 50 mm wearing course on top of the concrete to simplify maintenance.

Pavement class selection shall be made based on an assessment of the project in question. Chapter 2.4 discusses various conditions that should be surveyed and considered in the selection and design of pavements.

2.4 Detailed Assessment of Pavement Selection

Pavement selection should be made based on a **planning horizon** of 20 - 30 years. Consideration should be given to plans for future changes or reconstruction of the bridge. Pavement choice and future maintenance must be considered together. Evaluations must also be made regarding possible changes in winter maintenance that might affect the need for bridge deck waterproofing.

Traffic development on the bridge must be established using traffic projections. Both total traffic volume and the proportion of heavy vehicles are of interest.

Traffic patterns and speed are factors that determine the requirements to wearing course evenness and pavement stability. It must be established if traffic will flow unrestricted over the bridge or if there is a risk of congestion and stop, for example due to intersections or roundabouts at the end of the bridge.

Frequent **changes in wearing course type** (concrete - asphalt) along a route should be avoided. On major routes (trunk roads and major national roads) concrete wearing course should be avoided on small bridges with asphalt pavement on the approaching road. Correspondingly, if the approaching road has concrete wearing course, small bridges should also have concrete wearing course.

Fixed **joints** do not allow for the adjustment of wearing course thickness up or down. Thus the selection of pavement class or type of joint is not independent choices. Connecting the wearing course to the joint must be detailed, also with regard to future maintenance. Any differences in elevation that might occur should be adjusted for with simple means.

Climate is of significance when it comes to the use of salt in winter maintenance, see Chapter 2.3. Furthermore, temperature should be considered when selecting pavement materials. Low temperature and rapid temperature variations may result in cracks in the asphalt material or frost damage to concrete. High temperature in the asphalt may result in stability problems.

Special attention should be paid to the risk of instability and distortion of asphalt pavements on bridge decks on steep grades exposed to the sun. This is particularly the case on acceleration and deceleration sections.

The various **bridge types** have different needs for waterproofing. Below are given a number of relevant conditions to be considered.

Span width: Thick pavement is in itself a safeguard against damage; i.e. wearing through the pavement or other causes of leakage. At the same time design loads will have a major impact on construction costs.

Grade: Steep grades demand on good adhesion of the pavement to the bridge deck as well as to the stability of the pavement. This is especially important on steel decks.

Special bridges: Suspension bridges and movable bridges place, in addition to weight limitations, special demands on pavement flexibility and adhesion to the surface.

Maintenance: The pavement must be planned for optimal maintenance considering economy, traffic operation and workers' safety.

The structural bridge deck evenness should be assessed before pavement is selected. Due to unevenness, a **levelling layer** may be required to ensure acceptable wearing course evenness.

For concrete overlays no levelling layer is necessary. Levelling can be done simultaneously with placing of the wearing course.

With asphalt wearing course, the levelling layer shall be placed on top of the waterproofing and any protective layer and below the wearing course. The stability of the levelling layer must be adapted to the thickness required to attain adequate evenness.

2.5 Evenness of Wearing Course

Wearing course evenness on bridges shall correspond to that on the adjoining road.

Road asphalt wearing course evenness requirements are given in Handbook 018, Road Construction.

Concrete wearing course evenness requirements are given in Process Code 2, process 84.5, and are differentiated according to evenness class:

Evenness class 1:- AADT > 8000
- Motorway
- Speed limit \geq 90 km/h

Evenness class 2:- 8000 > AADT > 4000
- Bridges in urban areas

Evenness class 3:- 300 < AADT < 4000

Evenness class 4:- AADT < 300

The most stringent evenness class is selected when at least one of the listed class criteria apply. AADT is the traffic volume at bridge opening or after placing of a new wearing course.

3 Description of Pavement Classes and Types

In the following chapters the various pavement classes are described along with the corresponding pavement types and the conditions for their use.

Sizes and quantities in Chapter 3 indicate intended values. Deviations allowed are handled in Chapters 4, 5 and 6.

3.1 A1 - Asphalt Wearing Course

An asphalt wearing course placed directly on the concrete bridge deck without any form of priming or waterproofing will protect the bridge deck against traffic wear, but will not provide any protection against water or salt intrusion.

Pavements of this class should be considered only in areas where salt is not used in winter maintenance.

The bituminous wearing course should be placed after ordinary concrete pre-treatment, ref. Chapter 4.2.

Advantages with asphalt wearing course directly on the concrete bridge deck are:

- *A simple and inexpensive solution*
- *Less sensitive to weather conditions*

Disadvantages with this solution are:

- *Damage to thin asphalt on concrete layers may easily occur*
- *Extended concrete inspection is required*

Maintenance

Before any repaving the bridge deck should be inspected. The inspection shall include the coring of samples of the asphalt and concrete deck. The samples shall be investigated regarding concrete quality, chloride content as well as adhesion between asphalt and concrete. The number of samples shall be determined in each individual case.

On bridges with low traffic volumes it may be sufficient to remove asphalt locally, e.g. along ruts and curbs, for visual control.

New pavement shall be assessed based on the bridge deck condition and the general criteria for pavement system selection. Before repaving a special assessment must be made to determine if old asphalt pavement shall be removed.

3.2 A2 - Asphalt Wearing Course with Simplified Waterproofing

Simplified waterproofing includes priming of the concrete bridge deck with a material that prevents water intrusion and/or increases the strength of the top concrete layer prior to paving. Priming will provide a certain protection against water and salt intrusion, but such protection will be of limited duration. Ruts are therefore allowed to be filled only once.

Before the second repaving is performed, an inspection of the bridge deck shall be made. If the entire asphalt pavement is not removed, the inspection shall include a representative part of the surface. New pavement shall then be assessed based on the bridge deck condition as well as the general criteria for bridge deck system selection.

Advantages of simplified waterproofing are:

- *A simpler and less expensive solution than full waterproofing*
- *Lower design loads*

Disadvantages with the solution are:

- *The process is sensitive to weather conditions (with the use of epoxy)*
- *Requires extended concrete inspection*

Both pavement class alternatives require a dry substrate. However, pavement type A2-1 is more sensitive to moisture than pavement class A2-2.

3.2.1 A2-1 Waterproofing with Low Viscosity Epoxy

The pavement is designed in the following manner (normal values):

Layer	Type	Thickness mm	Weight kg/m ²
Waterproofing	Priming with Low Viscosity Epoxy, Two Layers wet-in-wet		0.3 - 0.5 + 0.3
	Sanded with Fine Sand 0.5-1.2 mm or 0.5-1.5 mm		1 - 2
	Tack Coat PmBE60 Sanded with Fine Sand 0.5-1.5 mm		0.3 - 0.4 1 - 2
Levelling Layer (as needed)	Asphalt Concrete, Asphalt Gravel Concrete	-	-
Wearing Course	Asphalt Concrete, Topeka	35 - 45	80 - 115
Sum		> 35	> 85

Maintenance

Ruts may be filled once. Worn down areas shall be repaired in the following manner before filling of ruts:

- Wearing course edges must be clean cut.
- Exposed concrete shall be sandblasted or steel brushed until the surface is clean.
- The concrete is treated with low viscosity epoxy, two applications wet-in-wet sanded with fine sand (0.5-1.2 mm).

At the end of the first rut filling period the bridge deck shall be inspected. The inspection shall include taking of core samples from the asphalt and concrete bridge deck. The samples shall be investigated with regard to concrete quality, chloride content and adhesion between asphalt and concrete. The number of samples shall be determined in each individual case.

New pavement is thereafter assessed based on concrete bridge deck condition and the general criteria for pavement system selection.

3.2.2 A2-2 Waterproofing with Polymer Modified Bitumen Emulsion

The pavement is designed in the following manner (normal values):

Layer	Type	Thickness mm	Weight kg/m ²
Waterproofing	Sealed with PmBE60 Placed in Two Layers both Sanded with Fine Sand 0.5-1.5 mm:		
	1. Layer PmBE60 Sanded with Sand		0.3 - 0.5 1 - 2
	2. Layer PmBE60 Sanded with Sand		0.2 - 0.4 1 - 2
Levelling Layer (as needed)	Asphalt Concrete, Asphalt Gravel Concrete	-	-
Wearing Course	Asphalt Concrete, Topeka	35 - 45	80 - 115
Sum		> 35	> 85

Maintenance

Ruts may be filled once. Worn down areas shall be repaired in the following manner before filling of ruts:

- Wearing course edges must be cut clean if necessary.
- Exposed concrete and/or worn down pavement shall be cleaned of all loose material and treated with PmBE60 in one or two layers depending on the condition of the concrete surface. Each PmBE60 layer is sanded (0.5 - 1.5 mm). Any excess sand is removed.

At the end of the first rut filling period the bridge deck shall be inspected. The inspection shall include taking of core samples from the asphalt and concrete bridge decks. The samples shall be investigated with regard to concrete quality, chloride content and adhesion between asphalt and concrete. The number of samples shall be determined in each individual case.

New pavement is thereafter assessed based on concrete deck and waterproofing condition and the general criteria for pavement system selection.

3.3 A3 - Asphalt Wearing Course with Full Waterproofing

The pavement class requires the use of one or more waterproofing layers between the concrete deck and the wearing course.

This pavement class represent a complete and permanent protection of the bridge deck (provided maintenance is performed according to given guidelines).

Waterproofing systems in this class must be protected against mechanical damage and the wearing course must not be worn through.

Wearing down of wearing course and waterproofing layer will require extensive repairs. The wearing course must therefore be maintained, normally with rut filling before it is completely worn down.

Advantages with full waterproofing are:

- *Good protection of the concrete bridge deck*
- *Simple pavement maintenance.*

Disadvantages with this solution are:

- *Weather sensitive execution*
- *Relatively high dead load*
- *Risk of blister formation.*

All pavements within the pavement class require dry surfaces. The likelihood of favourable results increases with surface dryness. Moisture susceptibility of supporting surfaces, however, varies with the various types of pavements. Generally the moisture susceptibility decreases in the following sequence:

- *A3-3*
- *A3-1*
- *A3-2*
- *A3-4*

This is the main reason why pavement type A3-4 today has become the most frequent choice.

The following densities are chosen when describing quantities in kg/m³:

- *Waterproof mastic asphalt: 2.5*
- *Top 4S: 2.2*

3.3.1 A3-1 Waterproofing with Epoxy and Waterproof Mastic Asphalt

The pavement is designed in the following manner (normal values):

Layer	Type	Thickness mm	Weight kg/m ²
Waterproofing	Priming and Sealing with Epoxy Two Layers wet-in-wet. Last Layer Sanded with Fine Sand 0.5-1.5 mm	1	2 1 - 2
	Waterproof Mastic Asphalt	15±5	37.5±12.5
Levelling Layer (as needed)	Asphalt Concrete, Asphalt Gravel Concrete	-	-
Wearing Course	Mastic Asphalt, Topeka, Stone Mastic Asphalt, Asphalt Concrete	> 40	> 100
Sum		> 55	> 140

Maintenance

The pavement is maintained by filling of ruts. Where both the wearing course and the waterproofing layers are worn through extensive repairs are required. Filling of ruts shall therefore take place before such wear has occurred.

When preheating is used with rut filling it must be done before the wearing course has been worn down in order not to expose the waterproofing layer to excessive heat.

3.3.2 A3-2 Waterproofing with Prefabricated Membrane

The pavement is designed in the following manner (normal values):

Layer	Type	Thickness mm	Weight kg/m ²
Waterproofing	Tack Coat		0.2 - 0.3
	1-2 Layers Prefabricated Membrane, fully Bonded to the Concrete Deck (Tack Coat/Self-Bonding)	5 - 10	5 - 15
Protective Layer	Asphalt Concrete	15 - 20	35 - 45
Levelling Layer (as needed)	Asphalt Concrete, Asphalt Gravel Concrete	-	-
Wearing Course	Asphalt Concrete, Stone Mastic Asphalt, Topeka, Mastic Asphalt	> 40	> 100
Sum		> 60	> 140

If the pavement is exposed to excessive sunlight, heavy traffic, steep grades and/or frequent decelerations or accelerations it is advantageous to increase the wearing course thickness beyond the values indicated above, but within maximum allowable design load.

Maintenance

The pavement is maintained by filling of ruts. Where both the wearing course and the waterproofing layers are worn through extensive repairs are required. Filling of ruts shall therefore take place before such wear has occurred.

When preheating is used with rut filling it must be done before the wearing course has been worn down in order not to expose the waterproofing layer to excessive heat.

Membrane repairs shall be undertaken according to directions from the supplier.

3.3.3 A3-3 Waterproofing with Polyurethane Membrane

The pavement is designed in the following manner (normal values):

Layer	Type	Thickness mm	Weight kg/m ²
Waterproofing	Primer		0.2
	Polyurethane (sprayed)	1.5 - 2.0	2 - 3
Bonding	Topeka 4S, Mastic Asphalt (Sta2/Sta4)	10±5	22±11
Levelling Layer (as needed)	Asphalt Concrete, Asphalt Gravel Concrete	-	-
Wearing Course	Mastic Asphalt, Topeka, Stone Mastic Asphalt, Asphalt Concrete	> 40	> 100
Sum		> 52	> 130

Waterproofing with polyurethane gives complete moisture protection of the bridge deck to the outside horizontal curb corner. To attain adequate bonding between membrane and any other layers in the superstructure, Topeka 4S or 10 mm thick mastic asphalt is recommended.

If the pavement is exposed to excessive sunlight, heavy traffic, steep grades and/or frequent deceleration or acceleration it is advantageous to increase the wearing course thickness beyond the values indicated above, but within maximum allowable design load.

Maintenance

The pavement is maintained by filling of ruts. Where both the wearing course and the waterproofing layers are worn through, extensive repairs are required with removal of worn waterproofing, cleaning of the concrete and construction of a new waterproofing layer. Rut filling shall therefore take place before such wear has occurred.

When Topeka 4S/mastic asphalt is being used for bonding, this layer will function as a warning layer. But because this layer does not easily withstand wear from studded tires any rutting must be mitigated immediately.

3.3.4 A3-4 Waterproofing with PmB-based Materials

The pavement is designed in the following manner (normal values):

Layer	Type	Thickness mm	Weight kg/m ²
Waterproofing	Tack Coat PmBE60, Sanded with Fine Sand 0.5-1.5 mm		0.3 - 0.5 1 - 2
	Topeka 4S	12±3	26.5±6.5
Levelling Layer (as needed)	Asphalt Concrete, Asphalt Gravel Concrete	-	-
Wearing Course	Topeka, Stone Mastic Asphalt, Asphalt Concrete	> 40	> 100
Sum		> 52	> 130

Pavement type A3-4 is equivalent to the three previously mentioned pavement types with regard to waterproofing effectiveness.

On steel bridge decks pavement type A3-4 predominates, but the consumption of tack coat is normally reduced to 0.10-0.15 l/m².

Tack coat is applied to the bridge deck to palliate dust and provide good bonding between the bridge deck and the 12+3 mm thick Topeka 4S membrane. This is a very binder and filler rich fine-grained material, which gives a waterproof membrane free of voids at temperatures of 180-190 °C. Topeka 4S is placed with mastic asphalt paver or manually. The membrane is placed up to vertical surfaces.

If the bridge pavement will be exposed to excessive sunlight, heavy traffic, steep grades and/or frequent decelerations or accelerations there is a risk of corrugation. To some extent this can be avoided by limiting the membrane thickness to 9 mm at the same time as the wearing course is increased to the maximum design load allowed.

This pavement type is less moisture susceptible during application than epoxy and polyurethane treatment (A3-1 and A3-3).

Maintenance

It is important that the waterproofing is protected against mechanical stress, and wearing down of the wearing course must be avoided. The pavement is maintained by rut filling or milling of ridges and by renewing the wearing course within the allowable design load.

Where wear has resulted in exposed concrete or steel, this type pavement is more easily repaired than pavement types A3-1, A3-2 and A3-3.

3.4 B1 - Monolithic Concrete Wearing Course

Monolithic wearing courses are contracted together with the structural bridge deck simply by providing additional cover to the top reinforcement. Wearing course thickness is selected as indicated in Chapter 2.

Prior to pouring the location of the top reinforcement shall be carefully controlled (height) and it must be checked that the reinforcement is securely fastened (no loose or protruding steel bars).

Advantages with monolithic concrete wearing courses are:

- *There is no risk of delamination or formation of blisters, solidity is guaranteed.*
- *Placing of the wearing course is an integral part of bridge deck casting, no additional costly work operations are required.*
- *The wearing course material is essentially the same as that in the bridge structure, the material "breathes".*
- *The bridge deck structure may be inspected and controlled*

The disadvantages with monolithic concrete wearing courses are:

- *Desired evenness is seldom attained*
- *The bridge deck has no waterproof membrane to protect against salt and other aggressive agents; depends only*
- *Formation of cracks in plastic or hardened state may affect the durability of bridge deck structure.*

In some cases monolithic wearing courses have been laid with a separate wear-resistant concrete placed "wet-in-wet" with the structural concrete. With currently available concrete qualities for load-bearing structures the benefits with this method are considered minor compared to problems with the execution and the increased risk of cracking.

If the desired bridge deck evenness is not attained it can be grinded off, locally or all over. The operation should preferably be undertaken with diamond blade drum machine grinder. Experience has shown that the grinding process may give reduced wear resistance if the right grinding method is not used. The amount of grinding must be chosen in accordance with its objectives. If the purpose is to satisfy evenness and keep as much wearing course as possible only ridges and knobs are removed, i.e. depressions are not touched. If the objective is a deck with a uniform appearance and frictional properties with superior driving comfort, also depressions must be evened out. To prepare for grinding the wearing course should be laid about 10 mm thicker than required minimum.

Maintenance of monolithic wearing courses will consist of removing ridges between ruts and filling/waterproofing of any cracks that might have formed. Grinding will, depending on wearing course thickness, be undertaken one or more times until the entire layer is worn through, see Figure 1.

Approach road paving must be shaped to allow for the vertical alignment to be lowered by grinding. This places limitations on the type of joints that can be used.

When monolithic wearing courses are worn down, repaving may be undertaken in accordance with one of the alternatives described in Chapter 3.1, 3.2, 3.3, or 3.5.

