GUIDELINES FOR ROAD DESIGN, CONSTRUCTION, MAINTENANCE AND SUPERVISION

Volume I: DESIGNING

Section 2: DESIGNING BRIDGES

DESIGN GUIDELINES (DG 1.2.4)

Part 4: WATERPROOFING OF BRIDGES

INTRODUCTION

Both concrete and reinforcing steel suffer different damages during the service life of reinforced concrete bridges. Numerous damages resulting from the water and salt water penetration as well as from chemical and physical impact on reinforced concrete structures due to

- unsuitable quality of the cement concrete,
- insufficient thickness of the protective concrete cover above the reinforcing steel,
- penetration of water and salt water through cracks into the concrete,
- carbonatization of cement concrete,
- highly aggressive atmosphere containing sulphur, carbon, and nitrogen oxides, etc.,

Can be foreseen to a great extent in advance and such harmful actions can be taken into consideration by selecting an adequate method of waterproofing. The significance of individual impacts as well as of their entirety can be defined on the basis of approved professional knowledge.

The serviceability and durability of cement concrete bridges are crucially affected by the application method and the quality of the waterproofing. Different approved materials for the waterproofing are capable to take specific loading without adverse consequences, however only up to a certain extent. Therefore, the selection of an appropriate waterproofing material is as important as its application.

C O N T E N T S

1. SUBJECT OF DESIGN GUIDELINES

The intention of the present design guidelines is to define a suitable quality of protecting new bridges as well as of renewal of protection of existing ones. For this purpose, some characteristic approved up-to-date methods and materials for waterproofing are described.

The procedures indicated herein are appropriate particularly for waterproofing of bridges and retaining walls thus ensuring their protection from physical and chemical actions imposed by both surface and ground water.

2. REFERENCE REGULATIONS

The DG 1.2.4 is based on the following regulations:

EN standards

EN 1107-1
EN 1109
EN 1110
EN 1426
EN 1427
EN 1429
EN 1431
EN 1849-1
EN 12311-1
EN 12593

DIN codes

DIN 16726
DIN 52123
DIN 52131
DIN 1996-6
DIN 1996-10
DIN 1996-14
DIN 1996-15
DIN 1996-16
DIN 1996-17
DIN 1996-18
DIN 1996-19
DIN 51366
DIN 51755
DIN 52004
DIN 52005
DIN 52016
DIN V 52021
DIN 52023
DIN 52040
DIN 53150
DIN 53211
DIN 53215
DIN 53505
DIN 53854
DIN 53855
DIN 53857
DIN 54307

Austrian codes (ÖN)

ÖN C 9231
ÖN C 9232
ÖN 3800/1

Technical regulations

ISO 2592
SIA 280-10
RVS 15.362
TL Min – Stb
ZTV BEL-B
ZTV TL bitfug 82

3. EXPLANATION OF TERMS

The explanation of the terms applied in the present design standard is as follows:

Bituminous waterproofing coat is a method of application of a hot or a cold liquid bituminous binder to seal perfectly the asphalt surfaces.

Bituminous waterproofing sheeting is a sealing strip with a bearing inlay covered with bituminous compound; it can be stuck or welded on the substrate.

Drainage epoxy concrete is a gap-graded concrete with a high percentage of macro-cavities; an epoxy resin is used as a binder.

Roughness depth is a coefficient of the volume of deepening below the top of the grains on the layer surface to the appurtenant surface; it is also a criterion of the macro-texture determined by the sand-patch-method or by the Moor's measurement of the water outflow.

Waterproofing means sealing of surfaces against water penetration.

Levelling layer is a layer to ensure an even substrate and its adequate height.

Levelling with trowel is filling up of deepening due to substrate roughness using a suitable material applied with a trowel up to the top of the grains in the substrate.

Adhesive is a substance based on bituminous or synthetic materials intended for sticking of the waterproof membrane to the prepared substrate.

Sticking of waterproofing sheeting means to create a good adhesion with the substrate by pouring heated bituminous mixture below the waterproofing sheeting.

Poured asphalt is an asphalt mixture that is dense liquid in a heated condition; therefore it is not necessary to thicken it during application.

Bridge deck surfacing consists of the waterproof membrane and the wearing course.

Wearing course is a durable top layer of the bridge deck surfacing ensuring traffic safety. Its composition depends on the traffic and climatic loading as well as on the basic purpose of use.

Priming coat is made of an epoxy resin or a solution of a bituminous binder; it penetrates into the substrate thus improving adhesion of the subsequent layer; all hollows are filled up with the priming coat as well.

Substrate is the surface below the waterproofing system to be applied.

Water jet method is a hydro-mechanical procedure of surface preparation, i.e. of cleaning and roughening.

Overlapping means that two adjoining waterproofing sheeting slightly overlap each other.

Joint is an opening (groove) between two adjoining structural elements or in a certain structural element to prevent uncontrolled cracks or to equalize differences in length due to temperature changes.

Bonding layer is an intermediate layer to improve the sticking together and to ensure a permanent layer connection.

Header joint is a foreseen or a conditional contact of two or more adjacent structural elements without any interconnection or where these elements are linked by the aid of a mean of joining.

Waterproof membrane is the base layer of the bridge waterproofing. It is made of materials containing bituminous binders or synthetic resins.

Sealing is a combination of layers to seal the substrate. It consists of the priming coat, the sealing coat or levelling with trowel, the waterproof membrane, and the protective layer.

Sealing strip is a material of a certain cross-section to fill up and seal the joints.

Welding of bituminous waterproofing sheeting is a procedure where both the substrate and the sheeting surface are heated uniformly and over the entire width by means of suitable torches to create conditions for an adequate softening of the bituminous mixture thus ensuring a sufficient adhesion of the bituminous sheeting to the substrate.

Sealing coat means application of a continuous film of an adequate binder to a porous substrate.

Protective layer is a layer applied to protect the waterproof membrane from damage; it can also improve the bridge waterproofing.

Joint sealing compound is a cold or a hot liquid mixture without any fixed shape; it is intended to seal the joints by pouring, which ensures their expected performance.

4. TYPES AND CHARACTERISTICS OF WATERPROOFING METHODS

The selection of the waterproofing method to be applied depends in particular on the following:

- the type and purpose of a bridge;
- specific local impacts: traffic, climate, road design, bridge structural particularities, and bridge maintenance.

Bridges can be effectively protected from harmful water actions either by

- stiff materials (so-called “white tub method”), or
- different combinations of predominantly flexible waterproofing layers (so-called “black tub method”).

The basic sealing material in the "white tub methods" is water-impermeable cement concrete. However, the use of such concrete is limited particularly to the bridge elements not exposed to salt actions. Therefore, methods including sealing materials bonded to the substrate are more appropriate in any case. For this purpose, a durable adhesion of the waterproofing membrane to the prepared substrate shall be ensured by means of a suitable bonding layer.

This conditions to execute the following:
- application of the priming coat, and
- application of the sealing coat or levelling with a trowel.

The method of waterproofing of the entire bridge shall be specified in detail in the bridge design.

Any bridge waterproofing "black tub method" using stuck layers generally consists of the bonding layer, the waterproofing membrane, and the protective layer (figure 4.1).

4.1 Priming coat

For vertical or extremely inclined surfaces where the water cannot stagnate it is recommended to apply a priming coat based on a solution of a bituminous binder. Such priming coat additionally requires the execution of a sealing coat or levelling with a trowel.

To horizontal or slightly inclined surfaces priming coats based on epoxy resins with suitable gritting shall be applied.
The priming coat shall ensure adequate bond strength and the vapour barrier.

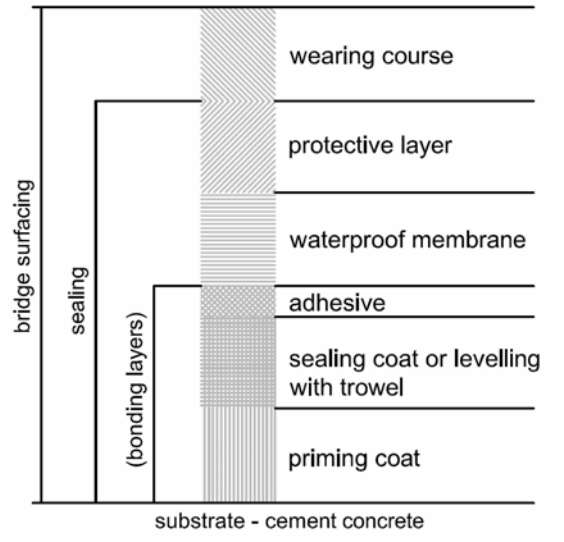


Fig. 4.1: Bridge surfacing system ("black tub")

4.2 Waterproofing membrane

An appropriate waterproofing membrane shall be carried through with materials welded, stuck or sprayed onto the bonding layer.

The waterproofing membrane shall be capable to follow all the bridge displacements.

4.3 Protective layer

To protect the waterproofing membrane on slightly inclined or horizontal surfaces, a protective layer shall be applied. A perfect adhesion of the protective layer to the waterproofing membrane shall be ensured by means of effective sticking together. For greater inclinations of the waterproofing membrane, the latter shall be protected with materials that ensure the required protection only by a partial (spot) bond with the base.

5. BASIC MATERIALS

The applicability of all materials to be applied for the waterproofing of the entire bridge, i.e. quality and compatibility shall be checked by suitable preliminary tests and verified by the certificates.

Precise makers' instructions for use shall be ensured for all materials.

5.1 Types of materials

Materials intended for bridge waterproofing shall be made of bituminous binders or synthetic organic compounds. For certain layers within the waterproofing system, some other materials can be used as well.

5.1.1 Materials with bituminous binder

Materials with a bituminous binder are particularly suitable for the following procedures:

o For bonding layers:
- for priming coat: solutions of bituminous binders;
- for sealing coat or mixtures for levelling with a trowel: bituminous binders modified with polymers (eventually with admixtures);
- for adhesive: bituminous binders with adequate admixtures.

o For waterproofing membranes:
- bituminous sheeting for sticking;
- bituminous sheeting for welding;
- bituminous binders modified with polymers.

o For protective layers and wearing courses:
- bituminous concrete;
- crushed gravel with bituminous mastic;
- poured asphalt.

o For coating to seal the layer surface:
- solutions of bituminous binders;
- bituminous binders modified with polymers.

When stuck or welded bituminous sheeting is used for the bridge waterproofing, special bituminous strips shall be used to bandage the butt joints of the sheeting. Those bituminous strips shall be coated with a protective layer to prevent transition of bituminous materials from or through these strips into the adjacent materials, i.e. upper asphalt layers.

To seal the joints of bridge surfacing and adjoining materials, the following shall be applied:

- bituminous joint sealing compound, or
- bituminous sealing strip.

In both cases mentioned above a suitable solution of a bituminous binder shall be applied as a priming coating.

5.1.2 Materials with synthetic organic compounds

Materials with synthetic organic compounds can be used for the following bridge waterproofing methods:

o For bonding layers:
- for priming coats: liquid polymers – reaction (epoxy) resins;
- for sealing coats or mixtures for levelling with a trowel: liquid polymers (reaction (epoxy) resins) with appropriate admixtures;

o For partly protective layers:
- polymer felts (fabrics);
- drainage reed-mats.