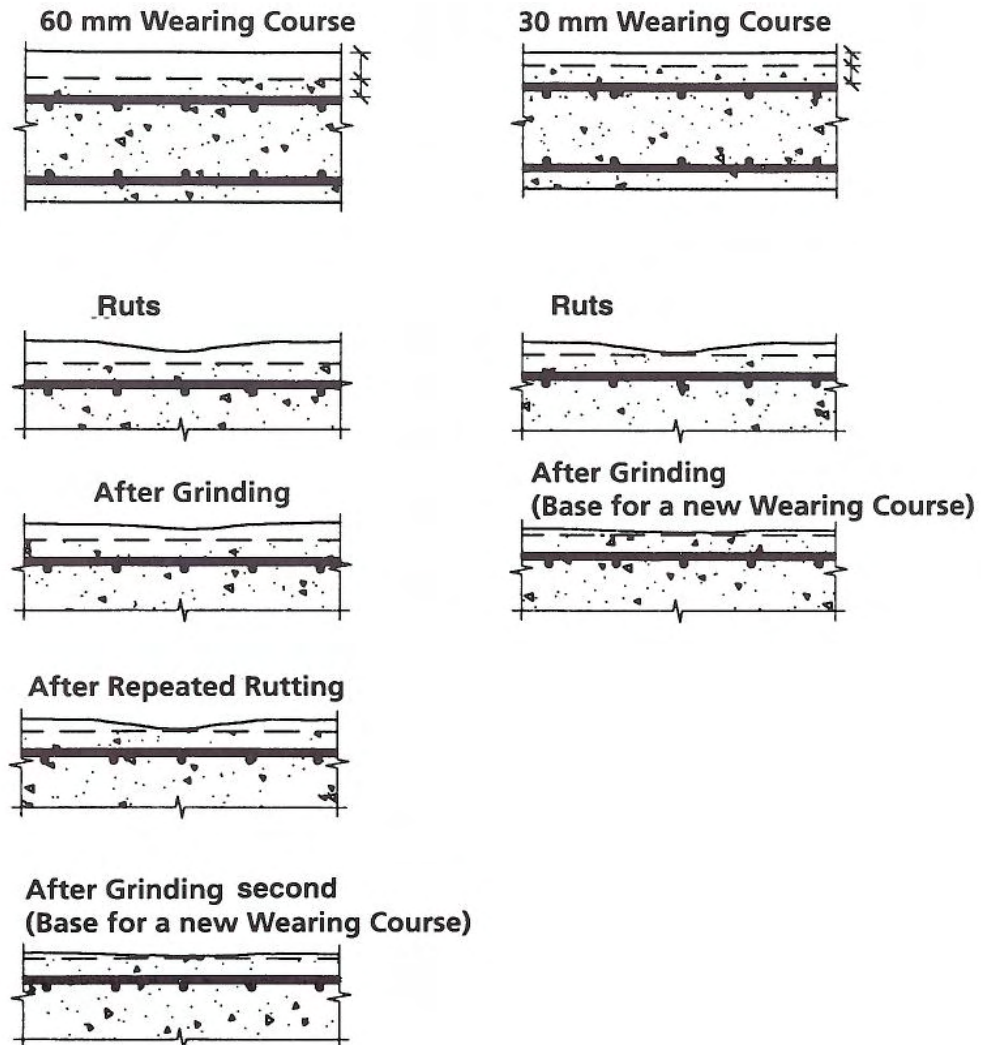


Figure 1 Grinding of Monolithic Wearing Course

3.5 B2 - Concrete Overlay

Concrete overlay involves placing of a separate concrete layer directly on top of the bridge deck structure after this has hardened and deformations largely completed. The concrete overlay shall be designed especially with regard to durability. As a main rule the concrete will contain steel fibre reinforcement and shall be bonded to the concrete substrate.

Advantages with concrete overlays as wearing course are:

- *A wearing course without plastic deformations regardless of thickness variations*
- *The execution is less sensitive to weather than when using membrane/asphalt pavement*
- *Highly durable and long service life, obviously dependent on wearing course thickness.*

Disadvantages with concrete overlay are:

- *Risk of delamination, i.e. lack of bonding between overlay and substrate.*
- *Risk of uneven surface especially if light levelling equipment is used.*

Delamination must be considered as an uncertainty with regard to future durability but has so far normally not been a direct cause of damage until the overlay has been nearly worn down. If the original overlay is thin bonding problems must be anticipated to increase both during execution and as the overlay wears.

In recent years slip form pavers have been used for placing concrete overlay on bridges. This has resulted in bridge decks with high evenness and superior driving comfort. The choice of heavy/complicated or light/simple equipment must be made based on bridge size, traffic volumes etc.

Concrete overlay, which does not provide satisfactory evenness, may be ground in the same manner as monolithic wearing courses. When using light levelling equipment some grinding should be anticipated.

Minimum overlay thickness should normally not be less than 60 mm both with regard to the execution and to facilitate the use of wear-resistant concrete.

Maintenance of concrete overlay will consist of removing any ridges between ruts or alternatively of filling the ruts. Moreover, maintenance may consist of filling/waterproofing of cracks and/or epoxy injection to mitigate delamination of the overlay to the substrate. Regarding assessments in conjunction with grinding, see Chapter 3.4.

3.6 C1 - Combined Waterproofing/Wearing Course

On older, worn concrete bridges not designed for additional loads, a combined waterproofing/wearing course layer consisting of Topeka 4S sanded with pre-coated chippings can prevent or limit the development of further damage.

The combined waterproofing/wearing course is placed after pre-treatment of the concrete (Chapter 4). The pavement type provides some moisture protection if traffic is limited. Regular inspections and follow-up/maintenance are therefore required to limit further damages. Ref. point 3.1/3.2 with regard to advantages and disadvantages.

The advantage with combined waterproofing/wearing course is:

- Increased service life for older bridges

Disadvantages with this solution are:

- Require frequent attention and maintenance
- Little resistance against deformation leading to early rutting with heavy vehicle traffic.
- Requires extended concrete inspection

C1 - Combined Waterproofing/Wearing Course

The pavement is constructed in the following manner (normal values):

Layer	Type	Thickness mm	Weight kg/m ²
Waterproofing	Tack Coat PmBE 60, Placed in One or Two Layers both Sanded with Fine Sand, 0.5 - 1.5 mm		0.3 - 0.5
	Topeka 4S ^{*)}	15 - 20	33 - 44
Sanding	Pre-coated Chippings (Af), 4-8/8-11 mm		3 - 5
Sum		> 15	> 35

*) Topeka 4S if binder content is reduced to 11.5 - 12 % at the planning stage.

If the bridge can take higher pavement loads, but cannot withstand full waterproofing, Topeka 4S is recommended exchanged with Top8/Top11 or Sta8/Sta11 and modified binder. It is important to aim for adequate stability at the same time as keeping the binder content as high as possible to ensure waterproofing properties.

Maintenance

Frequent follow-ups and repairs must be undertaken to mitigate bridge deck rutting. Worn down spots are cleaned, loose material removed and repairs undertaken using similar type material. Quantities should be assessed based on the bridge deck condition.

4 Pre-treatment prior to Paving

4.1 Bridge Deck Casting

Bridge deck casting shall be planned and executed with the intention of establishing a suitable basis for the wearing course. Special properties to be emphasized are evenness, surface texture and absence of cracks.

4.1.1 Measures to Minimize Cracking

Experience shows that for bridge decks constructed with low water/binder ratio, the concrete is inclined to get cracks forming in the plastic phase of the concrete. Measures to minimize or avoid cracks must therefore be given special attention.

The risk of cracks is determined by a number of technological and methodological factors. The following measures are recommended:

Concrete composition:

- 1. Select aggregate with lowest possible water demand if such an option exists.*
- 2. Select low alkali cement rather than high alkali cement. (Norcem moderate heat high strength cement is apt to produce less cracks than Norcem Standard Cement with similar mix design).*
- 3. No more than a maximum of 0.9% of lignosulfonate should be used, normal plasticizer with 40% dry matter, along with high alkali cement and no more than a maximum of 0.6% plasticizer with low alkali cement (% given in proportion to cement by weight).*
- 4. Use one of the superplasticizers that yields the highest effect and longest pot life (workable period). Melamines normally give the best effect together with air-entrainer while naphthalenes are best suited to reduce viscosity where high silica dosages are being used.*
- 5. In hot weather and/or with long hauls use retarders, minimum 0.8 kg/m^3 , preferably $1.0 - 1.5 \text{ kg/m}^3$, to improve workability and reduce thixotropy. (Indicated dosage applies to retarder with about 10% dry matter).*
- 6. Select a combination of aggregates with as high an overall fineness module as feasible for casting/levelling while keeping the concrete's water demand as low as possible.*
- 7. Select a sufficiently high binder content to allow for keeping water reducing additive dosages below 8 kg/m^3*
- 8. Note that a stable mixing procedure is required to produce a consistent product. The mixing procedure, especially the sequence whereby the various materials are added to the*

mixer, is critical for the mixing effect and resulting water requirements. Cement ought to be in contact with water before adding water-reducing additives. Plasticizer is added simultaneously with water while superplasticizer addition is delayed.

9. *If fresh concrete quickly loses workability the risk of cracking increases. Quick slump loss may result from the following factors:*
- *water content too low (point 7)*
 - *the cement has been moistened by additive (point 8)*
 - *plasticizer content too high (point 3)*
 - *superplasticizer with too low pot life/workable period (point 4)*
 - *high concrete temperature or excessive and lasting water absorbing aggregate.*

Execution:

1. *The auto mixer drum must rotate at very low speed during transportation (especially on long hauls) in order to reduce frictional heat generation in the concrete mix.*
2. *When the vehicle arrives at the construction site the drum must run about 3 minutes at maximum speed to prevent coagulation. If additional superplasticizer dosage is required (normal with hauls beyond 20 minutes) remixing is an integral part of post-dosing.*
3. *With decks sufficiently thick to be produced in several layers the top layer should be 25 - 30 cm.*
4. *Vibrating screed strike-off must be performed at very low speed. Strike-off timing must be assessed and adapted to deck grade, concrete consistency loss etc. to obtain best results possible.*
5. *Curing membrane shall be applied immediately after strike-off with a 0.4 - 0.5 l/m² dosage (0.15 - 0.2 l/m² normally recommended). Wax based curing membrane should not be used when the bridge deck is to be waterproofed with epoxy or polyurethane or if a concrete overlay is to be placed. (See arguments below).*
6. *As soon as the concrete has lost some of its workability, careful sprinkling with a fresh water mist should be undertaken. This should continue until regular watering can start. During conditions with low/moderate risk of drying up, plastic foil or insulation mats may replace watering.*
7. *When there is a risk of freezing temperatures and water cannot be used, the surface must be covered with insulation mats to avoid frost damage and/or large temperature gradients. Also above freezing insulation can be required to avoid thermal cracking, especially the first night after pouring.*

Reasons for cracks are numerous and effects accumulate. There will therefore always be some risk of cracking. Cracks must be repaired prior to waterproofing and laying of wearing course. If the deck surface is polished/towelled, cracks will be filled only near the surface and cannot later be found and repaired. Precise strike-off and best possible curing is therefore recommended and not towelling/polishing of the concrete surface.

Concrete surface curing membrane shall be removed before waterproofing and wearing course is placed. With as high curing membrane consumption as 0.4 - 0.5 l/m² extensive work effort may be required. (The wax is for example squeezed out during sand blasting). A wax based curing membrane will destroy the bonding to subsequent layers and must therefore be removed completely. When using acrylic curing membrane this is not as critical. This is the reason for not recommending wax based curing membranes on bridge decks.

Concrete deck curing procedures shall as a minimum include the application of curing membrane after levelling and continuous moist curing for seven days.

There are a number of different screed rail and vibrating screed types but none should be considered superior. Screed rails directly on top of reinforcement are not advisable because the in print, when refilled, will function as a dummy joint. It is not advisable to use concrete screed rails to be left in when pouring the concrete. When using vibrating screed with runners to be pulled along the top reinforcement, addition reinforcement stiffness must normally be provided by for example using a larger number of chairs.

4.1.2 Evenness and Surface Texture

Bridge decks must be finished according to reinforcement cover requirements and within stated tolerance requirements (HB185 Design Rules for Bridges, part III and Process Code - 2, Process 84).

Evenness deviations may be gauged using straightedge with knobs at both ends. Deviation from correct height differences and compounded site deviation can be measured with a leveller or total station.

Strike-off shall be performed to ensure a dense and well-compacted concrete surface. The vibrating screed is pulled slowly with uniform speed. Timing of levelling should be adjusted to the deck grade and concrete consistency loss to minimize the extent of distortions and corrugations. Any unevenness and inhomogeneities are repaired immediately by float finishing. Immediately thereafter a curing membrane or other type protection is applied to prevent moisture loss.

Levelling is done using applicable vibrating screed guided by attached and solidly supported screed rails. Where screed rails are supported by top reinforcement it must be firmly attached directly to the lower reinforcement with chairs. The lower reinforcement must be rigidly supported by reinforcement spacers against the form. Placing of reinforcement spacers and chairs shall correspond to screed rail placement.

When casting in winter, spring and fall, concrete surfaces must be protected against frost damage. When constructing thick bridge slabs during unfavourable weather conditions with crack generating temperature gradients, the concrete surface shall also be protected with appropriate cover, insulation or similar. The protection shall remain until the risk of temperature-generated cracks has passed.

A bridge deck having a wearing course placed in a separate operation is recommended not to be towelled. A bridge deck being provided with asphalt wearing course should not be surface grooved.

Grooving is performed only on concrete surfaces that will carry traffic directly or that will serve as substrate for concrete overlay. Grooves should be 1 - 2 mm deep going across the bridge. Grooving is preferably performed using a special piano wire rake or a wide, thin piassava broom.

4.2 Pre-treatment of Concrete Decks

Pre-treatment consists of deck surface cleaning as well as repair of local defects such as cracks, casting flaws and ridges beyond allowable deviation. Pre-treatment shall include all surfaces that waterproofing or wearing course will be in contact with.

4.2.1 Cleaning

Cleaning shall ensure that the cement skin is removed.

Applicable methods may be dry sandblasting, abrasive blasting, grinding and milling (lawn mower size) with "loose" teeth, high-pressure washing, high-pressure washing with sand added and wet sandblasting.

Contamination from cable injection grout, oil, grease, paint etc. is removed not to reduce concrete surface bonding properties. Smooth areas should be given a particularly forceful treatment to obtain clean and rough surface.

Oil and grease not removed by the regular cleaning shall be removed using detergents and warm water cleaning or flame cleaning.

Special attention is given to remove wax based curing membrane.

When selecting cleaning method (wet or dry method) consideration should be given to desired moisture condition of the base layer before paving.

Dust and remnants from cleaning shall be removed from the deck immediately, for example by hosing with water, oil-free compressed air or with an efficient vacuum cleaner, because dust has a tendency to stick to the cleaned surface. Cleaning of bridge decks shall be done with clean fresh water. After the bridge deck has been cleaned no equipment that might leave oil spills should be driven or parked on the cleaned surface.

After cleaning the surface bonding potential shall be checked with a pull-off test glued to the surface using a quick-setting epoxy adhesive, see Appendix 3 for description of execution and extent of control. With cleaning extending over several days, the control should be undertaken concurrently and the results reported to the person in charge of the cleaning operation. Minimum tensile strength requirements are 1.5 N/mm^2 .

After the cleaning is completed no more than seven days should pass before paving commences because, apart from normal befouling, precipitation of lime might reduce adhesion of a cleaned deck.

4.2.2 Casting Flaws, Depressions and other Defects

Flaws in the concrete and deviations in the reinforcement cover shall be mitigated.

Minor casting flaws and depressions can be repaired with cement-based mortar fastened to the base with epoxy adhesive or epoxy mortar sanded with dry sand free of dust. The epoxy mortar thickness shall not exceed about 20 mm. The same type of epoxy mortar is used for priming and mortar. Sand quality, quantity and aggregate gradation in mortar and for sanding shall be in accordance with epoxy supplier specifications. Major casting flaws or defects are chiselled away and recast with cement based mortar or concrete glued to the base layer with epoxy mortar. When patching with cement based material adequate curing conditions must be provided to prevent rapid drying.

Exposed reinforcement shall be cleaned with sandblasting. All loose material shall be removed with water and oil-free compressed air. Then epoxy primer is applied and the reinforcement protected with epoxy putty about 5 mm thick. Reinforcement with inadequate cover is given additional protection with epoxy putty or epoxy concrete priming as described in A2-1 pertaining to pavement types.

Epoxy treated surfaces shall be sanded with dry sand free of dust. After curing all loose material shall be removed to ensure secure bonding for the continued paving.

Any holes passing through (strut holes etc.) are filled with expanding mortar glued in the upper 5 cm with epoxy glue after removal of lining ducts in that zone. Ventilation hoses from cable ducts are cut even with the concrete surface and sealed with epoxy that is sanded, if nothing else is specified.

Instead of filling depressions, associated ridges can be grinded away provided remaining reinforcement cover is within specifications.

If waterproofing shall be undertaken all knobs, steps and ridges above 3 mm shall be grinded away.

When the stated maximum epoxy mortar thickness is exceeded, delamination between the concrete deck and the repair mortar may occur due to temperature expansion coefficient differences between concrete and epoxy.

4.2.3 Cracks and Fractures

Bridge deck cracks must be repaired even if waterproofing shall be placed.

Filling of cracks with epoxy shall comply with requirements in Appendix 2.

Repair methods should be selected based on the extent of cracking. Pressure injection is the safest (and most expensive) method for waterproofing of individual cracks. Experience shows that filling of cracks with repeated application of special low viscosity epoxy will also give good results.

When treating individual major cracks according to the “ketchup bottle method” cracks are filled repeatedly wet-in-wet (usually three to six times) with special low viscosity epoxy until bubbling ceases and no additional epoxy is sucked in. The treatment must therefore be restricted to limited areas at a time, and worked over and over again. Epoxy spills are dressed with dry sand free of dust. The following conditions must prevail to ensure success with this method:

- 1 Concrete and epoxy temperature must be above 15 °C, preferably 20-25 °C.*
- 2 The cracks must be dry.*
- 3 The cracks must not be filled with dust and dirt. Cleaning may be done with compressed air similar to what is being used to clean machine parts.*

Areas with multiple fine hair cracks can be repaired by pouring special low viscosity epoxy on the concrete surface, working forth and back over the cracked area with a squeegee until the epoxy starts losing consistency. The epoxy is then sanded with dry dust free sand. Similar conditions as with the “ketchup bottle method” must prevail for the improvement to be successful.

Filling of cracks should be checked randomly by taking of core samples.

Repairs of cracks should preferably be delayed until after the deck has been cleaned. Additional cracks will normally appear after sandblasting or similar cleaning. Even if visible cracks are repaired before cleaning the need for a second round of treatment should be expected.

On newly cast bridge decks and bridge decks not exposed to construction traffic, cleaning of cracks for dust and dirt may be omitted by filling visible cracks before cleaning. During the cold season extra heating can be avoided by repairing visible cracks while the concrete is still warm from hydration heat. Crack repairs during fall, winter and spring should be undertaken inside a heated tent.

4.3 Pre-treatment of Steel Decks

Pre-treatment of steel decks is carried out for two reasons:

- To protect the steel materials against corrosion
- To ensure bonding between the bridge deck and layers above

Production, corrosion protection, transportation and erection of steel bridge structures shall be undertaken in accordance with Handbook 185, Design Rules.

After transportation and erection, connections (welded joints) and damaged areas shall be identified and repaired as stated in Handbook 185, Design Rules.

The bridge deck shall be sandblasted to Sa 2.5-3 (ISO 8501-1). Blasting profile 25-60 μm . Then an approved corrosion protection (as a minimum a shop primer with a high zinc content with a 15-20 μm dry film thickness), which is temperature resistant up towards 400 °C, is applied.

Then the deck shall be blasted clean with water and oil-free compressed air.

Before placing of waterproofing and wearing course, a tack coat of polymer modified bitumen emulsion (PmBE60) or solvent based bituminous tack coat is applied. Tack coat is applied as described below.

Polymer Modified Bitumen Emulsion, PmBE60

Tack coat PmBE60 is applied in the quantity of 0.10 - 0.15 l/m². It is important to use correct quantities. No areas shall remain untreated and ponds shall not form.

Deck temperature shall be above +10 °C during application and curing of the tack coat.

In practice bonding has been known to fail when undertaken at low temperatures.

Sanding with fine sand 0.5 - 1.5 mm is undertaken immediately in the quantity of 1 - 2 kg/m².

Emulsion setting time depends on weather and temperature conditions. Sand will reduce setting time as well as reducing problems with sticking to machine parts etc.

After the emulsion has set, excess sand is removed with compressed air.

Solvent Based Bituminous Tack Coat

Special solvent based bituminous tack coat for steel decks is applied in the same manner and to the same quantity as PmBE60 but normally there is no need for sanding.

Waterproofing Layer and Wearing Course

The waterproofing layer (membrane) and wearing course are placed on a coated, cleaned and dry deck in the same manner as with other pavement types. On bridges with steel deck, pavement class A3 is selected, normally A3-4.

5 Paving and Control

5.0 General

All materials specified shall satisfy requirements given in Appendix 2-8 and requirements given in documents referred to.

5.0.1 Description Method

The description of the paving process for the various **pavement types** within each pavement class is undertaken in the following manner:

Reference: States where the pavement or parts of it is described.

Description: States supplemental description to “references”.

Control: States general guidelines for control of materials and execution.

5.0.2 Levelling Layer

With an uneven structural bridge deck it may be necessary to use the levelling layer to achieve acceptable wearing course evenness.

When using asphalt wearing course the levelling layer shall be placed on top of the waterproofing and below the wearing course. Asphalt concrete (Ab) or asphalt gravel concrete (Agb) with an upper nominal stone size from 8 to 16 mm depending on levelling layer thickness, is normally used.

Epoxy materials can only be used for minor adjustments with thickness not exceeding 20 mm.

Minor unevenness to the structural bridge deck can also be corrected by grinding.

Major deviations (found most often at the joints) are far more significant than the straightedge deviations found on the concrete slab itself.

When using concrete overlay no special levelling course is required. Levelling may be undertaken simultaneous with placing of the wearing course.

5.0.3 Preparations

Prior to paving certain general preparations are undertaken:

- 1 Levelling of the bridge deck, possibly including alignment adjustment.
- 2 Repair of any surface defects, filling of any holes, ref. Chapter 4.2.2.
- 3 Deck cleaning, ref. Chapter 4.2.1.
- 4 Checking of potential surface bonding properties with pull-off test, ref. Chapter 4.2.1.
- 5 Deck inspection, crack repairs, ref. Chapter 4.2.3, and any remaining defects, ref. Chapter 4.2.2.
- 6 Final removal of all loose materials with oil-free compressed air.

Any new alignment should be established with regard to:

- road alignment
- minimum overlay thickness
- material consumption; i.e. wearing course dead load
- structural capacity.

Vertical alignment adjustments rarely have any significance. Attention shall, however, be given to vertical clearance for overpasses etc.

5.0.4 Breaks in the Longitudinal Profile

When crossing from one longitudinal profile to another (for example when wedging overlay to the existing wearing course or when correcting deviation that occurred during casting) the wedging length must be in accordance with the evenness class of the bridge.

To provide adequate traffic safety, driving comfort, and to reduce the dynamic load the following relative wedging slopes may be used:

Evenness class	1	:	$I_{max} = 2 ‰$
Evenness class	2 and 3	:	$I_{max} = 4 ‰$
Evenness class	4	:	$I_{max} = 8 ‰$

The wedging break points should be rounded off as well.

When wedging or ending overlay against existing wearing course, casting shall be done against a clean-cut edge. The wedging area must be ground or milled down to ensure that specified overlay thickness is attained.

5.1 A1 - Asphalt Wearing Course

5.1.1 A1 Asphalt Wearing Course Directly on the Concrete Deck

5.1.1.1 Reference

- ASPHALT - Guidelines
- Road Construction, Handbook 018, Public Roads Administration

5.1.1.2 Description

The execution is described in the following points:

- 1 Existing asphalt pavement (if any) is removed.
- 2 Pre-treatment of the concrete deck is performed in accordance with Chapter 4.2, section 4.2.1 - 4.2.3.
- 3 Joints, inlets and drain pipes are cleaned and repaired, if need be.
- 4 The concrete deck is bonded with PmBE60 or other suitable polymer modified bitumen emulsion. The bonding agent is applied in the range of 0.2 - 0.5 kg/m² depending on surface texture and absorption.
- 5 Wearing course is normally selected based on the same criteria as for adjacent roads. The wearing course shall be produced and placed in accordance with Handbook 018, Road Construction. One should aim for voids in the wearing course being near the lowest value allowed for the wearing course in question. Wearing course thickness shall be adapted to allowable bridge deck dead load, wearing course stability and waterproofing ability as well as the transition to adjacent road.

Wearing course thicker than 80 mm should be placed in two layers. Thin asphalt pavement on concrete decks is particularly prone to damage.

- 6 Waterproofing of the wearing course tie-ups to curbs should be assessed individually depending on slope etc. Asphalt wearing course placed directly on the concrete deck provides little or no waterproofing of the concrete and waterproofing along the curb is therefore not required.

If some degree of waterproofing along the curb is desired this can be sealing of the wearing course to a distance of about 30 cm from the curb. This treatment should be extended 10 cm up along the curb before paving.

5.1.1.3 Control

Control of asphalt pavement shall be undertaken in accordance with:

Road Construction
Handbook 018, Public Roads Administration

Inspection, Sampling and Testing Methods for Asphalt Pavement
Internal Report 1741
Road Research Laboratory

5.2 A2 - Asphalt Wearing Course with Simplified Waterproofing

5.2.1 A2-1 Waterproofing with Low Viscosity

5.2.1.1 Reference

- ASPHALT - Guidelines
- Road Construction, Handbook 018, Public Roads Administration.

5.2.1.2 Description

Newly cast concrete decks shall be given minimum one week moist curing and then minimum two weeks drying before paving commences. It is very important that the concrete deck moisture content is as low as possible. As a minimum the deck surface shall be dry during paving, see Appendix 9.

Epoxy material used for priming shall satisfy requirements stated in Appendix 2, Table 1.

The execution is described in the following points:

- 1 Existing asphalt pavement (if any) is removed.
- 2 Pre-treatment of the concrete deck is performed in accordance with Chapter 4.2, section 4.2.1 - 4.2.3.
- 3 Joints, inlets and drainpipes are cleaned and repaired if necessary.
- 4 The concrete deck is primed with low viscosity epoxy in the quantity of 0.3 - 0.5 kg/m². The quantity will depend on the concrete surface and absorption. The epoxy is applied using brush, paint roller or high-pressure sprayer. The epoxy shall be solvent-free from the supplier and must not be thinned with solvent during the operation. The concrete surface shall be dry when epoxy is applied. The concrete temperature shall not be below +10 °C.
- 5 An additional layer of low viscosity epoxy in the quantity of about 0.3 kg/m² is applied wet-in-wet onto the first layer. The quantity will depend on the concrete surface, i.e. to what extent the surface is saturated by the first epoxy layer. If curing of the first layer has been completed before the second can be applied the first layer shall be sanded with dry, dust free fine sand (0.5-1.2 mm or 0.5-1.5 mm) to ensure bonding between the epoxy layers.

- 6 Before curing the last epoxy layer shall be sanded with dust free, dry fine sand (0.5-1.2 mm or 0.5-1.5 mm). Sufficient sand shall be used to give the surface a sandpaper-like appearance (about 2 kg/m²).
- 7 After the epoxy primer has cured excess sand is removed by sweeping or some other method.
- 8 Treated, cleaned and dry concrete deck as well as vertical surfaces to a height of about 10 cm are sprayed or brushed with PmBE60 (see Appendix 7) normally in the quantity of 0.3 - 0.4 l/m². Higher or lower consumption may be needed depending on surface porosity. Tack coat quantity is important, no areas must remain untreated but also no ponds must form. The tack coat is immediately sanded sparingly, 1- 2 kg/m², with fine sand, 0.5 - 1.5 mm. With tack coat application the deck and air temperature must be higher than +10 °C.

Setting time is weather and temperature dependent. The sand will reduce setting time as well as lessen problems with sticking/bonding to machines etc.

After the tack coat has set, normally in 1-6 hours, excess sand is removed with compressed air.

- 9 On cleaned, cured and dry tack coat an asphalt concrete wearing course is placed, for instance Topeka or a similarly heavy and durable material. The wearing course must be produced and placed in accordance with Handbook 018, Road Construction. Voids in the wearing course shall be as close as possible to the lowest value allowed for the particular wearing course type used. The wearing course thickness shall be adapted to the design load, wearing course stability and waterproofing properties as well as the transition to adjacent road.

With thickness over 80 mm the wearing course is considered to provide some moisture protection of the concrete. Thin asphalt pavements on concrete bridge decks are particularly vulnerable to damage.

- 10 Where of the wearing course is coming in contact with curbs the waterproofing shall be individually assessed. As a minimum sealing, repeated applications of PmBE60 shall be performed until saturation of the wearing course to a width of 30 - 50 cm from the curb. The sealing is sanded excessively to speed up setting and to prevent sticking to vehicle tires.

Other waterproofing methods are described under pavement type A3-1.

5.2.1.3 Control

Control of epoxy materials shall be performed in accordance with Appendix 2.

Control of the asphalt pavement shall be performed in accordance with

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5.2.2 A2-2 Waterproofing with Polymer Modified Bitumen Emulsion PmBE60

5.2.2.1 Reference

- ASPHALT - Guidelines
- Road Construction, Handbook 018, Public Roads Administration

5.2.2.2 Description

Newly cast concrete decks shall be given a minimum of one week curing and then a minimum of two weeks drying before paving proceeds. It is very important that the moisture content of the concrete is as low as possible. As a minimum the deck surface shall be dry during paving.

Polymer modified bitumen emulsion, PmBE60, shall satisfy the requirements given in Appendix 7.

The execution is described in the following points:

- 1 Existing asphalt pavement (if any) is removed.
- 2 Pre-treatment of the concrete deck is done in accordance with Chapter 4.2, section 4.2.1 - 4.2.3.
- 3 Joints, inlets and drainpipes are cleaned and repaired if necessary.
- 4 Treated, cleaned and dry concrete decks as well as vertical surfaces to a height about 10 cm are sprayed or brushed with PmBE60 in a quantity of 0.3 - 0.5 l/m². The tack coat is immediately sanded sparingly, 1 - 2 kg/m², with fine sand, 0.5 - 1.5 mm. During the operation the deck and air temperature shall be above +10 °C. The quantity of tack coat is important and will depend on the concrete surface texture and absorption. No areas shall remain untreated but also no ponds must be allowed to form that might lock in moisture.

Setting time is weather and temperature dependent. Sand will reduce setting time as well as reduce problems with sticking/bonding to machines and so on.

After the tack coat has set, normally in 1-6 hours, excess sand is removed with compressed air.

Then a layer of PmBE60 is similarly applied. A somewhat smaller quantity is used, 0.2 - 0.4 l/m². The tack coat is immediately sanded with fine sand, 0.5 - 1.5 mm, in the amount of 1 - 2 kg/m².

After the tack coat has set, normally in 1-6 hours, excess sand is removed with compressed air.

- 5 On cleaned, set and dry tack coat an asphalt concrete wearing course such as Topeka or similarly heavy and durable material is placed. The wearing course must be produced and placed in accordance with Handbook 018, Road Construction. Voids in the wearing course shall be as close as possible to the lowest value allowed for the particular wearing course type used. The wearing course thickness shall be adapted to the design load, the wearing course stability and waterproofing properties as well as the transition to adjacent road.

With thickness over 80 mm the wearing course is considered to provide some moisture protection of the concrete. Thin asphalt pavements on concrete bridge decks are particularly vulnerable to damage.

- 6 Waterproofing of the transition between the wearing course and curbs shall be individually assessed. To prevent water intrusion the waterproofing shall be carried out immediately after placing of the wearing course. As a minimum, sealing shall be performed with repeated application of PmBE60 until saturation of the wearing course to a width of 30 - 50 cm from the curb. The sealing is sanded excessively to speed up setting and to prevent sticking to vehicle tires.

Any additional waterproofing between the deck and curb may be achieved by application of pure polymer modified bitumen (PmB) in the transitions, provided one has absolutely dry surface, warm weather and binder temperature up towards the upper limit allowed.

Other waterproofing methods are described under pavement type A3-1.

5.2.2.3 Control

Control of epoxy materials shall be performed in accordance with Appendix 7.

Control of the asphalt pavement shall be performed in accordance with

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5.3 A3 - Asphalt Wearing Course with Full Waterproofing

5.3.1 Pre-treatment of the Bridge Deck

Newly cast concrete decks shall be given a minimum of one week of moist curing and then a minimum of two weeks of drying before paving commences. It is important that the concrete deck is as dry as possible. As a minimum the surface shall be dry during paving, ref. Appendix 9.

Pre-treatment of concrete decks consists of surface cleaning and repair of local cracks, defects and depressions beyond allowable deviations. The pre-treatment is described in Chapter 4.2 and shall encompass all surfaces the waterproofing or wearing courses are in contact with.

For pavement type A3-1 and A3-3 it is particularly important that any wax based curing membrane is completely removed from the concrete deck.

Pavement type A3-4 is less sensitive to wax based curing membrane remnants on the concrete deck. This is also the case with remnants like bitumen when rehabilitating or renewing pavement on older bridges.

Treated concrete surfaces shall have a tensile strength of minimum 1.5 N/mm² (see Appendix 3).

The job requires nice, dry weather and temperature above +10 °C in the deck and air during execution.

Pre-treatment of steel decks shall prevent corrosion as well as ensuring bonding between the steel decks and overlying layers. Pre-treatment is undertaken as described in Chapter 4.3.

5.3.2 A3-1 Waterproofing with Epoxy and Waterproof Mastic Asphalt

5.3.2.1 Reference

- ASPHALT - Guidelines
- Road Construction, Handbook 018, Public Roads Administration

5.3.2.2 Description

Pre-treatment of the Concrete Deck

This is described in Chapter 5.3.1.

It is particularly important that wax based curing membrane remnants are completely removed when cleaning the concrete deck.

Epoxy Treatment

Epoxy treatment of the concrete bridge slab consists of applying two layers of solvent free epoxy. The first layer shall be with low viscosity epoxy to facilitate intrusion into the concrete surface and priming it. The second layer that is sanded with fine-grained aggregate shall function as a sealant.

The second layer can be tar epoxy.

The epoxy materials shall satisfy the requirements in Appendix 2, Table 1.

The sanding material shall consist of clean aggregate from weathering resistant rock. It shall be dry, free of dust and coatings, normally with a gradation between 0.5 and 1.5 mm.

Where grades or traffic represent a major risk of sliding, increased friction may be obtained by sanding with coarser material, such as 2 - 4 mm, with a maximum particle size of 4 mm. Only small quantities of such material should be used. Increasing particle size increases the risk of puncturing the epoxy layer.

When applying epoxy the concrete deck temperature shall exceed +10°C. The concrete deck surface shall be dry. There shall be no risk of dew forming. Bright sunlight and wide temperature variations should be avoided, and the temperature shall preferably be falling while paving and during the epoxy curing period.

The epoxy job shall be undertaken under cover or within a tent with adequate ventilation if weather conditions so require.

Epoxy materials may be applied using roller, brush, squeegee or similar. The application may also be sprayed on with special equipment. After spraying of the first layer, the material shall always be treated with a broom or similar to reduce the extent of minor holes in the second layer. The spraying pressure shall be generated by liquid pumps without air or other gasses coming in unwanted contact with the epoxy material before it leaves the nozzle.

The application shall ensure that the epoxy material is evenly distributed over the entire surface. The entire bridge slab shall be covered and the layer shall overlap previous layers by a minimum of 10 cm.

Mixed epoxy material shall be applied within its normal pot life (workable period), typically about 30 minutes.

Material consumption shall be about 0.5 l/m² in the first layer and about 1.0 l/m² in the second. The second shall be applied wet-in-wet with the first layer, normally within maximum 20 hours (at a temperature of +20°C) after the first layer has been placed. Layer number two shall be sanded with fine sand 0.5 - 1.5 mm, normally 1 - 2 kg/m².

Where weather and other conditions indicate that the first layer will be cured before the next layer is applied, both layers shall be subject to sanding.

Sanding shall take place in such quantity and at such time that the completed surface appears as a coarse sandpaper with protruding aggregate particles.

The completed epoxy coating shall not be exposed to traffic or other mechanical strain with the exception of that necessary to continue the paving job.

Visible perforations in the completed epoxy layers shall be sealed by locally applying new epoxy, which is then sanded. No stone particles shall penetrate both layers.

Application onto remaining pavement layers must not be undertaken before acceptable curing of the epoxy layers has taken place (1-4 days depending on temperature).

Waterproof Mastic Asphalt

Waterproof mastic asphalt shall be produced and placed in a manner to satisfy the requirements to waterproof mastic asphalt as stated in Appendix 8.

Waterproof mastic asphalt is placed to a 15 mm thickness and shall nowhere be less than 10 mm or more than 20 mm. The minimum thickness of 10 mm shall ensure complete waterproofing, the maximum thickness shall ensure against deformation of the waterproofing layer. Placing may be effected manually or with a paver. The material is placed directly against vertical surfaces such as curbs, inlets and so on.

Waterproof mastic asphalt should always be placed starting from the highest point to prevent water from unanticipated precipitation to be held back towards the joint(s) that can force its way underneath the waterproofing of previously placed pavement. Both with manual and machine paving the edge of the already placed pavement shall be heated with a joint heater and the joints carefully brushed by hand. If blemishes still remains new hot material shall - provided the joint area temperature is acceptable - be applied and finished to attain complete homogeneity in the joint. If not, the joint shall be carefully heated with propane gas, hot material applied and the joint finished in a manner to achieve full homogeneity.

The waterproofing layer must not be exposed to vehicle traffic beyond that necessary to continue the paving job.

Other construction traffic shall be avoided. Exception may be made in special cases. Care should be taken to keep the surface free of stone and gravel materials. Standing vehicles shall be avoided. Signs for slippery roadway should be put up.

The waterproofing layer shall not be left exposed for longer periods of time. The wearing course shall be laid within 2-3 days after the waterproofing layer has been placed.

There is a major risk of blisters forming on an unprotected waterproofing layer. The formation of blisters can destroy the functionality of the waterproofing layer.

Wearing Course

The wearing course shall be produced and placed in accordance with Handbook 018, Road Construction.

Attempts shall be made to limit voids in the wearing course close to the lowest level allowed for the wearing course in question.