5.1.3 Other materials

To reinforce the waterproofing membrane made of bitumen modified with polymers, suitable plastic or steel wire meshes, or appropriate fabrics made of glass or polyester fibres shall be used.

The protective layer for waterproofing of bridges
built-in in fills can consist of the cement concrete of suitable composition or of the cement mortar as well.

For sealing of vertical cement concrete surfaces different materials such as wooden plates, bricks, polystyrene, etc. can be used as a protective layer.

5.2 Quality of materials

All specified values for the individual characteristics of basic materials are limit values therefore they shall be ensured unconditionally.

5.2.1 Materials with bituminous binder

5.2.1.1 Solution of bituminous binder

As the priming coat a cold solution of oxidized (blown) or road bitumen in organic solvents shall be used.

The technical conditions for the characteristics of the bituminous binder solutions are indicated in the table 5.1.

Instead of a bituminous binder solution an unstable bituminous emulsion can be used as the priming coat provided that this has been foreseen in the design and/or approved by the client's engineer. The unstable bituminous emulsions shall comply with the requirements indicated in the table 5.2.

5.2.1.2 Bituminous binder modified with polymers

For sealing modified bituminous binders are applicable. They are prepared in suitable plants as a homogenous physical mixture or a product of the chemical reaction of bitumen and temperature resistant polymer – elastomer or plastomer.

The manufacturer shall indicate in detail the characteristics of the bituminous binder modified with polymers as well as its application.

The bituminous binder modified with polymers used as a sealing coat or for levelling with a trowel within the waterproofing system shall fulfil the requirements given in the table 5.3.

Table 5.1: Technical conditions for the characteristics of the bituminous binder solutions

Characteristics of bituminous binder solution	Unit	Required value	Regulation for testing
Percentage of bitumen	% by	30 to 50	DIN 53215
R&B softening point of extracted bitumen:	mass		EN 1427
- oxidized bitumen		80 to 125	
- road bitumen	°C	54 to 72	
Penetration of extracted bitumen	°C	10 to 45	EN 1426
Breaking point of extracted bitumen by Fraass, maximum:	mm/10		EN 12593
- oxidized bitumen	°C	- 10	
- road bitumen	°C	- 2	
Flash point by Abel-Pensky, minimum:	°C	21	DIN 51755
Flowing-out time by Ford	s	15 to 80	DIN 53211
Drying time (dry to dust)	h	3	DIN 53150

Table 5.2: Technical conditions for the characteristics of the unstable bituminous emulsions

Characteristics of bituminous emulsion	Unit	Required value		Regulation for testing
		UBE 60	UBE 70	
Type of charge	-	anion, cation		ÖN C 9232
Appearance	-	brown, liquid,		ÖN C 9231
Percentage of water, maximum	% by	homogenous		EN 1431
Stability: residuals after sieving (rejects)	mass	42	32	
- after 4 weeks, maximum				
- after 1 week, maximum	% by	0.5	-	
Flowing-out time:	mass	-	0.5	DIN 52023
- 4 mm orifice at 20°C, maximum	% by			
- 4 mm orifice at 40°C, maximum	mass	12	-	
		-	60	
	s			
	s			
Type of used bitumen	-	to be indicated		
Characteristics of extracted bitumen				
- percentage of ashes, maximum	% by	2.5		DIN 52005
- R&B softening point of bitumen, max.	mass	49		EN 1427
- R&B softening point of bitumen, min.	°C	37		EN 1427
Effect of water on the binder film	°C	crushed aggregate		DIN 1996-10
	-	entirely coated		

5.2.1.3 Bituminous adhesive

The characteristics of the bitumen used for the bituminous adhesives for sticking of waterproof membranes (hot procedure) onto the substrate shall comply with the requirements indicated in the table 5.4.

5.2.1.4 Bituminous sheeting

The required characteristics of bituminous sheeting used for welded or stuck both horizontal and slightly inclined waterproof membranes are indicated in the tables 5.5 and 5.6.

Table 5.3: Technical conditions for the characteristics of bituminous binders modified with polymers

Characteristics of modified bituminous binder	Unit	Required value PmBIT 80	Required value PmBIT 40	Regulation for testing
Density at 25°C, minimum	g/cm^3	1.00		DIN 52004
Equiviscous temperature (EVT)	°C	to be indicated		DIN 51366
Penetration (100g, 5s, 25°C), minimum	mm/10	80	40	EN 1426
R&B softening point, maximum	°C	49.5		EN 1427
R&B softening point, minimum	°C		50	EN 1427
Breaking point by Fraass, maximum	°C	- 15	-10	EN 12593
Flash point by Cleveland, minimum	°C	200		ISO 2592
Elastic strain (60 min, 7°C), minimum	%	50		DIN V 52021
Stability against segregation at EVT 100°C or maximum 180°C; difference between R&B softening points, maximum	°C	2		"Tubentest"
Relative mass change after heat treatment, maximum	% by mass	2		DIN 52016
Change of R&B softening point after heat treatment:				DIN 52016, EN 1427
- increase, maximum	°C	8		
- decrease, maximum	°C	2		
Change of penetration after heat treatment:				DIN 52016, EN 1426
- decrease, maximum	%	40		
- increase, maximum	%	20		
Elastic strain after heat treatment, minimum	%	50		DIN 52016 DIN V 52021

Table 5.4: Technical conditions for the characteristics of bituminous adhesives

Characteristics of bituminous adhesive	Unit	Required value	Regulation for testing
Percentage of filler	% by mass	0	DIN 1996-6
Percentage of ashes, maximum	% by mass	1	DIN 52005
R&B softening point of bitumen, minimum	°C	90	EN 1427
Breaking point of bitumen by Fraass, maximum	°C	- 10	EN 12593
Penetration of bitumen	mm/10	23 to 30	EN 1426
Shear strength at 50°C, minimum	N/mm^2	0,8	RVS 15.362
Specific shear strain at 50°C	%	to be indicated	

Table 5.5: Technical conditions for the characteristics of bituminous sheeting for slightly inclined waterproof membranes

Method of execution	Required value: Procedure with sticking: Sheeting thickness	Required value: Procedure with sticking: Bituminous binder content	Required value: Procedure with welding: Sheeting thickness	Regulation for testing
	mm	g/m^2	mm	
With one sheeting, minimum	3.0	2000	4.5	
With two sheeting, minimum	3.0	2000	3.6	DIN 52123
Bandaging, minimum	2.0	1600	2.0	

Table 5.6: Technical conditions for the characteristics of bituminous sheeting for horizontal waterproof membranes

Characteristics of bituminous sheeting for horizontal waterproofing	Unit	Required value	Regulation for testing
Stability at –5°C (bending on thorn of r=30 mm)	-	stable	EN 1109
Stability at 90°C, mean value of flow, maximum	mm	0.5	EN 1110
Breaking force, longitudinally and transversally, (5 cm), mean value minimum	N	800	EN 12311-1
Elongation at breakage: [*1]	%	2	EN 12311-1
- of sheeting with glass fabric, mean value minimum	%	2	
- of sheeting with polyester felt, mean value minimum	%	40	
Shear strength at 50°C:			RVS 15.362
- of sheeting, mean value minimum	N/mm^2	0.8	
- of applied bituminous mixture, mean value minimum	N/mm^2	0.8	
Applied bituminous mixture:			
- softening point, minimum	°C	150	EN 1427
- linear shrinkage, maximum	%	2	EN 1107-1
- filler content, maximum	% by mass	30	EN 1849-1
Mass of polyester felt, minimum	g/m^2	200	DIN 52123
Thickness of sheeting:			EN 1849-1
- mean, minimum	mm	5	
- individual, minimum	mm	4.7	
Thickness of bituminous mixture layer:			DIN 52123
- below bearing fabric, minimum	mm	3	
- above bearing fabric	mm	0.5 – 1.3	
Quantity of stone grains greater than 0.71 mm, max.	% by mass	5	DIN 52123
Absorption of water, maximum	% by mass	5	DIN 53495
Water-permeability (pressure 1 bar/24 hours)	-	watertight	DIN 52123

[*1] *The bituminous mixture applied onto the sheeting shall not crack.*

Table 5.7: Supplemental technical conditions for the characteristics of bituminous sheeting for vertical waterproof membranes

Characteristics of bituminous sheeting for horizontal waterproofing	Unit	Required value	Regulation for testing
Stability at 0°C	-	stable	EN 1110
Stability at 70°C			EN 1110
Breaking force, longitudinally and transversally (5 cm):			EN 12311-1
- bearing layer glass fibre fabric, minimum	N	400/300	
- bearing layer polyester felt, minimum	N	800/800	
Elongation at breakage:			EN 12311-1
- bearing layer glass fibre fabric, minimum	%	2	
- bearing layer polyester felt, minimum	%	40	
Mass of bearing layer:			EN 1849-1
- bearing layer glass fibre fabric, minimum	g/m^2	54	
- bearing layer polyester felt, minimum	g/m^2	200	
Thickness of sheeting:			EN 1849-1
- mean minimum	mm	4	
- individual minimum	mm	3.7	
Content of mineral fillers, maximum	%	25	EN 12311-1
Water-permeability (pressure 1 bar/24 hours)	-	watertight	EN 12311-1

Supplementary requirements for the characteristics of bituminous sheeting for vertical and extremely inclined waterproof membranes are given in the table 5.7.

The bearing layer for the bituminous mixture in the sheeting for horizontal waterproof membrane shall be a glass fibre fabric or polyester felt. It shall have a suitable breaking strength and heat resistance.

The bituminous sheeting surface shall be uniform, dry, without extraneous inclusions and cracks, and suitably protected either with a polyethylene foil or adequate stone grains.

In general, the bituminous sheeting for the waterproof membranes shall be 1,000 mm wide, whereas its edges shall be even. The maximum allowed tolerance of the sheeting width amounts to ± 10 mm.

Self-adhesive bituminous strips for bandaging of butt joints of bituminous sheeting used for the waterproof membrane shall be approximately 200 mm wide.

When the sealing is carried through with overlapping of bituminous sheeting, the latter shall have at least at one end a shape of a wedge of 80-100 mm width.

Disuniting of bituminous sheeting in individual layers is not permitted, and the coil of the sheeting shall not be deformed.

5.2.1.5 Asphalt mixtures for protective layers and wearing courses

The required characteristics of asphalt mixtures for protective layers and wearing courses of the bridge surfacing are predominantly similar to those for road pavement structure. They are defined in detail in the relevant technical regulations and specifications.

For asphalt mixtures used for protective layers and wearing courses of bituminous concrete, crushed gravel with bituminous mastic and poured asphalt, mixtures of stone grains of 8 to 11 mm size and of appropriate modified bituminous binder are suitable.

For protective layers, stone grains originating from carbonate rock can be used.