Connection Wearing Course/Curb

The connection between wearing course and curb shall be waterproof.

This can be accomplished by not having the wearing course placed all the way up against vertical surfaces, but terminating about 20 mm short, to form a joint-opening over the entire wearing course depth. The joint-opening is formed using a wooden screed rail. After the wearing course is placed, rolled and cooled, the screed rail is removed and the joint-opening completely filled with joint sealant. Filling of joint-openings shall preferably take place on the same day the wearing course is laid. If this cannot be done the screed rail shall remain until joint sealant filling can take place. The joint-opening shall be clean (free of dust) and dry when filled. Cleaning can be undertaken using compressed air and possibly by drying with propane burner. Normally rubber asphalt is used as joint filling material along curbs.

Alternative procedures can be relevant (joint backing, sealing etc.).

5.3.2.3 Control

Control of epoxy material shall be performed in accordance with Appendix 2.

Control of placed and cured epoxy bonding to the concrete deck shall be performed in accordance with Appendix 3.

Control of waterproof mastic asphalt shall be performed in accordance with Appendix 8.

Control of the asphalt pavement shall be performed in accordance with

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Control of joint sealant shall be performed in accordance with Appendix 4.

5.3.3 A3-2 Waterproofing with Prefabricated Membrane

5.3.3.1 Reference

- ASPHALT - Guidelines
- Road Construction, Handbook 018, Public Roads Administration

5.3.3.2 Description

Pre-treatment of Concrete Deck

This is described in Chapter 5.3.1.

Waterproofing Layer of Prefabricated Membrane

Prefabricated membrane is placed in one or two layers (depending on type) that are fully bonded or welded to the concrete deck or underlying membrane.

The membrane shall give lasting waterproofing across the entire surface and at all connections. The membrane shall be free of damage and weak spots where mechanical strain may result in holes.

The membrane shall possess such properties that breakage will not occur with repeated stretching to an extent to which it will normally be subject.

The membrane materials shall satisfy the requirements in Appendix 5.

There are a number of prefabricated membrane types. These are mostly polymer modified asphalt membranes with inserted reinforcement of glassvlies/polyester weave or polyester/aluminum.

Technically the prefabricated membranes can be divided into two groups. One group consists of membrane types that are bonded to the support with a special bitumen or all-welded. The other group consists of self-bonding membranes.

Job Execution

In general the following applies:

Knobs and ridges that will prevent complete contact between membrane and concrete is removed.

Treated, cleaned and dry concrete deck with a temperature above +5 °C is bonded according to specifications from producer or supplier.

It is important to provide for proper coverage (no untreated spots), but neither must ponds of tack coat form. It is important that treated areas are completely dry before the membrane is rolled out.

The membrane should be placed along the bridge deck. The laying starts at the lowest side towards the top to ensure runoff unhindered by joints.

Overlapping along the roadway shall be 10 cm and at end joints 15 cm. The overlaps shall be carefully bonded/welded. The joint shall have properties corresponding to that of the membrane elsewhere.

The membrane shall be carefully bonded to prevent water intrusion at all connections at bridge edges and against joints. See Chapter 6.

With double layered membrane construction, other membrane layers (protective membrane) are normally bonded/welded onto underlying layers similarly to the way the first was bonded/welded, provided directions from producer/supplier do not indicate otherwise. The layers shall be mutually offset to produce a minimum of 20 cm overlap.

Placing membrane with tack coat

Previously an oxidized bitumen 92/27 or 110/30 were used as tack coat. Today use of polymer-modified bitumen may be appropriate. The tack coat shall be heated in thermostat-controlled melting pots. The temperature of oxidized bitumen should not exceed 220-230 °C. See the supplier's description regarding polymer-modified bitumen.

The membrane is rolled out on a coated, dry and clean concrete deck in a wave of low viscosity tack coat. It is important that the tack coat is forced forward in front of the membrane roll to ensure complete bonding to the deck as well as avoiding enclosed air pockets. Normal consumption of tack coat is 1.5-2.0 kg/m².

With stiff membranes or in cold weather it may be an advantage first to spread the warm tack coat in an even layer. Then the membrane is welded to the deck with a propane burner. In this manner any stresses in the membrane material is released and bulges and air pockets are avoided.

Otherwise reference is made to directions from the producer/supplier.

Placing of fully welded membrane

The polymer based asphalt membrane shall have a welding underside and the membrane shall be fully welded to the deck with a gas burner mounted on a paver.

The membrane is rolled out on a coated, dry and clean concrete deck and is fully welded so that the bitumen flows in front of the roll. It is important that the tack coat is forced forward in front of the membrane roll to ensure complete bonding to the support as well as avoiding enclosing air pockets. Overheating of bitumen must be avoided.

Otherwise reference is made to directions from the producer/supplier.

Placing of self-bonding membrane

The contact surface of the self-bonding membranes is coated with a silicon treated protective paper to be removed when placed. The membrane is positioned correctly and is placed by having the silicon paper being pulled evenly out. After adjustment/rolling the tacky surface is pressed firmly against the deck. To ensure adequate bonding, especially at the joints, a hand-operated roller should be used.

*If water has formed on the membrane it must dry naturally. **Propane burner must not be used.***

Otherwise reference is made to directions from the individual producer/supplier.

Protective layer

When working with the membrane and prior to placing the protective layer, there must be no traffic on the membrane beyond that necessary to continue the paving job. The waterproofing shall therefore be covered with a protective layer of fine-grained bituminous material as soon as possible. The layer shall be as waterproof as possible. The protective layer will serve as a warning layer when the wearing course is worn through.

Asphalt concrete Ab4 may be used as protective layer. Asphalt concrete shall be produced in accordance with Handbook 018, Road Construction.

Any bonding between membrane and protective layer is undertaken according to directions from the producer/supplier.

The protective layer is placed to a thickness of 15-20 mm after compaction by hand or with paver that will not damage the membrane. The material is placed directly against vertical surfaces such as curbs, inlets and so on. The temperature of the material should not exceed 140°C.

When paver is used it is an advantage to put some asphalt as protection at the end of the membrane to avoid displacement when starting the paver.

Rolling shall be carried out with care. A light paver shall be used with the first passes to avoid displacement of the membrane. The protective layer shall, however, be rolled in a manner to obtain maximum waterproofing.

Hauling of materials shall as far as possible take place on already paved areas.

When driving on the membrane, some material shall be spread under wheels of the vehicle. Care shall be taken when starting and braking. The trucks shall dump the material into the paver and then leave.

Wearing Course

The wearing course shall be produced and placed in accordance with Handbook 018, Road Construction.

Voids in the wearing course shall be close to the lower limit allowed for the wearing course type in question.

Connection Wearing Course to Curb

Connections between wearing course and curb shall be waterproof.

This may be achieved by not placing the wearing course all the way up against vertical surfaces but having it terminated about 20 mm short, to form a joint-opening over the entire wearing course depth. The joint opening is formed using a wooden screed rail. After the wearing course is placed, rolled and cooled, the screed rail is removed and the joint-opening completely filled with joint sealant. Filling of joint-openings shall preferably take place on the same day the wearing course is laid. If this cannot be done the screed rail shall remain until joint sealant filling can take place. The joint-opening shall be clean (free of dust) and dry when filled. Cleaning can be carried out using compressed air or drying with propane burner. Normally rubber asphalt is used as joint filling material along curbs.

Alternative procedures may be relevant (joint backing, sealing etc.).

5.3.3.3 Control

Control of prefabricated membrane shall be performed in accordance with Appendix 5.

Control of the asphalt pavement shall be performed in accordance with

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Control of joint sealant shall be performed in accordance with Appendix 4.

5.3.4 A3-3 Waterproofing with Polyurethane Membrane

5.3.4.1 Reference

- ASPHALT - Guidelines
- Road Construction, Handbook 018, Public Roads Administration

5.3.4.2 Description

Pre-treatment of the Concrete Deck

This is described in Chapter 5.3.1.

It is especially important that wax based curing membrane remnants are completely removed when cleaning the concrete deck.

Job Execution

In general, the following applies:

Treated, cleaned and dry concrete deck is primed in accordance to specifications from producer/supplier. Deck and air temperature shall be above +10 °C. Relative humidity shall not exceed 70%.

Polyurethane is very susceptible to moisture in the concrete. The moisture content in the concrete deck shall therefore be controlled in accordance with Appendix 9. Primer is normally applied with a roller or brush in a quantity of 0.2 kg/m².

It is important that the polyurethane membrane is placed on the primed surface immediately after the solvent has evaporated (15 min - 6 hours depending on temperature and humidity).

Polyurethane is a two-component system that bonds quickly and gives an elastic (crack covering) membrane. The material is normally applied with two-component sprayer to a 2 mm thickness.

The polyurethane membrane can be walked on after ½ - 3 hours and is cured through after 3-5 days at 20 °C.

Both the bridge deck and any curbs to outside corners and about 10 cm up along bridge railing posts are treated in the same operation.

The polyurethane material shall satisfy the requirements in Appendix 6.

To achieve acceptable bonding between membrane and overlying asphalt layer, a layer of Topeka 4S or mastic asphalt (Sta 2/Sta 4) is placed to a thickness of 10±5 mm. Before placing this layer the polyurethane shall be completely cured.

Wearing Course

The wearing course shall be produced and placed in accordance with Handbook 018, Road Construction.

Voids in the wearing course shall be close to the lower limit allowed for the wearing course type in question.

Connection Wearing Course/Curb

With this membrane type, proper waterproofing is ensured at connections between bridge deck and curb. But the solution is prone to damage due to mechanical strain, winter maintenance etc.

5.3.4.3 Control

Control of polyurethane materials shall be performed in accordance with Appendix 6.

Control of placed and cured polyurethane membrane bonding to the concrete deck shall be performed in accordance with Appendix 3.

Control of Topeka 4S or mastic asphalt (Sta 2/Sta 4) is performed in accordance with Appendix 7 or Appendix 8 respectively.

Control of the asphalt pavement shall be performed in accordance with

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5.3.5 A3-4 Waterproofing with PmB-based Materials

5.3.5.1 Reference

- ASPHALT - Guidelines
- Road Construction, Handbook 018, Public Roads Administration

5.3.5.2 Description

Pre-treatment of the Concrete Deck

This is described in Chapter 5.3.1.

This pavement type is less sensitive to wax based curing membrane remnants on the concrete deck. This is also the case as far as bitumen remnants go regarding pavement rehabilitation or renewal on older bridges.

Job Execution

Pre-treated, cleaned and dry concrete deck is sprayed or brushed with tack coat PmBE60 (see Appendix 7) including vertical surfaces to a height of about 10 cm. A quantity of 0.3-0.4 l/m² is used. The tack coat is sanded immediately with fine sand, 0.5 - 1.5 mm in a quantity of 1 - 2 kg/m². Deck and air temperature shall be above +10 °C during paving. If the concrete appears open/porous the quantity should be increased to 0.5 l/m². The quantity of tack coat is important. No untreated spots shall remain, but neither must ponds form.

Setting time is weather and temperature dependent. Sanding will reduce the setting time as well as reduce problems with sticking to machines and so on.

After the surface is dry (3-24 hours) excess sand is removed with compressed air.

A Topeka 4S waterproofing layer is placed with a thickness of 12±3 mm (26.5±6.5 kg/m²) on fully set, dry and cleaned deck. The waterproofing layer which is machine or manually placed with a material temperature < 190 °C, is self-compacting and shall be placed directly in contact with vertical surfaces.

The material temperature shall never exceed 200 °C to avoid damage to binder properties.

The waterproofing layer shall not be trafficked by other vehicles than necessary to proceed with the paving job. Other construction traffic shall be avoided.

The waterproofing layer shall not lay unprotected for any period of time. The wearing course shall be placed within 2-3 days of placing of the waterproofing layer. *There is a big risk of blisters forming on the unprotected waterproofing layer. Formation of blisters can destroy the functionality of the waterproofing layer.*

Wearing Course

The wearing course shall be produced and placed in accordance with Handbook 018, Road Construction.

Wearing course of suitable type and within allowable dead load is placed against vertical surfaces and then rolled. Voids in the wearing course should be held close to the lowest allowable limit for the wearing course in question.

On warm days the waterproofing layer will have a tacky surface. This may cause problems with sticking and bonding to paving equipment. The problem may be reduced by applying sand immediately before placing the wearing course, about 1 - 2 kg/m². Sand should be used sparingly in order not to reduce the adhesion between the waterproofing layer and the wearing course.

Connection wearing course to curb

When the wearing course is placed and compacted, sealing is undertaken along the side edges with the application of PmBE60 about 30-50 cm wide. This is repeated until saturation. The top layer is sanded excessively to speed up setting as well as preventing unwanted sticking/bonding to vehicle wheels. The sealing shall be undertaken immediately after placing of the wearing course to prevent water intrusion.

In areas where water regularly accumulates, additional waterproofing between pavement and curb may be achieved by applying pure polymer modified bitumen (PmB) in the connection, provided the pavement is absolutely dry, the weather nice and warm with a binder temperature near the upper allowable limit.

5.3.5.3 Control

Control of polymer modified bituminous materials shall be performed in accordance with Appendix 7.

Control of the asphalt pavement shall be performed in accordance with
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5.4 B1 - Monolithic Concrete Wearing Course

5.4.1 Reference

- Bridge Design, Handbook 100, Public Roads Administration
- Road Construction, Handbook 018, Public Roads Administration

5.4.2 Description

Monolithic concrete wearing courses are cast in the same manner as ordinary bridge decks, ref. Chapter 4.1 with the exception that the wearing course thickness will be added to the top reinforcement cover when considering strike-off level. Also see Chapter 3.4.

The surface of monolithic concrete wearing courses shall be grooved transversely. The grooving should be done immediately behind the vibrating screed with a subsequent application of curing membrane.

5.4.3 Control

Control of materials and execution shall be performed in accordance with:

- Process Code 2, Handbook 026, Public Roads Administration
- Laboratory Investigations, Handbook 014, Public Roads Administration.

5.5 B2 - Concrete Overlay

5.5.1 Reference

- Road Construction, Handbook 018, Public Roads Administration

5.5.2 Description

The work operations involved in placing of concrete overlay, apart from testing of mixing recipe and the operations described in Chapter 5.0.3, include:

Preparations:

- 1 *Placing slip form paver steering wires or screed rails for rail guided levelling equipment depending on type of equipment to be used.*
- 2 Control of overlay thickness from wires or rails.

Execution:

- 3 Application of epoxy glue along borders and casting joints. If the supporting surface is moist it must be dried with for example a propane burner combined with compressed air before epoxy is applied. Epoxy glue stripes shall be 30 cm wide along longitudinal borders and 50 cm along transverse borders or casting joints. All vertical-casting joints shall, moreover, be given an application of epoxy glue. (Regarding alternative gluing, see the guideline below).
- 4 Application of cement/latex glue on overlay areas where epoxy glue is not being employed.
- 5 Dumping, distribution and placing of overlay concrete.
- 6 Compacting and striking off overlay concrete.
- 7 Any manual edging or patching of defects.
- 8 Transverse grooving.
- 9 Application of curing membrane.

Follow up:

- 10 Any protection against frost and temperature variations, moist curing/protection against drying. (The scope of these measures should be adapted to weather conditions).

- 11 Final control with regard to evenness, cracks and delamination.

The individual activities are discussed in more detail below.

Evenness of Deck, Alignment

If unevenness results in the overlay locally having less than the required minimum thickness, this may be acceptable (up to about 2 - 3 m bridge lengths) provided the overlay in the area concerned is fully glued to the deck with epoxy glue. A slip form paver requires a certain minimum overlay thickness to be able to pass.

Cleaning of the Deck

Overlays are usually placed along one lane, or possibly along half width of the bridge at a time. When casting there will always be some spills outside the overlay area. Therefore it may be advantage to clean half the bridge width at a time. Otherwise reference is made to Chapter 4.2.1.

Gluing to the Deck

When placing overlay the deck should be slightly absorbent. Concrete substrates with a water/binder ratio of $m \leq 0.40$ containing *silica fume* should preferably be dry, **not** moistened by pre-wetting.

Low quality concrete substrates (C35 - C40) shall be pre-wetted for 1 - 2 days but letting the surface be allowed to dry (light gray) before the overlay is placed.

In some counties we have favourable experience with the use of a special cement mortar for bonding the overlay to the support instead of epoxy glue and cement/latex glue. Such alternative gluing is simpler to undertake and may be used where experience proves that it works.

Normal procedure when using cement mortar is:

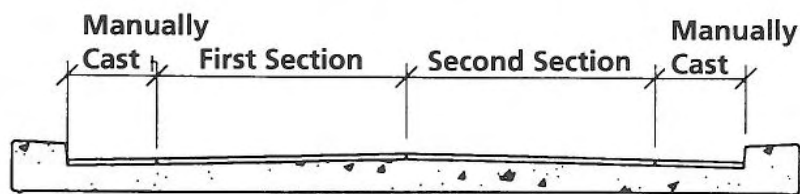
- 1. Old concrete is pre-treated with sandblasting or sand washing.*
- 2. The concrete is well pre-wetted. Before application of cement mortar, no free water shall remain on the surface, but the concrete shall be wet.*
- 3. The cement mortar is poured or dumped onto the pavement and is spread with rubber swab and brushed well into the support.*
- 4. Consumption on even concrete is about 1 kg/m².*
- 5. The new concrete is applied soonest and within 15 - 30 min. depending on weather/drying.*

Even if the most secure bonding is achieved with dry (light gray) concrete surface with $m \leq 0.40$, experience has still shown that acceptable bonding is achieved even if the surface is moist, i.e. dark gray. Free water on the substrate, however, cannot be tolerated when placing the overlay.

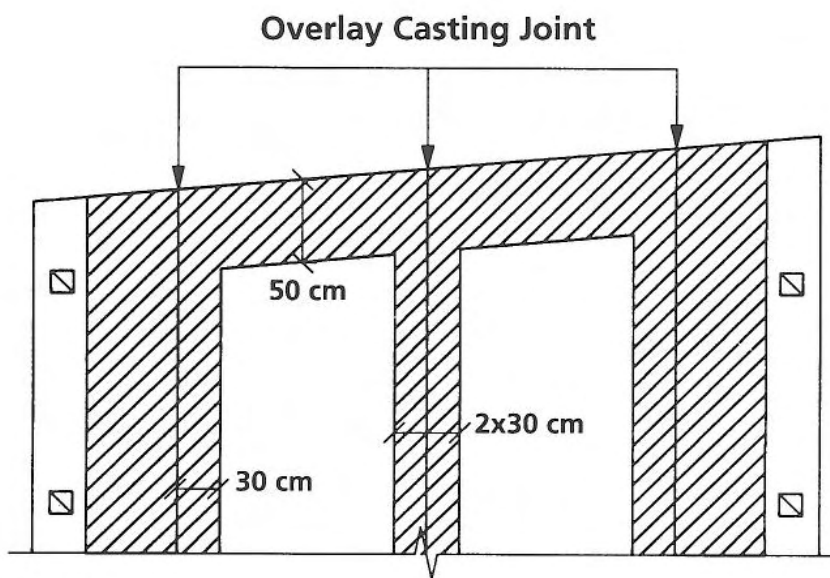
Where epoxy glue is used the concrete substrate should be as dry as possible and the support must be light gray dry. When placing overlay during humid weather conditions the following applies:

- free water on the pavement is removed by compressed air ahead of the glue and casting front*
- the substrate is dried with propane burner until light gray where the epoxy glue shall be placed*
- a less viscous consistency is used with cement/latex glue.*

Past experience has shown that if delamination occurs, it first appears along the overlay borders and at casting joints. This is where the bonding stresses from shrinkage and temperature movements are greatest. The intention is therefore to keep the overlay in place by using the best glue available at these locations and thus prevent delamination to spread to other areas. The best concrete glue known is a specially formulated epoxy glue for gluing fresh concrete to cured concrete. The principle for gluing of overlay to the support is shown in Figure 2.