The percentage of grains of size up to 0.09 mm shall amount to 7 – 10% by mass in the stone mixture for the asphalt mixture of bituminous concrete used for the protective layer. The ratio of percentages of grains of crushed and natural sand shall be from at least 3:1 in the protective layer above the two-layer waterproof membrane of bituminous strips to 1:1 above the single-layer waterproof membrane. The void content in the test specimen by Marshall shall amount to 2 – 3% by volume.

The asphalt mixture of crushed stone with bituminous mastic shall fully comply with the requirements for the layers of road pavement structures.

For the asphalt mixtures of poured asphalt used for the protective layer on bridges with higher traffic loading (medium and heavy traffic), the depth of impression (seal of 5 cm^2, 40°C, 30 min, 525 N) shall amount to 1 – 2.5 mm after 30 minutes. After additional 30 minutes, the depth of impression may be increased by maximum 0.4 mm.

5.2.1.6 Bituminous joint sealing compound

The required characteristics of durable elastic bituminous joint sealing compounds at boundary surfaces of different materials in the bridge surfacing and the adjacent elements are specified in detail in the table 5.8.

5.2.1.7 Bituminous joint sealing strip

The characteristics of durable elastic bituminous strips to seal the boundary surfaces, particularly the joints between protective layers/wearing courses and kerbs (within the framework of bridge walkways), shall be similar to those of bituminous joint sealing compound specified in the table 5.8, with the exception of the characteristics indicated in the lines 1 and 2, which cannot be checked on the sealing strip.

5.2.1.8 Bituminous coating for sealing of wearing courses

To seal the asphalt wearing courses the following bituminous coating shall be applied:

- bituminous emulsions,
- bituminous binders modified with polymers, or
- bituminous adhesives.

The characteristics of the materials mentioned above shall comply with the requirements indicated in the tables 5.2, 5.3, and 5.4.

Table 5.8: Technical conditions for the characteristics of bituminous joint sealing compounds

Characteristics of bituminous sheeting for horizontal waterproofing	Unit	Required value	Regulation for testing
Sealing capability at 180°C	-	good	
Sealing temperature	°C	to indicate	ZTV TL bitfug 82 Anhang 1
R&B softening point of compound, minimum	°C	85	EN 1427
Cone penetration at 25°C, (150 g, 5 s)	mm/10	40 to 90	ZTV-Anhang 3
Flow at 60°C, (5 hours, 75°), maximum	mm	5	ZTV-Anhang 4
Flow after overheating, maximum	mm	5	ZTV-Anhang 4
Change of R&B softening point after overheating (absolute), maximum	°C	10	EN 1427, ZTV-Anhang 5
Change of cone penetration after heat treatment at 70°C, maximum	%	25	ZTV Anhang 3, 5
Heat resistance by Nüssel at 45°C (24 hours), max.	-	6.5	DIN 1996-17
Frost resistance by Hermann (-20°C, 5 hours)	-	withstands 3 of 4	DIN 1996-18
Ductility by Raabe (-20°C, 15x30 mm), minimum	mm	5	DIN 1996-19
Segregation resistance (150°C, 30 min), maximum	%	5	DIN 1996-16

Table 5.9: Technical conditions for the characteristics of epoxy resins

Characteristics of epoxy resins	Unit	Required value	Regulation for testing
Viscosity at 23°C, maximum	Pa s	1	ZTV-BEL-B/1995 Part 3
Viscosity at 12°C, maximum	Pa s	4	
Viscosity at 8°C	Pa s	to be indicated	
Density of individual component	g/cm^3	to be indicated	
Residue after burning, maximum	% by mass	1	
Time of applicability, minimum	min	10	
Curing time:			
- 46 hours, 8°C, 75% relative air humidity		to be indicated	
- in normal climate, maximum	h	18	
- at 40°C and 75% relative air humidity, minimum	h	2	
- at 12°C and 75% relative air humidity, maximum	h	40	
Content of non-volatile substances, minimum	% by mass	98	
Water absorption in cured condition, maximum	% by mass	2.5	
Heat resistance (silicon oil), minimum	°C	250	
Bond strength after heat test, minimum	N/mm^2	1.5	
Soundness at storage, minimum	year	1	

Table 5.10: Technical conditions for the characteristics of sand to be spread onto the priming coats based on epoxy resins or bituminous binders

Characteristics of sand for spreading	Unit	Required value	Regulation for testing
Grain size distribution 0.2/0.7 mm			TL Min - Stb
- particles eliminable by washing off (<0.063 mm), maximum	% by mass	0.5	
- undersized grains, maximum	% by mass	5	
- oversized grains up to 1 mm, maximum	% by mass	10	
Grain size distribution 0.5/1.2 mm			
- particles eliminable by washing off (<0.063 mm), maximum	% by mass	0.3	
- undersized grains, maximum	% by mass	5	
- oversized grains up to 2 mm, maximum	% by mass	10	

5.2.2 Materials with synthetic organic compounds

5.2.2.1 Reaction (epoxy) resins

Solvent-less and filler-less heat resistant reaction resins of low viscosity shall be used as priming coats applied to the bridge cement concrete.

The reaction resins (epoxy resins) shall fulfil the requirements given in the table 5.9.

The composition of epoxy resins shall be determined by the IR-analysis. The characteristics of the basic component, hardener, extract, and reaction resin shall be established by a preliminary test. The results obtained serve as a basis for the subsequent conformity verifications.

5.2.2.2 Polymer felt

Felts for partly protective or dividing layers of the waterproofing systems shall be made of polypropylene or polyester fibres. The selection of the felt type depends on the application conditions.

The characteristics of the felt shall comply with the values indicated in the table 5.11.

5.2.2.3 Drainage reed-mats

The characteristics of reed-mats for partly protective or dividing layers shall be specified in the design. As a rule, the basic data on the particular drainage reed-mat stated by its manufacturer shall be taken into consideration.

5.2.3 Sand for spreading

The sand spread onto the epoxy priming coat shall have properties indicated in the table 5.10, unless specified otherwise in the instructions issued by the epoxy resin maker.

In certain cases such sand is suitable to be spread onto the bituminous priming coat as well.

Table 5.11: Technical conditions for the characteristics of felt

Characteristics of sand for spreading	Unit	Required value 300 g	400 g	500 g	Regulation for testing
Unit mass (per m^2)	g/m^2	300	400	500	DIN 53854
Permissible deviation from nominal mass, maximum	%	10	10	10	DIN 53854
Thickness a_{200} at nominal mass, min.	mm	2	2.5	3	DIN 53855/1
Permissible deviation from nominal thickness, maximum	%	10	10	10	DIN 53855/1
Maximum tensile force (longitudinally and transversally), minimum	N/50 mm[*1]	150	200	250	DIN 53857/2
Elongation at maximum tensile force, minimum	%	60	60	60	DIN 53857/2
Resistance to perforation, minimum[*2]	N	1,500	1,500	1,500	DIN 54307
Resistance to burning[*3]	-	B2	B2	B2	ÖN 3800/1
Resistance to decay[*4]	-		resistant		
Resistance to rock waters[*4]	-		resistant		
Water-permeability, minimum	$l/dm^2/min$	60	60	60	Darcy

Legend:
*[*1] for non-reinforced felts N/100 mm*
*[*2] for felts for tunnels at least 800 N, when the substrate is shot cement concrete*
*[*3] for tunnels*
*[*4] polyolefin felts comply with the requirements*

6. EXECUTION

6.1 General

The fundamental objective of a quality waterproofing of a bridge is to ensure a rapid and harmless drainage of surface and seepage water from the structure.

In general, the bridge waterproofing works can be carried through only in favourable weather conditions. The limit values of temperature and humidity of both air and cement concrete shall not be exceeded. These requirements confine the time suitable for a normal execution of he waterproofing works, and condition the working methods in severe weather conditions. In such cases, special steps shall be taken to ensure an adequate protection of works and an appropriate performance of the waterproofing.

The contractor is obliged to prove in advance the adequacy of the waterproofing method. He has to check the manufacturers' instructions for the application of materials. These instructions shall fully comply with the requirements indicated in the present design standard. The manufacturers' instructions shall be available on site at any time.

In general, the cement concrete of the new bridge shall be at least 21 days old prior to commencement of the waterproofing works. In case of repair works to a minor extent, the concrete shall be at least 7 days old before the beginning of the waterproofing works. When the manufacturer's directions allow the commencement the waterproofing works on surfaces of a younger cement concrete and/or such a procedure has been designed, this shall be preliminarily verified in conditions that fully comply with those during the work execution.

The individual procedures, i.e. from the substrate (cement concrete) preparation up to the application of the protective layer shall be carried through in conditions prescribed by the material manufacturers. When directed by the design, the waterproofing layers shall be stuck together as well as to the cement concrete on their entire surface. Any subsequent waterproofing layer must not be applied until it is evident that the previous layer has been properly executed.

Immediately prior to application of each layer it shall be verified whether an adequate drainage of the substrate is ensured, and the works shall be planned correspondingly.

Walking or driving on the waterproof membrane is allowed only as much as it is necessary to execute the following layer. Turning round of vehicles on the waterproof membrane is forbidden. Anyhow, the protective layer shall be applied as soon as possible.

The traffic on the protective layer is also allowed only for the needs of application of the wearing course, which shall be carried through as soon as possible.

If the traffic had to run on the protective layer for a longer period, the latter should be appropriately protected, e.g. with a provisional dividing layer and a wearing course.

Stop of vehicles and machinery on the protective layer and the wearing course is allowed only if suitable steps have been taken for their protection.

Transversal and longitudinal joints of the protective layer shall be adequately shifted with respect to those of the wearing course and vice versa.

For the compaction of asphalt mixtures in both protective layers and wearing courses only oscillating and dead weight rollers may be used.

A skilled person with certified knowledge shall manage all the works related to waterproofing.

6.2 Execution method

6.2.1 Substrate preparation

The efficiency of the bridge waterproofing depends on the substrate preparation, i.e. on the cement concrete surface.

From the cement concrete surface dust and major particles shall be removed by vacuum cleaners. All loose aggregate grains in the cement concrete shall be removed as well. Oil and grease stains shall be removed, eventually by removing of soiled cement concrete (cement glue and mortar) by means of mechanical hammers, sandblasting or high-pressure water jet. These procedures also ensure that the cement concrete surface is sufficiently rough and without sharp edges.

The required roughness depth of the cement concrete surface determined by the san method may amount to:
- up to 1.5 mm for welded bituminous sheeting,
- up to 2 mm for stuck bituminous sheeting,
- up to 4 mm on individual spots.

Eventual cracks as well as excessively porous or segregated spots on the cement concrete surface shall be treated with an epoxy resin and spread with washed quartz sand of 0.5/1 mm grain size distribution. Major irregularities shall be preliminarily made good by other suitable materials such as epoxy resins.

Prior to commencement of the waterproofing works, the cement concrete surface shall be dry. However, it can be partly damp in case that such materials are applied, which ensure a good adhesion to a damp substrate as well. The moisture content of the cement concrete surface shall be determined by means of sounds bored to a depth of 2 cm and measurements of the electric conductivity, or gravimetrically. The permissible moisture content shall not exceed 4 %.