Cross-Section



 : Epoxy glue

 : Cement/Latex Glue

Plan

Figure 2 Gluing of Overlay to the Deck

In the main area, i.e. the area within the epoxy glue, cement/latex slurry is applied by brushing it well into the surface. We are actually not sure if this gluing is necessary or not known, but there is always a risk associated with the removal of an element from a concept that has worked.

The cement/latex material is produced from

- liquid part latex: water = 1 : 2
- dry matter part cement: sand = 1 : 1

that is mixed to a suitable creamy consistency.

Ordinary sand such as 0 - 8 mm is used. If the slurry material becomes too wet it will separate. The material is mixed in an ordinary construction site mixer and most simply transported with a wheelbarrow from the mixer to the casting site.

The slurry material shall be brushed well into the substrate. It is not sufficient to just spread it over the surface. The slurry layer shall completely cover the substrate but must not be placed too thick. (Normal thickness 1 - 4 mm).

As latex, special products based on styrene butadiene or acryl is used. Attempts have also been made to omit sand in the slurry but it is anticipated that the use of sand facilitates efficient brushing.

Relevant epoxy products are supplied with various viscosities (different brand names). As a general rule low viscosity epoxy is advantageous in cool weather and on rough surfaces. The epoxy glue setting time should be harmonized as far as possible with the curing of the concrete. The epoxy glue can be applied with a pneumatic gun, roller or swab.

When placing overlay the epoxy stripes are distributed first, brushing of slurry material follows. It does not matter if slurry material comes in contact with the epoxy glue.

The Overlay Concrete

The concrete must have a consistency and a composition that is suitable for compaction and levelling equipment. Especially a slipform paver is particular about the concrete. On each new project one day of testing should be anticipated to arrive at a favourable mix design. This is the case also if the recipe has shown good results earlier. Attempts to force a concrete recipe on a paver that "it does not like" will result in an inferior overlay.

Steel fibre reinforcement is being used in concrete overlays, 50 kg/m³ of 30 to 25 mm long fibres, alternatively 75 kg/m³ of 18 mm long fibres unless anything else is stated. No reinforcement such as wire mesh is used.

Omitting mesh reinforcement is favourable for several reasons:

- *It is possible to properly apply glue to the substrate.*
- *The fresh concrete can be dumped next to the paver, the concrete does not have to be laying for long and loose workability before compaction/levelling.*
- *It is simpler to place the overlay even if the support has ridges.*
- *The risk of the reinforcement being placed too high and being exposed after a short period of wear is eliminated.*

The main effect of the steel fibre is to distribute stresses in the overlay. This lessens concentration of stresses that potentially can generate cracks and delamination. The steel fibre contribute to improved impact resilience in the cured concrete and reduced tendency of

cracking due to plastic shrinkage in the early phases. It is not known if the fibre is really necessary is not known but also here it is connected with some risk to eliminate one element from a proven concept.

In fresh concrete the steel fibres function as extremely elongated aggregate grains, i.e. they have an adverse effect on workability. Moving or distributing concrete manually is very strenuous work. This must be compensated with a larger mortar content and a smaller share of coarse aggregate in the concrete. The loss of wearing resistance this may cause can be compensated with a higher concrete strength class. Reduced workability may result in inability to cast samples that reflect the actual strength class of the concrete.

The fibres contribute significantly in increasing the concrete's water demand, and this must be taken into consideration when determining mix design and admixture dosage. The practical limit with regard to strength is therefore probably lower for fibre concrete than for concrete without fibres.

The fibre concrete moves so heavily in the mixer that the fibres should normally not be added until the plasticizer and super plasticizer have achieved their effects. Alternatively reduced batch size can be used.

Maximum particle size D_{90} for overlay concrete shall be 16 mm, alternatively in the range 16 - 20 mm. Aggregate for concrete wearing course shall be from hard, tough and durable rock. The aggregate gradation shall be continuous and the particle shape favourable with regard to water demand and use of maximum proportion of coarse aggregate in the concrete. The aggregate shall not have smooth surfaces or coating that will reduce adhesion of the cement glue. The flakiness number for aggregate 11, 2 -16 mm shall be < 1.45 . The coarse aggregate shall satisfy the requirements for aggregate used in concrete decks stated in Handbook 018, Road Construction.

Using larger maximum particle size than specified may result in compaction and levelling problems where the overlay thickness is modest. Smaller maximum particle size can result in unfavourably high water demand for the concrete. Coarse aggregate should preferably be clean, crushed durable rock because crushed aggregate provides better bonding to the cement and higher compressive and tensile strength than natural gravel.

The fine aggregate should be well graded natural sand with a content of particles less than 0.25 mm preferably at 8 - 15%, i.e. somewhat higher than what is favourable for soft cast concrete of the same strength class. The use of crushed fine aggregate is less favourable with overlays than with road concrete because of

- *smaller thickness and thus reduced tendency of edges to sag*
- *the steel fibre has already reduced workability to the extent such reduction is acceptable.*

The type of cement for overlay concrete should be standard cement or preferably moderate heat high strength cement. With strength class C65 and higher the use of moderate heat high strength cement will as a rule be a requirement.

Silica fume should be used in overlay concrete but the dosage must be limited so that the concrete does not bond too firmly to the levelling equipment. A normal dosage is 15 kg/m³.

With overlay concrete both plasticizer and superplasticizer is normally used. Superplasticizer may preferably be on a naphthalene basis (reduces cohesivity in concrete). Air-entrainer cannot be used with concrete to be kept to a high strength class except in small dosages. Plasticizer and super- plasticizer contribute within relevant consistency levels little to increased slump, but still contribute significantly to improved compactability of the concrete.

When using concrete with a softer consistency than about 7 - 8 cm slump, which often is a condition for using light levelling equipment, notice should be made of the technological parameters that affect the tendency of concrete to crack in the early plastic phase, ref. Chapter 4.1.1.

Concrete Casting, Placing of Overlay

Overlay concrete is dumped on the bridge deck on top of the cement/latex glue. It is spread across the deck, compacted and stroken off.

Where the bridge is on a grade it was previously considered "correct" to cast uphill. Experience has shown that pavement can just as well be cast in a "downhill" direction provided the concrete slippage is compensated with additional concrete in front of the vibrating screed. The casting direction can therefore be determined based on practical considerations in each individual case.

When vibrating screed is used, the overlay concrete must be compacted with poker vibrator before being stroken off. The vibrating must be performed thoroughly to achieve uniform and good contact to the deck. Use of poker vibrator along the screed rails/side boards is particularly important.

If specified evenness is not achieved also the overlay can be grinded. The overlay may be prepared for grinding by raising the strike-off level 10 mm, ref. Chapter 3.4.

If concrete trucks will be driving on the deck where overlay is placed, dirt must be washed (hosed) from the wheels before they can enter the bridge.

In addition, reference is made to the job description in Chapter 4.1.1 which is relevant also for overlay.

Post-treatment

*As a rule edges behind the levelling equipment, have to be finished manually. The float should be moved **out towards** the already completed wearing course or vertical border to achieve a tight connection. Any surface defects are corrected by hand with new, fresh concrete. Then piano wire rake or a wide, thin piassava broom is drawn across the bridge to produce 1 - 2 mm deep grooves.*

The curing membrane is sprayed on immediately after surface treatment is completed. Experience has shown that a curing membrane consumption of about 0.5 l/m² or more gives adequate protection against drying, making additional curing measures unnecessary provided concrete of “paver consistency” of 0 - 3 cm slump is being used. With wetter consistency watering should be used, ref. Chapter 4.1.1.

When there is a risk of frost or large temperature variations the first day, the overlay should be protected with tarpaulin or preferably 10 mm Ethafoam mats the first two nights.

5.5.3 Control

Control of materials and execution shall be performed in accordance with:

- Process Code 2, Handbook 026, Public Roads Administration
- Laboratory Investigations, Handbook 014, Public Roads Administration.

Moreover, 1 - 2 weeks after execution there shall be performed control of:

- evenness, with measuring wedge against straightedge on knobs,
- possible delamination, especially along casting joints and terminations, by knocking with hammer or an iron bar,
- possible cracking, visual control of dried deck.

5.6 C1 - Combined Waterproofing/Wearing Course

5.6.1 Reference

- ASPHALT - Guidelines
- Road Construction, Handbook 018, Public Roads Administration.

5.6.2 Description

Pre-treatment of the Concrete Deck

Pre-treatment of the concrete deck is performed as described in Chapter 5.3.1.

This pavement type requires that damage, especially rutting, is repaired with materials with large deformation resistance (cement mortar and similar).

Job Execution

Pre-treated, cleaned and dry concrete deck is sprayed or brushed with PmBE60. A quantity of 0.3 - 0.5 l/m² is used. The tack coat is immediately sanded with fine sand, 0.5 - 1.5 mm in a quantity of 1 - 2 kg/m². During the operation the deck and air temperature shall be above +10 °C. If the concrete appears open/porous, another layer of PmBE60 is applied, in a quantity of 0.3 - 0.4 l/m², which is immediately sanded with fine sand of corresponding type, and quantity. The quantity of tack coat is important and will depend on the concrete surface texture and absorption. No areas shall remain untreated but also no ponds must form that might lock in moisture.

Setting time for the emulsion is weather and temperature dependent. Sand will reduce setting time as well as reduce problems with sticking/bonding to machines and so on.

After the surface is dry (3-24 hours), excess sand is removed with compressed air.

On fully set, dry and cleaned pavement a waterproofing layer/wearing course of Topeka S4 is placed by machine with a thickness of 15 - 20 mm (33 - 44 kg/m²) covered with pre-coated chippings 4 - 8/8 - 11 mm in a quantity of 3 - 5 kg/m². To obtain better material stability the binder content may be reduced to 11.5 - 12%.

If the bridge can withstand greater dead load, but cannot stand the load of full-fledged waterproofing, it is recommended to replace Topeka 4S with Top8/Top11 or Sta8/Sta11 and modified binder. It is important to aim for adequate stability at the same time as the binder content is kept as high as possible to ensure the waterproofing properties. The material is placed with a minimum layer thickness 2.5 times the upper nominal stone size (20 - 30 mm / 50 - 75 kg/m²) and covered with pre-coated chippings in the size and quantity stated.

The material temperature shall never exceed 200 °C to avoid damage to properties of the binder.

After the Topeka 4S is placed there should be a pause (for cooling of the pavement) before spreading of the pre-coated chippings. This will reduce the risk of the wearing course being punched through and of reduced surface properties (friction).

On extra warm days or after longer periods of normal summer weather the pavement surface might easily become tacky resulting in traffic problems because of sticking, messing up etc. Such problems can be alleviated by sanding with dry sand with particles < 4 mm.

5.6.3 Control

Control of polymer modified bituminous materials shall be performed in accordance with Appendix 7. When using other types material than Topeka 4S the results shall be checked against job mix formula.

6 Waterproofing of Details

When pavement types providing full waterproofing are used, terminations of the waterproofing against such items as vertical surfaces, inlets, joints, posts etc. represent weak points in the waterproofing. These areas must therefore be given special attention.

For other pavement classes, which do not provide full waterproofing, it is not necessary to pay similar attention to the terminations.

When using prefabricated membranes emphasis shall be put on directions given by supplier and producer regarding description and execution of waterproofing and wearing course terminations.

6.1 Terminations

6.1.1 Bridge End

To prevent or counteract intrusion of moisture under membrane and waterproofing layer at the bridge end, the membrane material shall be extended 20 - 30 cm down onto the vertical surface before backfilling and compaction takes place. (Waterproof mastic asphalt and Topeka 4S are only placed up to the edge).

The membrane is normally not extended all the way down to the relief slab. Neither is waterproofing between relief slab and abutment normally carried out

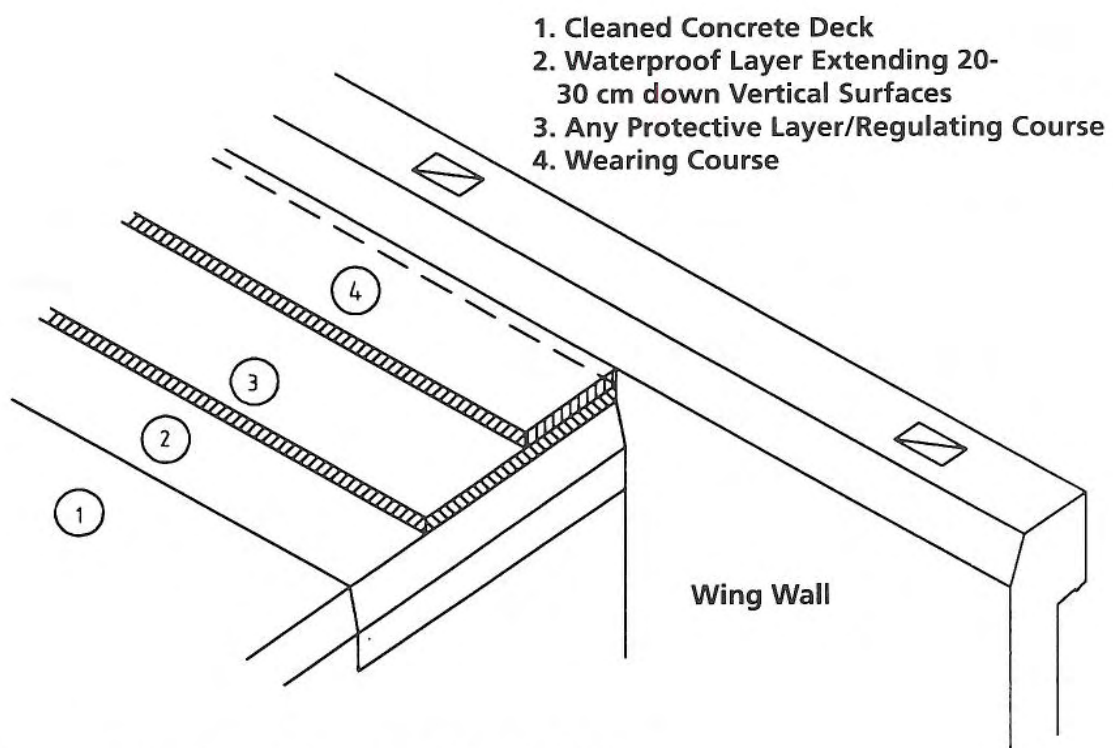


Figure 3 Termination at Bridge end before Backfilling

6.1.2 Bridge Joints

The bridge joints can in brief be divided into three main types depending on movement capacity and complexity:

1. Weakened-plane or dummy joints
2. Asphalt joints
3. Prefabricated bridge joints

Dummy joints are relevant only for bridge types such as culverts and short frame or slab bridges. The membrane is continued down at the bridge end as shown in Figure 3. Waterproofing layer of Topeka 4S and waterproof mastic asphalt and protective layer are extended to end of bridge. Wearing course is placed over the joint and compacted in the usual manner. Bridge end is marked to facilitate sawing a maximum 20 mm wide cut almost through the wearing course. This is filled with suitable joint sealant. Otherwise see Handbook 026, Process Code-2, and Process 86.122.

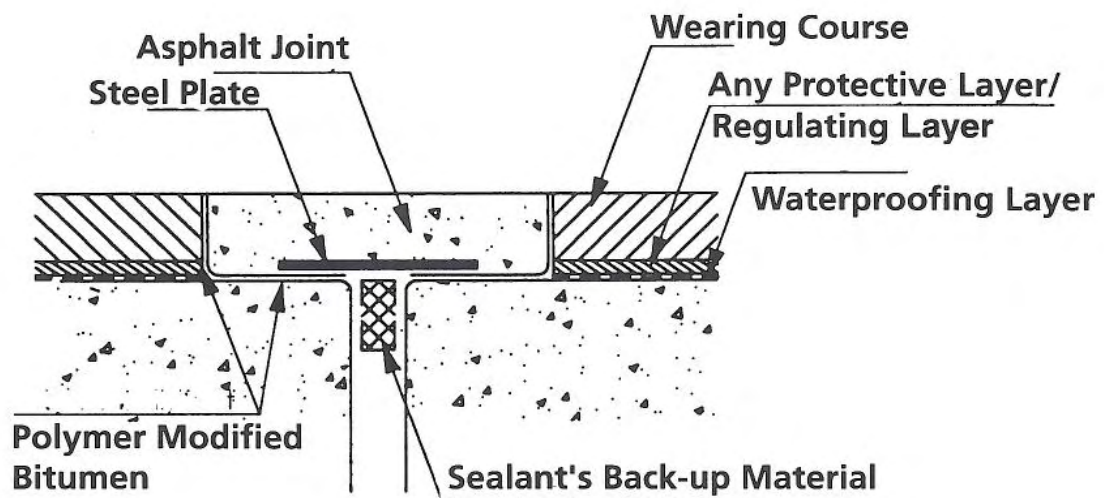


Figure 4 Example of Connection to Asphalt Joint with Pavement Class A3

If the waterproofing system uses epoxy, polyurethane or PmBE60, these are extended up to and minimum 10 cm down into the joint opening. The sealants back-up material is fitted and a board or similar placed over the joint opening to prevent the material from penetrating down. Waterproofing and wearing course is placed; also over the joint. (When using prefabricated membrane the membrane is extended forward to the edge of the joint opening before placing the board). Then a cut is sawn into the asphalt, one on either side of the joint opening, so that the asphalt joint gets the intended width. The wearing course and waterproofing layers are removed down to the concrete between the cuts. Concrete and asphalt edges are cleaned and polymer modified bitumen applied to the surface, see Figure 4. Then the steel plate is placed and the asphalt joint can be constructed.