Only informatively and exceptionally, the moisture content of the cement concrete surface may be established by newsprint as well: a sheet of newsprint manually pressed to the cement concrete surface must not show any visible traces of water absorption. Eventual moisture content of the concrete surface can be indicated by means of local heating with hot air: a heated dry surface is lighter.

The cement concrete surface on a bridge shall be as even as possible. In exceptional cases the following tolerances of the evenness below a 4 m measuring lath are permitted:
- at a length of 4 m: maximum 40 mm,
- at a length of 2 m: maximum 20 mm, and
- at a length of 1 m: maximum 10 mm.

To improve the evenness of the bridge superstructure surface, a levelling layer can be applied.

All height deviations greater than 40 mm shall be rectified directly on the cement concrete, as a rule before commencement of the waterproofing works. The same applies to all embossments that prevent application of the protective layer of a minimum required thickness.

Height deviations of the cement concrete surface between 15 mm and 40 mm below the designed level shall be made good with a suitable levelling layer of an epoxy mortar, micro-reinforced repairing cement mortar, or asphalt mixture. In case that the bridge surface having such deviations is of a minor extent thus allowing manual repairing work, the levelling layer shall be applied directly to the waterproof membrane (figure 6.1). Is the extent of an uneven surface greater, levelling shall be carried through by means of a mechanical application of an adequate levelling layer to the already applied protective layer of a uniform thickness. The supervising engineer shall direct the method of execution of the required levelling of the cement concrete on the bridge superstructure on the basis of assessment of the bridge surface condition.

The mean value of bond strength to seal the prepared cement concrete surface shall amount to at least 1.5 N/mm^2 (no individual measurement shall be less than 1 N/mm^2) thus ensuring a strong and durable adhesion with the layer above.

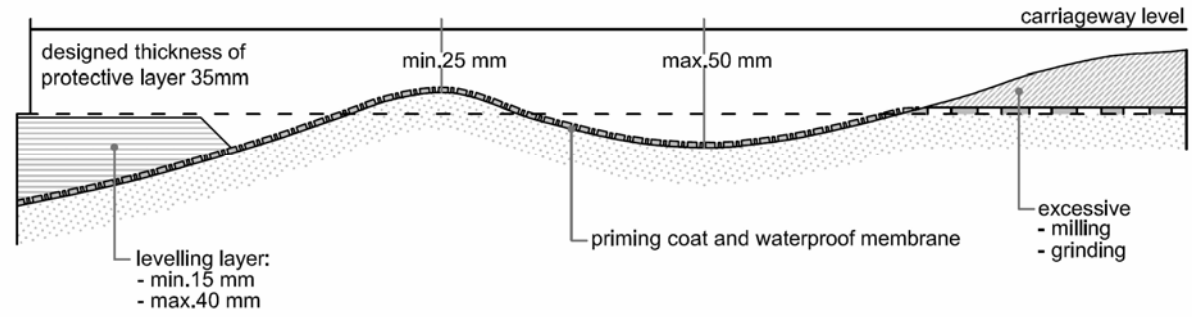


Fig. 6.1: Method of levelling to ensure limit values of protective layer thickness

6.2.2 Bonding layers

6.2.2.1 Priming coat with reaction resins

The priming coat to seal the bridge cement concrete surface shall be generally carried through with reaction resins followed by spreading of sand.

Reaction resins cannot be applied without suitable protective measures required in the following external conditions:

- during precipitations, dew or fog,
- relative air humidity above 85%,
- temperature of cement concrete substrate below +8°C,
- temperature of substrate above +40°C, or
- rapid increasing and decreasing of temperature.

The temperature of the substrate shall be at least 3K above the dew point.

Multi-component reaction resins shall be mixed in accordance with the maker's instructions. Changing of materials or their composition as well as of the mixing ratio is not permitted unless otherwise directed in the instructions.

The substrate roughness depth is generally not specified for the priming coats based on reaction resins.

Open pores on the prepared cement concrete surface shall be filled up with one or more epoxy resin coats. The first coat shall be applied according to the manufacturer's instructions by brush, roller or scraper. The resin consumption amounts to 300 – 500 g/m^2. The epoxy resin shall be sanded uniformly to prevent accumulation of resin slops. The still fresh surface of applied epoxy resin shall be uniformly spread with suitable quantity of dried quartz sand of 0.5/1.2 mm (exceptionally 0.2/0.7 mm) of grain size distribution.
The spread sand not adhering to the epoxy resin surface shall be removed.

When the bridge cement concrete is exposed to aggressive water on the inner side as well, all concerned horizontal and vertical surfaces shall be adequately protected with a priming coat, i.e. epoxy resin spread with sand.

Joints of priming coats and individual layers shall be carried through stepwise, in a straight line and shifted by at least 10 cm one to another.

In case of machine application of the waterproof membrane, an additional layer of epoxy resin (approx. 400 g/m^2) shall be applied onto the sanded surface.

The mean value of the bond strength for sealing of the prepared cement concrete surface as well as for the surface coated with the priming coat based on epoxy resin shall amount to 1.5 N/mm^2 minimum. A predominant failure shall occur in the cement concrete substrate.

The roughness depth of the surface coated with the priming coat based on a reaction resin and spread with sand shall not exceed 1.5 mm.

6.2.2.2. Priming coat with bituminous binders

In certain conditions, it is also possible to apply a priming coat with a suitable bituminous binder for the waterproofing of concrete bridges. This is particularly recommended for surfaces of greater inclinations, whereas for surfaces of smaller inclinations and especially for considerably loaded surfaces the material mentioned above is less appropriate.

The roughness depth for the priming coat with bituminous binders shall amount to 0.8 mm minimum.