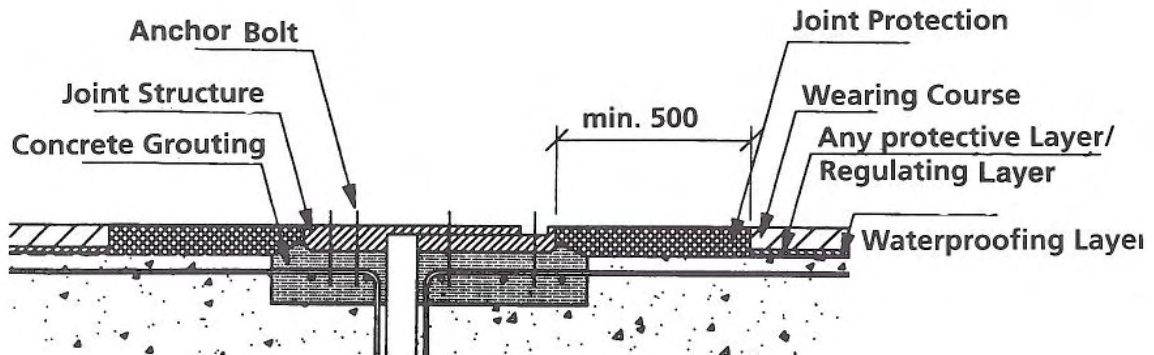


Figure 5 Example of Connection to Prefabricated Bridge Joint for Pavement Class A3

Prefabricated bridge joints are normally put in after the wearing course is laid, for best possible height-wise adaption. Too low a joint increases impact stress and the risk of fatigue. Too high a joint increases the risk of snowplows etc. to catch the joint structure risking injury to personnel and damage to equipment. Joint protection is placed on either side of the joint (see Figure 5) to protect against such snowplow damages.

As usual membrane, waterproofing and protective layers are extended to the cutout for the joint structure. The joint cutout is covered temporarily to facilitate bringing the paving equipment past. Asphalt and temporary cover in the joint and joint protection area are removed up to the saw-cut on either side and cleaned. Joint structures are suspended by installation equipment that will facilitate precise height adjustment. Then a concrete substrate is placed and finally possible joint protections.

Membrane connection to joint protection is shown in Figure 5. For prefabricated membrane, reference is made to supplier's directions.

6.1.3 Inlets

At edges placed higher than the bridge surface, surface water can be lead away with through-going drain pipes, see Figure 6.

Regarding choice of material and design details of inlets reference is made to Process Code-

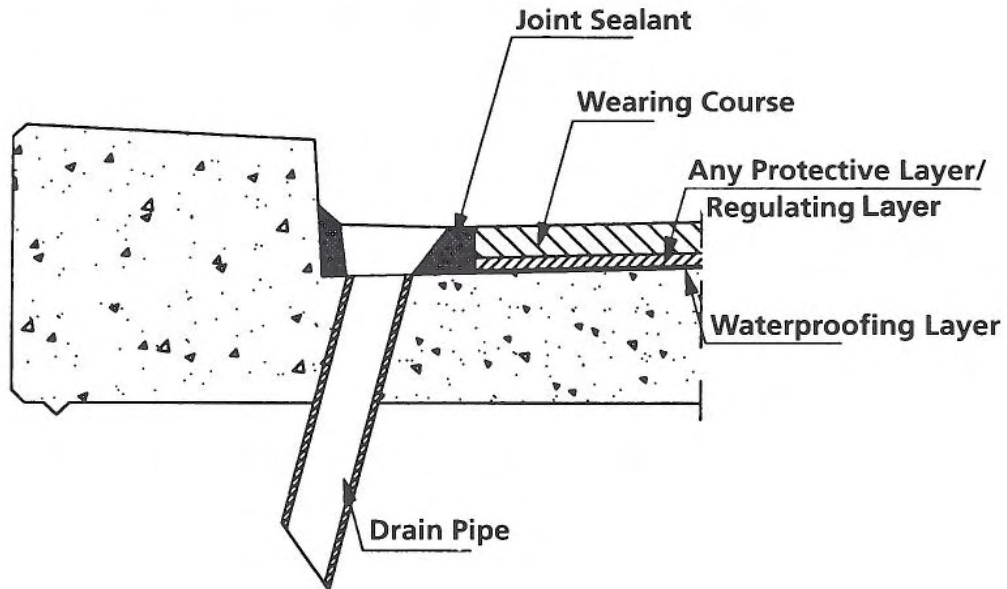


Figure 6 Example of Connection to Through Drain Pipes for Pavement Class A3

Pipes and collars are placed in the casting form with the top of the collar just below the planned bridge pavement surface level. When reusable forms are employed, block-outs can be placed for later drainpipe installation.

Alternatively, holes can be drilled in the finished concrete and pipes installed with epoxy glue and joint sealant. The waterproofing layer shall be flush with top of pipe. The funnel shaped drain in the upper part of the levelling course/wearing course can be shaped with mastic asphalt, Topeka 4S, joint sealant or some other suitable material.

6.1.4 Termination without Edge Beam

Before waterproofing the bridge railing attachment shall be sealed as described in the Public Roads Administration Handbook 100, Bridge Handbook-6, Bridge Railing.

The waterproofing shall cover the surface and be terminated about 10 cm onto the bridge slab.

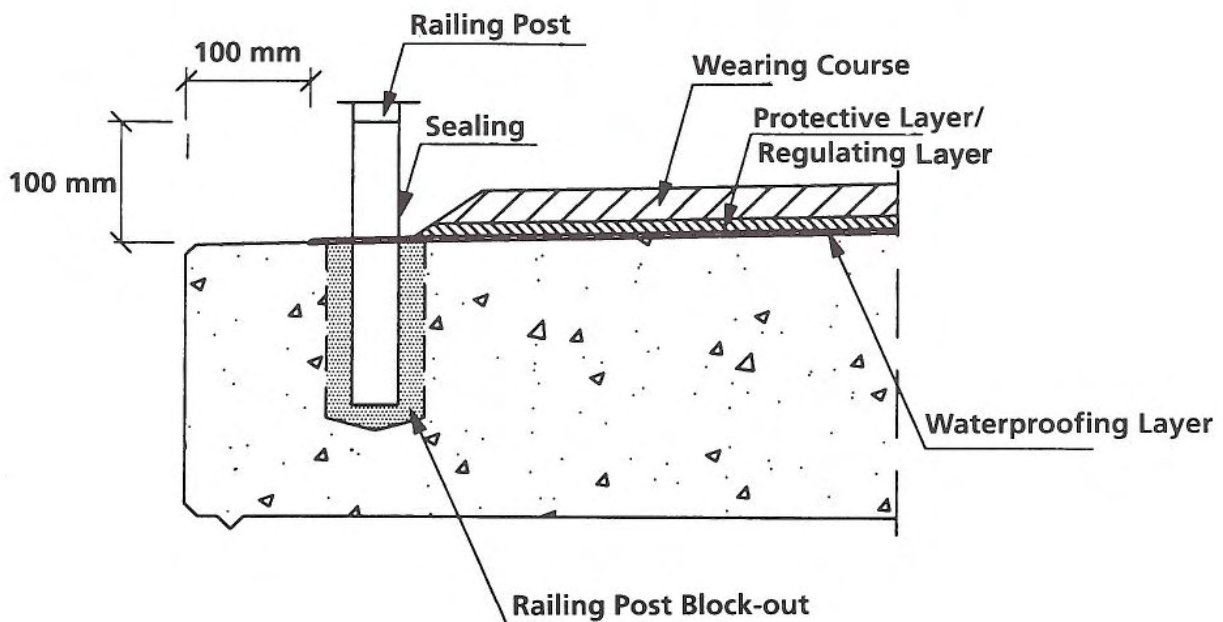


Figure 7 Example of Termination without Edge Beam for Pavement Class A3

6.1.5 Connection to Curbs and Edge Beams

Connections to curbs and edge beams for the various pavement types are described in Chapter 5.

When using prefabricated membrane, A3-2, connection between wearing course and curb may be done as illustrated in Figure 8.

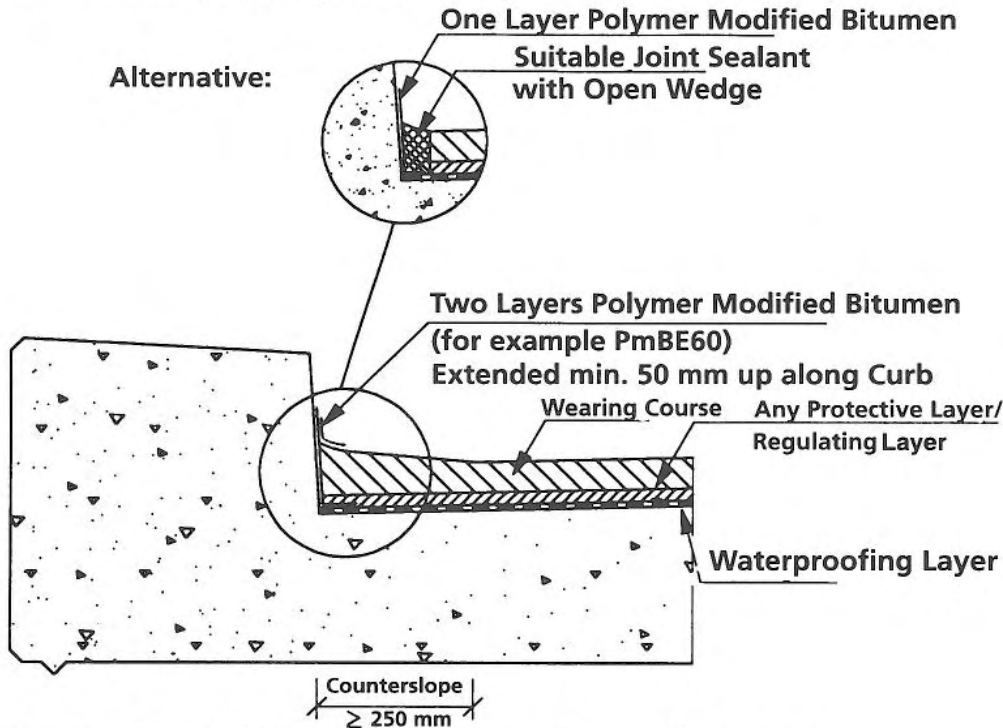


Figure 8 Prefabricated Membrane: Example of Connection to Curb

With simple curb connection, fully bonded membrane is placed against the curb. Tack coat is applied to smaller, fitted membrane pieces, and they are pressed well against the curb. Adjacent membrane is overlapped with minimum 15 cm.

Polymer modified bitumen is applied to curb, minimum 50 mm above top wearing course as well as 50 mm onto the membrane.

If the wearing course is extended all the way to the edge (without sealant) the area must be given a generous dosage of polymer-modified bitumen, minimum 50 mm up along the curb and 100 mm in over the wearing course. Both solutions require an open wedge or the construction of a slope away from the curb in a manner that will not allow water to be standing in the transition between wearing course and curb area. Constructed slopes must fit with cross and longitudinal bridge slopes as well as inlet locations. When constructing slopes Sta8/Sta11 or similar should be used.

The protective layer is placed all the way up to the curb. The wearing course is placed against screed rail or curb. Filling material, such as an extruded polyethylene list, is placed in the joint opening that is filled with joint sealant.

Other methods may be suggested by individual membrane producers or suppliers.

6.1.6 Posts

With combined vehicular and pedestrian/bicycle roads on the same level there is a need for connection between pavement and bridge railing posts for the intermediate guardrail. The upper part of Figure 9 shows details of post fastening with bolts and footplate. This solution is also possible with prefabricated membrane. The lower part of Figure 9 shows post cast into the railing post block-out. When tack coat and/or polyurethane are used it is applied up along the post to the top of wearing course. All solutions require that the post installation is completed and the mortar cured before membrane work proceeds. Depending on the type of railing, wearing course paving up to and under the bridge railing itself may cause problems. One possibility is to place this strip manually with suitable self-compacting material such as Topeka 4S or mastic asphalt. Regarding details on fastening of posts, reference is made to Public Roads Administration Handbook 100, Bridge Handbook part 6: Bridge Railing.

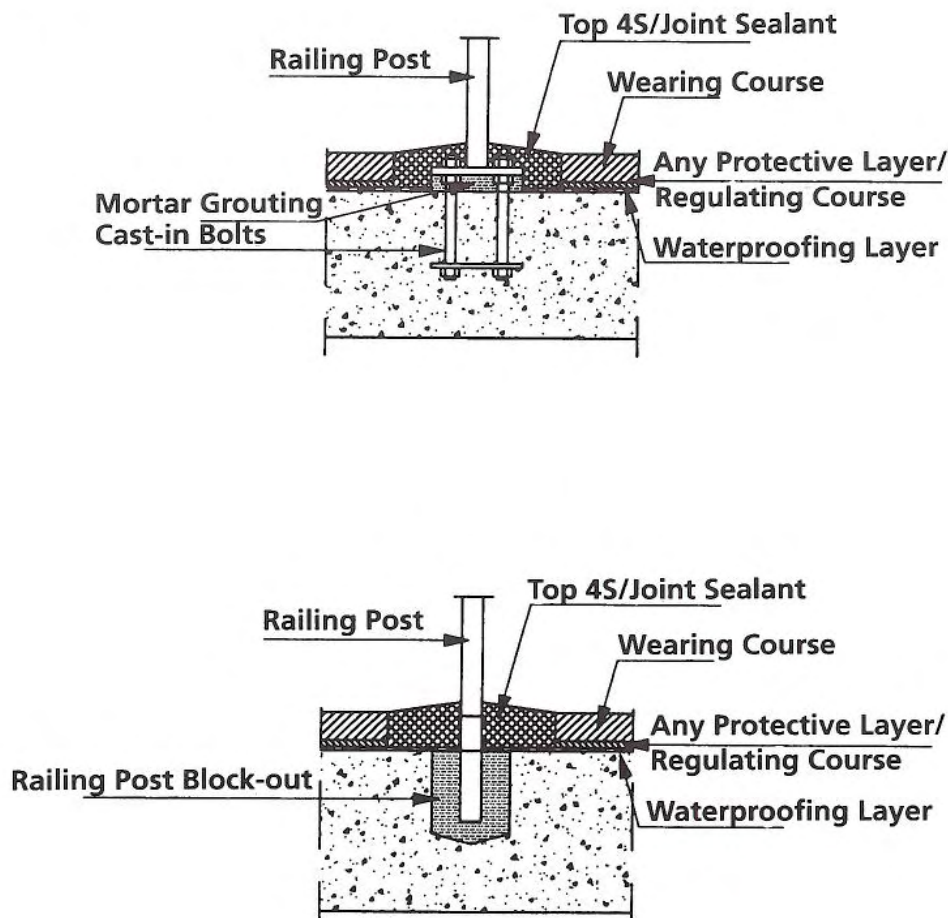


Figure 9 Example of Connection to Posts for Pavement Class A3

6.2 Curbs and Edge Beams

Protection of concrete curbs and edge beams shall be performed in accordance with special description.

Some materials used for protection of curbs and edge beams are aggressive towards asphalt or may reduce adhesion between concrete and waterproofing/asphalt and between asphalt layers. It is therefore important that the jobs are performed in a rational sequence and that material spilling is reduced as much as possible.

Steel curbs shall be protected in accordance with special description.

6.3 Joint-Protection

The term joint-protection refers to materials placed up towards the joints to protect these from damage from winter maintenance equipment such as plows and graders. Joint-protection shall be considered only in conjunction with prefabricated bridge joints. Such protection is normally made up of durable material such as mastic asphalt with special aggregate.

Joint-protection of concrete or other durable materials requires little maintenance but provides poor driving comfort as adjoining asphalt is worn away. Protection using more repair-friendly material such as mastic asphalt facilitates keying of adjacent ruts. This will improve driving comfort but requires more frequent maintenance. Joint-protection height should be about 5 mm above the joint structure itself.

The joint-protection is built a minimum of 50 cm to either side of the joint. With regard to driver comfort, the joint protection width or keying length between the joint-protection and wearing course should satisfy recommendations in Chapter 5.0.4. This should also apply to concrete wearing courses where a number of wearing/grinding stages are anticipated.

Use of joint-protection means an additional material joint where leakage in the waterproofing may take place. Cracks towards the joint-protection can be avoided by selecting materials with mutually good adhesion or by sealing the joint carefully.

Appendix 1

Glossary

Pavement	Generic term for all layers applied to bridge deck after it has been finally prepared and cleaned
Pavement class	Describes groups of pavement types by main divisions of concrete/asphalt as well as waterproofing quality
Pavement type	Describes actual pavement structure
Protective layer	Layer that protects the waterproofing layer against damage, especially during placing of the wearing course
Bridge deck	The structural part of the bridge, here understood to consist of reinforced concrete and steel
Glassvlies	Mat of glass fibre that is woven, but where the fibres are oriented in all directions
Priming	Surface reinforcement with a material that penetrates into of the pores of the basic material and fills these or partly completely
Waterproofing layer	Layer that prevents intrusion of surface water into the bridge deck
Regulating layer	Layer built into the pavement to adjust unevenness in underlying layers
Wearing course	The upper pavement layer intended to take the wear from traffic

Appendix 2

Quality Control of Epoxy Materials for Waterproofing and Injection of Bridge Decks

1 Preliminary control

Documentation on epoxy material properties shall be presented before the job starts. The documentation shall give information on material properties in accordance with Table 1 and 2.

In accordance with brand regulations a complete "Health Environment Safety product data sheet" shall be available that gives information on:

- any toxic/health hazardous additives
- if storage/mixing and/or temperatures above 230 °C might generate toxic agents/fumes in hazardous concentration
- need/requirement to wear personal protective gear.

2 Control of epoxy materials used

During work progress at least one sample of epoxy material shall be taken per bridge. With larger bridges one sample shall be taken per 1000 m² of bridge deck. These samples shall be used as random samples to check if the material supplied is in accordance with documentation provided and requirements in Table 1 and 2.

The sample size shall be at least 2 litres of each component. Immediately before samples are taken the materials shall be stirred to ensure representative samples.

The samples shall be well packaged and sent immediately to the Road Technology Department or to one of the independent institutes for materials testing. The samples shall be labelled with:

Epoxy make and type
Component type (A or B, resin or curing agent)
Mix ratio
Sample number
Date of sampling
The material's intended application
Bridge name
Road number
County
Sender.

In addition, for each bridge a copy on any documentation available regarding the use of epoxy materials shall be enclosed.

Table 1 Specifications on Tar Epoxy and Low Viscosity Epoxy for Waterproofing

Test	Method	Unit	Tar Epoxy Requirements	Low Viscosity Epoxy* Requirements
1 Component Viscosity	ASTM D-2393-86	Ns/m ²		
2 Component Density	ASTM D-1475-90	-		
3 Mix Viscosity	ASTM D-2393-86 (see note 3)	Ns/m ²	0.5-2.0	max. 0.5
4 Pot Life	ASTM D-2393-86	Minutes	20-120	20-120
5 Content of Volatile Components	DIN 16945 point 4.8 (03.89) (see note 5)	Weight %	max. 8.0	max. 5.0
6 Hardness	DIN 53505 (06.87) (see note 6)	Shore D	min. 35	
7 Adhesion against Concrete	Appendix 3 or DIN 50014/ ZTV SIB 90 TP OS Chapter 6.3	N/mm ² (MPa)	min. 1.5	min. 1.5
8 Consequences of Erroneous Mixing	As with Sample 5 and 7 (see note 8)			

* Low viscosity epoxy shall be waterproof and free of solvent

NOTES TO TABLE 1

3 Mix viscosity

The testing shall take place after ASTM D-2393-86 note 4. The components are mixed for three minutes. One minute after completed mixing the viscosity is measured.

5 Contents of volatile agents

Epoxy weighing 5 g is placed in a glass bowl with an inner diameter of 75 mm. The glass bowl diameter (D) is allowed to vary between 70 and 80 mm. If the diameter deviates from 75 mm the weighed quantity of epoxy is adjusted to maintain the same epoxy layer thickness. The precision of the weighing shall be ± 0.2 g from the estimated. After seven days of curing at 20 °C the samples are heated at 140 °C ± 2 °C for three hours.

The content of volatile agents is estimated as weight loss during curing and during the heating period according to the following formula:

$$\text{Weight loss (curing)} = \frac{I - F}{F} \cdot \left(\frac{75}{D}\right)^2 \cdot 100 \quad (\%)$$

$$\text{Weight loss (heating)} = \frac{F - E}{F} \cdot \left(\frac{75}{D}\right)^2 \cdot 100 \quad (\%)$$

where

I = weighed quantity of epoxy

F = epoxy by weight before heating to 140 °C (after seven days of curing)

E = epoxy by weight after heating to 140 °C for three hours

D = bowl diameter

Requirements stated in Table 1 refer to total weight loss.

The testing shall be performed for two different mixes of the epoxy material and with two bowls for each mix.

6 Hardness

The testing shall be performed for two different mixes of epoxy material. Hardness is measured after seven days of curing.

8 Consequences of erroneous mixing

Mixing of the material is performed with a 10% excess of curing component.

Table 2 Specification of Epoxy for Injection

Test	Method	Unit	Requirement
1 Viscosity of Mix *	ASTM D 2393-86	Ns/m ²	0.1-0.5 measured at 20 °C 0.1-1.0 measured at 5 °C
2 Pot Life	ASTM D 2393-86	Minutes	20-120 measured at 20 °C
3 Components of Volatile Agents *	DIN 16945 point 4.8	Weight %	< 1
4 Hardness *	DIN 53505, 06.87	Shore D	min. 50 measured at 20 °C
5 Bonding on Concrete	DIN 50014/ ZTV SIB 90 TP OS Chapter 6.3	MPa	> 1.5 or Concrete Breakage

* See the respective notes to Table 1

Appendix 3

Measuring Concrete Surface Tensile Strength and Membrane Adhesion

General

Testing of concrete surface tensile strength and membrane adhesion shall be performed as stated.

Test equipment

Figure 1 and 2 show two types equipment. In Figure 1 the tensile force is applied with a hydraulic jack. In Figure 2 there is a spring that is tightened and the force applied is read from a scale with a maximum dial indicator (Elcometer Mod. 106).

In Figure 1, part no. 6, the test cup is one 2" piece of steel pipe that is threaded on the inside and surface grinded on the testing side. The test cup must be cleaned by grinding or sandblasting after use.

In Figure 2, part no. 9, the test cup, also called Dolly, consists of specially shaped aluminum with a 20 mm diameter. These test cups are intended for use once only, but may be cleaned and reused.

Measuring the concrete surface tensile strength

After cleaning the bridge deck as stated in Chapter 4.2.1 the Client's representative points out the areas where measurements shall be taken.

All loose material and dust is removed with a soft brush. Glue, such as suitable epoxy glue, is spread evenly over the test surface. The test cup or dolly is placed and pressed down into the glue. After the glue has cured, pull-off is done in accordance with the type equipment being used (installation/performance). If an excess of glue is pressed beyond the area of the test cup, the excess is removed down to the concrete surface with core drilling.

The tensile force applied is recorded, estimated and reported in N/mm^2 .

It shall be recorded where breakage occurs: In concrete, in glue/concrete or in the glue (glue/test cup).

Measuring membrane adhesion

The equipment is best suited for measuring adhesion of pavements treated with epoxy or polyurethane.

Cleaning, gluing and testing are performed as described above. Before the test cup is pulled free a groove shall be drilled or cut through the membrane layer down to the concrete. This is best done with a diamond drill crown or diamond core drill with an inside diameter equal the outer diameter of the test cup.

The force applied at break is recorded and reported in N/mm^2 .

It is recorded where breakage occurs. In concrete, membrane/concrete, membrane, membrane/glue or glue.

Requirements

Minimum requirements to tensile strength and adhesion are 1.5 N/mm^2 , or breakage in the concrete.

Scope of control

One test with four pull-offs shall be performed per 250 m^2 bridge deck commenced on. This is done three times. If the results are acceptable the scope of the testing is changed to one test per 1000 m^2 of bridge deck. If any test results are below par the process starts over again from the beginning.

Areas heavily contaminated (from oil etc.) shall be subject to special control.

One test consists of four test cups placed on an area of maximum 2 m^2 .

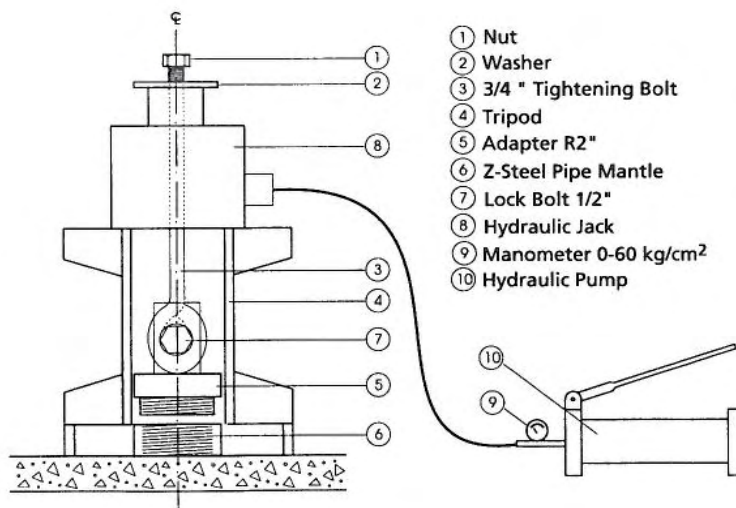
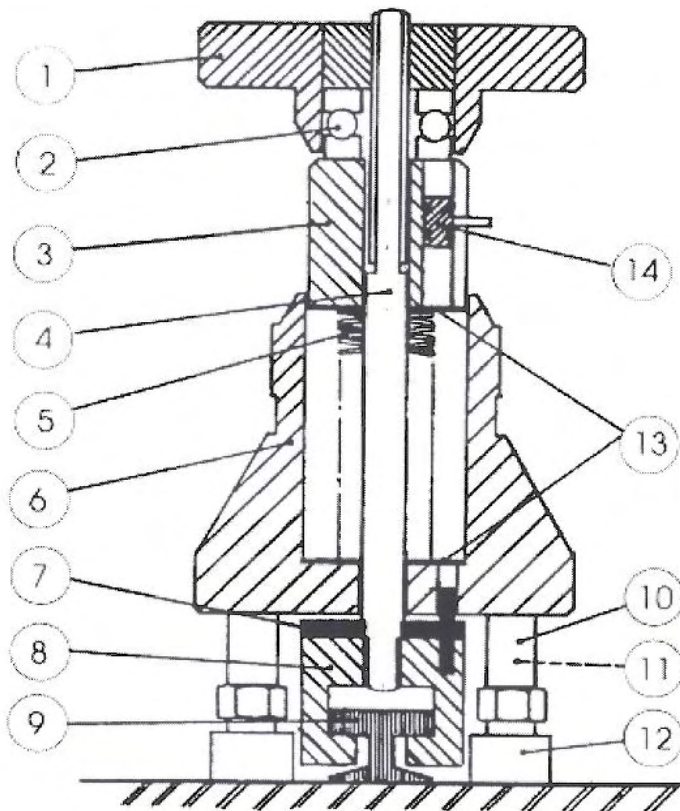


Figure 1 The Force is applied with Hydraulic Jack.



Part no.	Number	Material	Drawing no. 500 lbs	Drawing no. 1000 lbs	Description
1	1	Aluminum	106-4	106-4	Wheel
2	1	Steel	Single thrust ball bearing (slf 3/8")		
3	1	Aluminum	106-6	106-11	Barrel
4	1	M. Steel	106-7	106-12	Spindle
5	36	Steel	Belleville washers No3 (500 lbs)		
5	20	Steel	Belleville washers No8 (1000 lbs)		
6	1	Aluminum	106-3	106-3	Body
7	1	Rubber	106-8	106-8	Buffer
8	1	M. Steel	106-13	106-13	Claw
9		Aluminum	106-2	106-2	Dolly
10	3	Aluminum	106-9	106-9	Spacer
11	3	M. Steel	1/4" whit X 1" long stud		
12	3	Steel	Swivel pad adaptors (put. 216-5)		
13	2	Steel	106-22	106-22	Scale correction shim
14	1	Aluminum	106-16	106-16	Indicator bobbin

Figure 2 The Force is applied with a Strong Spring.

Appendix 4

Rubber Asphalt Joint Sealant Requirements

Rubber asphalt joint sealant shall satisfy the requirements given in the table below.

Documentation on product properties shall be submitted to the Client before work commences.

Testing frequency is normally one test per bridge. One sample shall include about 2 kg. Samples are labelled and shipped in the same manner as stated in Appendix 2.

Test	Unit	Method	Requirement
Pouring Temperature		ASTM D1191	11 °C Lower than the "Safeheating" Temperature
Penetration at 25 °C with 150 g, 5 s, Penetration Cone	1/10 mm	ASTM D1191	max. 90
Flow	mm	ASTM D1191	max. 5
Tensile Test at -18 °C with 5 Cycles			2 Tests out of 3 must not Produce Break, Separation or other Opening Larger than 6.4 mm Deep in the Joint Sealant or between the Material and the Mortar Blocks

Appendix 5

Quality Control of Prefabricated Membranes for Concrete Bridge Deck Waterproofing

1 Preliminary control of prefabricated membranes

Prefabricated membranes shall satisfy requirements given in Table 1. Documentation shall be submitted on membrane material properties before work commences. In addition, data shall be provided on the makeup and necessary detailed technical directions for placing worked out.

2 Control of membrane materials used

During work progress a minimum of one sample shall be taken from each membrane type used.

On larger bridges one sample should be taken of each membrane type per 1000 m².

These samples are used as random checks to control if the material supplied is in accordance with the documentation provided and requirements in Table 1.

The sample size should be about 2 m².

It shall be stated how many rolls were subject to testing.

The sample material is packaged in such a manner that the membrane is not folded or damaged during shipment/transportation.

The samples are sent to the Road Technology Department or to an independent materials testing institute.

The samples shall be labelled with:

- Producer/supplier
- Product name - membrane type
- Sample number - date taken
- Bridge name
- Road number
- County
- Sender

In addition copy of relevant documentation on the membrane materials used shall be sent for each bridge.

Table 1 Specifications on Prefabricated Membranes

Test	Method	Requirement
1 Thickness	DIN 52123, point 5	Max. 0.5 mm Deviation from Average Thickness
2 Bending	DIN 52123, point 12	No Break
3 Resistance Against Water Pressure	DIN 52123, point 10	No Water Intrusion

NOTES TO TABLE 1

1 Determination of thickness

The testing shall abide by DIN 52123, point 5. Ten individual measurements shall be taken at random across the width of the membrane. The contact surface of the measuring equipment shall have a diameter of 10 mm and the force applied shall be 1.0-1.2 N.

2 Bending

The testing shall be undertaken according to DIN 52123, point 12. Bending test shall be performed on three specimens of size 50 x 200 mm. The specimens shall be taken in the membrane's longitudinal direction.

The temperature during testing shall be -20 ± 1 °C.

The specimens are placed together with bending plate in a freezer.

Exposure time shall be 2 hours.

The bending test itself is performed within 15 seconds after removal from freezer with a margin of 5 seconds for the bending itself.

3 Resistance against water pressure

The testing shall be undertaken according to DIN 52123, point 10. The test shall be performed on three specimens picked at random across the width of the membrane within a minimum of 10 mm from edge.

The samples are exposed to water pressure of 10 N/cm² at a temperature of 20 ± 2 °C for 24 hours.

Appendix 6

Quality Control of Polyurethane Materials for Concrete Bridge Deck Waterproofing

1 Preliminary Control

Polyurethane materials shall satisfy the requirements in Table 1. Documentation on the polyurethane material properties shall be submitted before work commences.

According to the brand regulations a complete “Health Environment Safety product data sheet” shall be available with information on:

- any toxic/health hazardous additives
- if storage/mixing and/or temperatures above 230 °C might generate toxic agents/fumes in hazardous concentration
- need/requirement to wear personal protective gear

Table 1 Specifications for Polyurethane Materials

Test	Method	Conditions	Requirements
1 Bending	DIN 52123, point 12	- 20 ± 1 °C	No Cracks or Breaks
2 Water Pressure Resistance	DIN 52123, point 10		No Water Penetration
3 Temperature Resistance (briefly)		+ 240 °C for 3 minutes	No Loss of Adhesion
4 Adhesion to Concrete		+ 23 °C	Minimum 1.5 N/mm ²
5 Adhesion to Overlying Layers		+ 23 °C	Minimum 1.5 N/mm ²
6 Elasticity	ZTV SIB 90 TP OS Chapter 6.9	+ 20 °C & - 5 °C	Living Cracks 0.2 - 0.4 mm
7 Aging Properties	ZTV SIB 90 TP OS Chapter 25.4.2		

Before work commences one shall also note information on temperature range and maximum humidity (RH%) allowed during placing, as well as necessary curing time before paving.

2 Control of Polyurethane Materials Used

During work progress, at least one sample of the polyurethane materials shall be taken per bridge. With larger bridges one sample shall be taken per 1000 m² of bridge deck. These tests are used as random checks to control that the material supplied is in accordance with documentation provided and requirements in Table 1.

The sample size shall be at least 2 litres of each component. Immediately before samples are taken the materials shall be stirred to ensure representative samples.

The samples are well packaged and sent immediately to the Road Technology Department or to one of the independent institutes for materials testing. The samples shall be labelled with:

- Make, type
- Component type
- Mix ratio
- Sample number
- Date of sampling
- Bridge name
- Road number
- County
- Sender

In addition, for each bridge a copy on any documentation available regarding the use of epoxy materials shall be enclosed.

Appendix 7

Specification and Quality Control of Materials Based on Polymer Modified Bitumen (PmB)

A general description shall be given on PmB-products in accordance with the following list:

- a PmB-grade and any brand name (product name)^{*)}
- b A completed "Health Environment Safety product data sheet" that shall give information on:
 - any toxic/health hazardous additives
 - if storage or asphalt production up to 200 °C might give off toxic agents/fumes in dangerous concentrations
 - if reheating for recycling might result in toxic agents/fumes in dangerous concentrations
- c Recommended storage temperatures, storing time and need for stirring
- d Density and volume tables for various temperatures
- e Analysis data (shall be typical for the product)

^{*)}PmB/PmBE60 shall be SBS-based (styrene-butadiene-styrene) with minimum 5% additive.

Polymer Modified Bitumen

Polymer modified bitumen shall be documented in accordance with Table 1. The material shall have durable functional properties, be uniform and free of water.

Table 1 Analyses Data for PmB

Properties	Method Condition	Unit	Requirement
1 Softening Point ¹⁾	Ball & Ring	°C	min. 80
2 Penetration	25 °C	0.1 mm	
3 Viscosity	135 °C	mm/s (mPas)	
4 Viscosity	180 °C	mm/s (mPas)	
5 Density	25 °C		
6 Solvability in 1,1,1-trichloroethane		%	
7 Flame Point	PMcc	°C	
8 Elastic Decline (method shall be given)	5 °C	%	min. 75 ²⁾
9 Storability	72 h, 180 °C Alt. max. Operating Temp, Diff. Softening Point. (upper-lower)	°C	
10 TFOT/RTFOT/Rotating flask Weight Loss Softening Point Breaking Point after Fraass Elastic Decline	5 °C	% °C °C %	min. -20

¹⁾ With distilled water as bath

²⁾ Empirical value from the Road Technology Department's Rheometer

Polymer Modified Bitumen Emulsion

Polymer modified bitumen emulsion, PmBE60, shall be documented in accordance with Table 2.

Table 2 Analyses Data for Polymer Modified Bitumen Emulsion

Properties	Method Condition	Unit	Requirement
1 Viscosity	STV, 4 mm, 25 °C or 50 °C	sec.	5-10
2 Uniformity			
3 Storability			
4 Binder Residual with Evaporation		%	60 ± 1
5 Materials Testing after Evaporation Penetration Softening Point Break Point after Fraass Elastic Decline	25 °C 5 °C	0.1 mm °C °C %	

Topeka 4S (Asphalt Mastic)

Gradation for Topeka 4S shall satisfy the requirements given in Table 3. The gradation curve should be as close as possible to half way between the grading limits and parallel with these.

Table 3 Gradation for Top. 4S

ISO-sieve	Retained percent by weight
8 mm	0
4 mm	0 - 10
2 mm	18 - 36
1 mm	28 - 48
500 µm	40 - 60
250 µm	55 - 70
125 µm	70 - 76
75 µm	74 - 80

The binder in Top 4S shall be polymer-modified bitumen that satisfies the requirements in this appendix. The binder content shall be 15 ± 0.4 %. The hardness measured by indentation shall be 45 - 300 seconds to full piston indentation.

Production and Placing of Topeka 4S

Binder content and gradation in the finished pavement shall be in accordance with the job mix formula within the tolerances in Table 4 and 5.

Table 4 Tolerances - Binder, Top. 4S

Pavement with Upper Nominal Particle Size	Tolerances, Quantity in percent			
	Single samples	Mean 2	of Number 5	of Samples 10
≤ 4 mm	± 0.40	± 0.30	± 0.20	± 0.15

Table 5 Tolerances - Gradation, Top. 4S

Particle Gradation	Tolerances, Quantity in percent			
	Single Samples	Mean 2	of Number 5	of Samples 10
On Sieve 2 mm or Coarser	± 6.0	± 5.0	± 4.0	± 3.0
On Sieve 250 µm to 1 mm	± 4.0	± 3.5	± 3.0	± 2.5
On Sieve 125 µm	± 3.0	± 2.5	± 2.0	± 1.7
On Sieve 75 µm	± 2.0	± 1.7	± 1.4	± 1.2

The temperature during production and placing shall never exceed 200 °C and during placing a temperature < 190 °C is aimed for.

To reduce the risk of the aggregate overheating the binder during mixing, filler is mixed in before or simultaneous with the binder where this is technically feasible.

All transportation of material shall take place with mobile melters with mixer. If the total haulage/waiting time after mixing exceeds 12 hours the mix shall be rejected.

Top. 4S can be placed when the pavement temperature is above +5 °C.

When paving, the substrate must be even without holes and free of contamination and moisture that may develop vapours and result in formation of blisters in the completed pavement.

Control of Materials on PmB-basis

Preliminary control

Before work commences documentation shall be submitted verifying that the requirements to individual components and compositions previously stated will be complied with.

Control of work completed

What is described here is for the Client's after-control of completed work. The contractor is obliged to have a documented operations control to ensure that results are within requirements. On request the documentation shall be presented to the Client.

If no other control routines have been agreed on in writing, the following procedure shall be followed:

When sampling, one sample is taken for the Client and one for the contractor. The contractor may use his sample in the operations control. At least one sample of polymer modified bitumen emulsion (PmBE60) and one of Topeka 4S shall be taken during work progress per bridge. With larger bridges one sample shall be taken per mixer of which one sample per 1000 m² bridge deck shall be analysed to determine material composition (gradation and binder content) and hardness (indentation according to Handbook 014, Laboratory Investigations).

The samples are taken to check that the material supplied is in accordance with documentation provided (job mix formula) and the requirements in Table 3.

The temperature in each mixer is checked regularly. The contractor is obliged to keep a log over mixer temperature and to present the log on request to the Client.

If the sample analysed lies outside the requirement, other relevant samples are analysed before any deductions, are agreed on. Aspects that are given special emphasis when considering deductions are binder content and hardness.

Reference is made to Handbook 015, Field Investigations for the procedure of sample taking and size.

The samples are sent the Road Office Laboratory or alternatively to the Road Technology Department.

The samples shall be labelled with:

- Producer/supplier and/or contractor
- Sample from: Mixer, paver, etc.
- Material temperature
- Sample number - date taken
- Bridge number, road number
- Sender

In addition a copy of relevant job mix formula for each bridge shall be enclosed.

Appendix 8

Specification and Quality Control of Waterproof Mastic Asphalt (Sta2 and Sta4)

Application

Sta 2 and Sta 4 described here are assumed used as waterproof mastic asphalt. This description differs so much from HB018 and ASPHALT - Guidelines, that the two should not be used.

Composition

Mastic asphalt is a uniform mixture of bitumen and dried, heated aggregate with a high filler content. Gradation of the aggregate and bitumen content is selected to achieve a workable material free of voids.

Mastic asphalt shall be composed of materials satisfying performance specifications in Table 1.

Table 1 Material Requirements, Waterproof Mastic Asphalt

Properties	
Aggregate Class	1-3
Binder	B40-B60 PmB

Material composition requirements shall be documented by having grading (Table 2) and hardness requirements (Table 3) being satisfied.

The grading curve should be as close as possible to midway between the grading limits and parallel to these.

Table 2 Particle Gradation, Waterproof Mastic Asphalt

ISO-sieve	Retained percent by weight	
	Sta 2	Sta 4
8 mm		0
4 mm	0	0-15
2 mm	0-15	24-44
1mm	15-47	39-57
500 µm	20-58	47-63
250 µm	25-64	55-69
125 µm	35-70	60-72
75 µm	50-72	66-76

Table 3 Hardness Requirements (DIN 1996), Waterproof Mastic Asphalt

Indentation, mm	
Waterproof Mastic Asphalt (Sta 2 and Sta 4)	≤ 15

Binder content shall be as high as possible and at the same time the hardness requirements must be satisfied. Natural asphalt or other stabilizing additives may be used if agreed with the Client.

When planning, the following filler content is assumed, Table 4:

Table 4 Filler Content for Planning, Waterproof Mastic Asphalt

Sta	2	4
Filler %	32	29

Binder content shall lie between the values in Table 5. The values are based on aggregate with a density of 2.65 g/cm³. The values shall be adjusted if the density deviates with more than 0.1 g/cm³.

Table 5 Binder Content for Planning, Waterproof Mastic Asphalt

Sta	2	4
Binder Content, %	12 - 15	10 - 12

Production and Placing

Binder content and particle gradation in the finished pavement shall be in accordance with the job mix formula within the tolerances in Table 6 and 7.

Table 6 Tolerances - Binder, Waterproof Mastic Asphalt

Pavement with Upper Nominal Particle Size	Single Sample	Tolerances, Quantity in percent		
		Mean 2	of Number 5	of Samples 10
≤ 4 mm	± 0.40	± 0.30	± 0.20	± 0.15

Table 7 Tolerances - Particle Gradation, Waterproof Mastic Asphalt

Particle Gradation	Single Sample	Tolerances, Quantity in percent		
		Mean 2	of Number 5	of Samples 10
On Sieve 2 mm or Coarser	± 6.0	± 5.0	± 4.0	± 3.0
On Sieve 250 µm	± 4.0	± 3.5	± 3.0	± 2.5
On Sieve 125 µm	± 3.0	± 2.5	± 2.0	± 1.7
On Sieve 75 µm	± 2.0	± 1.7	± 1.4	± 1.2

During production and laying the temperature limits in Table 8 shall be observed.

Table 8 Temperature Limits, Waterproof Mastic Asphalt

	Binder		
	B 40	B 60	B 85
Mixture Temp. during Production and Laying, °C	190 - 230	190 - 230	190 - 220

When PmB is used the temperature limits are determined in each individual case.

Filler is added before or simultaneous with the binder where this is technically feasible in order to reduce the risk of aggregates overheating the binder during mixing.

All transportation of material shall take place with mobile melters with mixer. If the total haulage/waiting time after mixing exceeds 12 hours the mix shall be rejected.

Waterproof mastic asphalt may be placed when the pavement temperature is above +5 °C.

When paving, the substrate must be even without holes and free of contamination and moisture that may develop vapours and result in formation of blisters in the completed pavement.

To prevent sliding, the mastic asphalt should not be placed on a substrate with longitudinal and transverse slope exceeding 5% unless special measures are employed.

Control

Preliminary control

Before work commences documentation shall be submitted verifying that the requirements to individual components and compositions previously stated will be complied with.

Control of work completed

What is described here is for the Client's after-control of completed work. The contractor is obliged to have a documented operations control to ensure that results are within requirements. On request the documentation shall be presented to the Client.

The following procedure shall be followed if no other control routine has been agreed on in writing:

When sampling, one sample is taken for the Client and one for the contractor. The contractor may use his sample in the operation control. During work progress at least one sample of waterproof mastic asphalt shall be taken per bridge. With larger bridges one sample shall be taken per mixer of which one sample per 1000 m² bridge deck shall be analysed to determine material composition (gradation and binder content) and hardness (piston indentation according to Handbook 014, Laboratory Investigations).

The samples are taken to check that the material supplied is in accordance with documentation provided (job mix formula) and the requirements in this appendix.

The temperature in each mixer is checked regularly. The contractor is obliged to keep a log over mixer temperature, and to present the log to the Client on request.

If the sample analysed lies outside the requirement, other relevant samples are analysed before any deductions are agreed on. Binder content and hardness are aspects that are given special emphasis when considering deductions.

Reference is made to Handbook 015, Field Investigations for the procedure of sampling and size.

The samples are sent the Road Office Laboratory or alternatively the Road Technology Department.

The samples shall be labelled with:

- Producer/supplier and/or contractor
- Sample from: Mixer, paver, etc.
- Material temperature
- Sample number - date taken
- Bridge number, road number
- Sender.

In addition a copy of relevant job mix formula for each bridge shall be enclosed.

Appendix 9

Documentation on Moisture in Concrete Deck

When waterproofing and paving, consideration shall be given to prevailing weather conditions and anticipated development. In particular, assessment should be made of moisture in the concrete deck before waterproofing and paving commences.

Knowledge about weather condition during the period before the work starts is valuable when assessing the concrete deck as far as moisture is concerned.

The moisture content in the concrete can be controlled by placing plastic foil (about 1 m²) on the concrete deck and sealing along the edges. After some time, 1 - 2 h, the foil is inspected with regard to condensation on the underside and/or darkening of the underlying concrete. If condensation or darkening occurs, the moisture content is too high and the membrane job should be postponed.

The relationship between the results of this test and the risk of damage to the waterproofing has not been verified by practical experience. This should be taken into consideration when using the method. The method might possibly indicate if the temperature development generates rising moisture/steam that may result in a risk of damage to the waterproofing, more so than answering what is the moisture content of the substrate even though this need not be a weakness with the method.

There is no equipment available for measuring moisture content in concrete. Experience with such equipment gives reason to be skeptical of the measurements. This is particularly the case with equipment based on measurement of conductivity between two sensors (studs) held against the concrete surface.

To be able to control moisture and temperature (pavement/air), use of tent might be necessary. Ventilation as well as heating and dehumidification of the air inside the tent shall be considered.

Appendix 10

Description of "Execution in Terms of Pay-Items"

This appendix gives examples of how waterproofing and wearing course can be described according to Process Code-2 (1997). The examples are intended as a guide when preparing tender documents.

Note! The descriptions must be assessed and possibly adjusted/supplemented in each individual case to ensure adequate coverage. In particular, selection of wearing course type and thickness must be coordinated.

A 1 ASPHALT WEARING COURSE.

84.521	Levelling and treatment of bridge deck to be paved.	m ²
84.541	Curing with curing membrane.	m ²
84.543	Moist curing with water sprinkling.	m ²
84.62	Sandblasting of concrete surface.	m ²
86.2	Wearing course and membranes. SB: Pavement type A 1, ref. Handbook 145.	
86.224	Bonding. SB: Tack coat is applied in accordance with Handbook 145	m ²
86.264	Wearing course of asphalt concrete. SB: Ab 16, kg/m ² .	ton

A 2 ASPHALT WEARING COURSE WITH SIMPLIFIED WATERPROOFING. A 2-1 WATERPROOFING WITH LOW VISCOSITY EPOXY.

84.521	Levelling and treatment of bridge deck to be paved.	m ²
84.541	Curing with curing membrane.	m ²
84.543	Moist curing with water sprinkling.	m ²
84.62	Sandblasting of concrete surface.	m ²
86.2	Wearing course and membranes. SB: Pavement type A2-1, ref. Handbook 145	

84.181	Acquisition of temporary shelter (tent)	RS
84.182	Erection and operation of temporary shelter (tent)	m ²
86.221	Priming with epoxy SB: Priming with low viscosity epoxy, two layers wet-in-wet. First layer 0.3-0.5 kg/m ² , second layer 0.3 kg/m ² . Sanding of second layer with fine sand 0.5-1.2 mm, or fine sand 0.5-1.5 mm, 1 - 2 kg/m ²	m ²
86.224	Bonding SB: Tack coat PmBE60 0.3-0.4 kg/m ² sanded with fine sand 0.5-1.5 mm, 1 - 2 kg/m ²	m ²
86.264	Wearing course of asphalt concrete SB: Ab 16, kg/m ² 2	ton
A 2	ASPHALT WEARING COURSE WITH SIMPLIFIED WATERPROOFING	
A 2-2	WATERPROOFING WITH POLYMER MODIFIED BITUMEN EMULSION	
84.521	Levelling and treatment of bridge deck to be paved	m ²
84.541	Curing with curing membrane	m ²
84.543	Moist curing with water sprinkling	m ²
84.62	Sandblasting of concrete surface	m ²
86.2	Wearing course and membranes SB: Pavement type A2-2, ref. Handbook 145	
86.222	Sealing with polymer modified bitumen emulsion SB: Sealing with PmBE60 placed in two layers that both are sanded with fine sand, 0.5-1.5mm. First layer 0.3-0.5 kg/m ² . Second layer 0.2-0.4 kg/m ² . Both layers sanded with 1 - 2 kg/m ² .	m ²
86.264	Wearing course of asphalt concrete SB: Ab 16,kg/m ²	ton
A 3	ASPHALT WEARING COURSE WITH FULL WATERPROOFING	
A 3-1	WATERPROOFING WITH EPOXY AND WATERPROOF MASTIC ASPHALT	
84.521	Levelling and treatment of bridge decks to be paved	m ²
84.541	Curing with curing membrane SB: A type curing membrane, which does not destroy the adhesion of subsequent layers (not wax based curing membrane) shall be used	m ²

84.543	Moist curing with water sprinkling	m ²
84.62	Sandblasting of concrete surface SB: Even if none-wax based curing membrane is used the curing membrane shall be removed completely	m ²
86.2	Wearing courses and membranes SB: Pavement type A 3-1, ref. Handbook 145	
84.181	Acquisition of temporary shelter (tent)	RS
84.182	Erection and operation of temporary shelter (tent)	m ²
86.221	Priming with epoxy SB: Priming and sealing with epoxy placed in two layers totalling 2.0 kg/m ² spread with fine sand 0.5-1.5mm on last layer. Layer number two can be tar epoxy.	m ²
86.231	Membrane of waterproof mastic asphalt SB: Thickness 15 ± 5mm, weight 35 ± 12.5 kg/m ²	m ²
86.261	Wearing course of mastic asphalt SB: Thickness mm, weight kg/m ²	ton
A 3	ASPHALT WEARING COURSE WITH FULL WATERPROOFING	
A 3-2	WATERPROOFING WITH PREFABRICATED MEMBRANE	
84.521	Levelling and treatment of bridge deck to be paved	m ²
84.541	Curing with curing membrane SB: A type curing membrane, which does not destroy the adhesion of subsequent layers shall be used (not wax based curing membrane)	m ²
84.543	Moist curing with water sprinkling	m ²
84.62	Sandblasting of concrete surface SB: Even if none-wax based curing membrane is used the curing membrane shall be completely removed	m ²
86.2	Wearing courses and membranes SB: Pavement type A 3-2, ref. Handbook 145	
86.224	Bonding SB: Tack coat is applied with 0.2-0.3 l/m ² until ample coverage (no untreated areas), but ponds should not form either. It is important that treated areas are completely dry before the membrane is rolled out.	m ²

86.232	Prefabricated membrane SB: Prefabricated membrane is placed in one or two layers that are bonded or welded to the underlying membrane.	m ²
86.24	Protective layer SB: Protective layer of Ab4 placed to a thickness of 15-20 mm fully compacted, either manually or with a paver that does not damage the membrane.	ton
86.25	Regulating layer SB: Regulating layer (Agb,Ab) is placed on completed membrane/protective layer.	ton
86.263	Wearing course of stone mastic asphalt SB: Thickness mm, weight kg/m ²	ton
A 3	ASPHALT WEARING COURSE WITH FULL WATERPROOFING	
A 3-3	WATERPROOFING WITH POLYURETHANE	
84.521	Levelling and treatment of bridge deck to be paved	m ²
84.541	Curing with curing membrane SB: A curing membrane type, which does not destroy the adhesion of subsequent layers (not wax based) is used	m ²
84.543	Moist curing with water sprinkling	m ²
84.62	Sandblasting of concrete surface SB: Even if none-wax based curing membrane is used the curing membrane shall be completely removed.	m ²
86.2	Wearing courses and membranes SB: Pavement type A 3-3, ref. Handbook 145	
84.181	Acquisition of temporary shelter (tent)	RS
84.182	Erection and operation of temporary shelter (tent)	m ²
86.221	Priming with epoxy SB: Cleaned and dried concrete deck is primed in accordance with specification from producer/supplier. Normal quantity 0.2 l/m ² . Pavement and air temperatures shall be >10 ⁰ C. Relative humidity < 70%.	m ²
86.233	Polyurethane membrane SB: Polyurethane is applied to the bridge deck and any curbs to outside corner and about 10 mm up along bridge railing post in 2 mm thickness using two-component sprayer.	m ²

86.234	Membrane of Topeka 4S SB: To achieve satisfactory bonding between polyurethane and the wearing course an approx.10 mm thick layer of Topeka 4S is laid. If mastic asphalt is used as wearing course, this process is omitted as the wearing course mastic asphalt is placed directly on the polyurethane membrane.	m ²
86.263	Wearing course of stone mastic asphalt SB: Thickness mm, weight kg/m ²	ton
A3 A3-4	ASPHALT WEARING COURSE WITH FULL WATERPROOFING WATERPROOFING WITH PmB-BASED MATERIALS	
84.521	Levelling and treatment of bridge decks to be paved.	m ²
84.541	Curing with curing membrane SB: A curing membrane type, which does not destroy the adhesion for subsequent layers (not wax based) is used	m ²
84.543	Moist curing with water sprinkling	m ²
84.62	Sandblasting of concrete surface SB: Even if none-wax based curing membrane is used the curing membrane shall be completely removed.	m ²
86.2	Wearing course and membranes SB: Pavement type A 3-4, ref. Handbook 145.	
84.181	Acquisition of temporary shelter (tent)	RS
84.182	Erection and operation of temporary shelter (tent)	m ²
86.224	Bonding SB: Tack coat is applied to the bridge deck and to vertical surfaces to a height of 10 cm, quantity 0.3-0.4 l/m ² until well covered, (no untreated areas), but ponds shall not form either. Immediately sanded with fine sand, 0.5-1.5 mm.	m ²
86.234	Membrane of Topeka 4S SB: Thickness 12±3 mm (25±6 kg/m ²)	m ²
86.25	Regulating layer SB: Regulating layer of asphalt (Ab, Agb) is placed on the completed membrane	ton
86.263	Wearing course of stone mastic asphalt SB: Thickness mm, weight kg/m ² .	ton

B 1		MONOLITHIC CONCRETE WEARING COURSE	
84.4132	Concrete C55 SV-40		m ³
	SB: Concerns structural bridge deck		
84.441	Monolithic concrete wearing course		m ²
	SB: Wearing course thickness 60 mm, comes in addition to reinforcement cover.		
84.522	Levelling and treatment of concrete wearing course.		m ²
84.541	Curing with curing membrane		m ²
84.542	Curing by placing of plastic foil or similar.		m ²
	SB: In case undertaken as an alternative to process 84.543 as agreed with Client	m ²	
84.543	Moist curing with water sprinkling		m ²
84.55	Heat insulation of concrete		m ²
	SB: Relevant when there is a risk of frost or significant heat loss from the concrete surface. Two temperature sensors are embedded, one in the middle of the cross-section and one on the concrete surface, per 250 m ² bridge deck area on which treatment is started.		
84.67	Grinding of concrete surface		m ²
B 2		CONCRETE OVERLAY WEARING COURSE	
84.523	Levelling and treatment of bridge deck as support for concrete overlay		m ²
84.541	Curing of curing membrane		m ²
84.543	Moist curing with water sprinkling		m ²
84.62	Sandblasting of concrete surface		m ²
84.811	Gluing of fresh concrete to cured concrete		m ²
	SB: Concerns epoxy glue on all vertical casting joints as well as 30 cm stripes along longitudinal casting border, 50 cm stripes along transverse casting borders.		
84.82	Gluing with cement bonding slurry		m ²
	SB: Relates to the area within stripes of epoxy glue.		
84.442	Overlay of concrete wearing course		m ²

84.325	Fibre reinforcement SB: Steel fibre reinforcement in concrete overlay 50 kg/m ³ of 20-30 mm fibre, alternatively 75 kg/m ³ of 15-20 mm fibre.	kg
84.522	Levelling and treatment of concrete wearing course SB: Evenness class 2	m ²
84.541	Curing with curing membrane	m ²
84.542	Curing by placing of plastic foil or similar. SB: Undertaken as an alternative to process 84.543, as agreed with Client	m ²
84.543	Moist curing with water sprinkling	m ²
84.56	Heat insulation of concrete SB: Relevant when there is a risk of frost or significant temperature variations day/night.	m ²



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