The prepared cement concrete surface shall be uniformly coated with a cold solution of bituminous binder (as a rule 200 to 400 g/m^2) using brushes or rollers. The quantity of the applied binder shall be the least possible, i.e. without surplus.

When a warm solution of bituminous binder is foreseen, it is usually applied by spraying.

During the application of the solution of bituminous binder the substrate surface temperature shall amount to at least +5°C.

Only in exceptional cases and when preliminarily approved by the supervising engineer, an unstable bituminous emulsion may be applied as a priming coat.

Application of the priming coat shall be avoided in the early morning hours.

The roughness depth of the substrate to which a bituminous priming coat is applied followed by application of the sealing coat or by levelling with trowel and by gritting, shall amount to 0.6 mm minimum.

6.2.2.3 Sealing coat

When application of an additional layer of epoxy resin, i.e. of a sealing coat is required to ensure the bonding layer or a continuous film of binder (in a thickness of 0.3 to 0.5 mm), washed quartz sand of grain size distribution of 0.5/1.2 mm shall be spread onto the priming coat in surplus. The unbound sand shall be removed as soon as the priming coat has hardened sufficiently.
As a rule, additional gritting of the sealing coat is not necessary.

6.2.2.4 Levelling with trowel

For levelling with trowel an epoxy mortar is generally used.

Levelling shall be carried through on the uncured priming coat based on epoxy resin. Only when approved by the engineer levelling may be executed on a cured priming coat.

By means of a trowel drawn over the peaks of grains jutting out from the substrate, the epoxy mortar shall be applied into the hollows of the rough cement concrete surface. The characteristics of the surface of such levelling shall be similar to those of the applied priming coat. Spreading with sand of grain size distribution of 0.5/1 mm shall be carried through without surplus.

In case of waterproofing with bituminous sheeting, for levelling with a trowel adequately heated bituminous materials can be used as well. Bituminous adhesive is particularly appropriate. By filling up the open pores on the cement concrete surface with the bituminous adhesive the subsequent works related to waterproofing are much less dependent on weather conditions. The required amount of bituminous adhesive for levelling with an adequate trowel is 1.5 to 2 kg/m^2.

Mixtures used for the levelling with a trowel must not be overlapped at the joints.

An excessive roughness of the cement concrete surface (above 4 mm, on certain spots even less) shall be generally levelled with an epoxy mortar. The mixing ratio epoxy resin : sand (of a uniform grain size distribution) shall amount to 1 : 3 to 1 : 4 unless otherwise directed by the manufacturer. As a rule, mixtures of materials already composed in the production plant shall be used.

The procedure of levelling with a trowel can be adopted as a base coat for sealing the asphalt wearing course surface at the carriageway edge.

6.2.3 Waterproof membranes

The following materials can be used to carry through the waterproof membranes:

- single bituminous sheeting,
- double bituminous sheeting,
- bitumen modified with polymers.

For bound (stuck) waterproof membranes or for connection of the waterproof membrane with the bonding layer an additional bonding layer might be necessary at times. The procedure of the execution of this layer is generally described in detail in the instructions of the maker of the waterproof membrane material. An informative quantity of the binder for such an additional layer amounts to approximately 250 g/m^2.

For unbound (floating) vertical or inclined waterproof membranes of bridges under construction non-stuck smooth or profiled polymer foils can be used.

The particularities of the waterproofing method with unbound waterproof membrane and the protection of polymer foils are generally described in detail in the manufacturer's instructions.

6.2.3.1 Single bituminous sheeting

A waterproof membrane with a single both welded or stuck bituminous sheeting can be executed

- for the intermediate waterproofing of individual bridge elements: below walkways, edge beams and kerbs, or
- for the upper waterproofing of bridges.

The bituminous sheeting for the intermediate waterproofing is generally applied longitudinally and stuck onto the bituminous priming coat by means of a bituminous adhesive. The sheeting shall extend into the carriageway area by at least 20 cm thus ensuring a quality connection with the upper waterproofing of the bridge. The sheeting shall be temporarily protected from eventual damage by means of non-sanded bituminous paper. The latter shall be removed from the carriageway area prior to execution of waterproofing works.

The mechanical characteristics of the bituminous sheeting for intermediate waterproofing may partly differ from the required values indicated in the table 5.6, when this is reasonably.

For the upper waterproofing with a single bituminous sheeting the latter is generally welded onto the substrate.

The reaction resin in the applied bonding layer shall be at least 48 hours old and sufficiently cured prior to commencement of the bituminous sheeting application.

When bituminous sheeting for the upper waterproofing of bridges is applied to the bituminous priming coat or to the bituminous adhesive compound levelled with a trowel, the latter shall be dry.

The air temperature during the application of waterproof membranes consisting of bituminous sheeting shall amount to at least +5°C, and the substrate must not be frozen.

First, the bituminous sheeting shall be unrolled and adjusted, as a rule in the longitudinal direction of the bridge superstructure. Unless butt joints are foreseen, the required overlapping width shall be allowed for as follows:
- on longitudinal edges
- thinned ones 8 cm minimum
- uniform ones 10 cm minimum
- on transversal edges 10 cm minimum.

In case of butt joints of bituminous sheeting, the spacing of sheeting shall not exceed 10 mm.

Transversal joints of bituminous sheeting shall be shifted by at least 50 cm.

Bituminous sheeting for which butt joints are foreseen shall be applied from the higher side of the bridge proceeding towards the lower one. On the contrary, application of bituminous sheeting joined by overlapping shall commence on the lower side of the bridge.

When a plastic foil is used to prevent sticking together of bituminous sheeting during storage, it shall be removed prior to application of the sheeting if its thickness is greater than 0.05 mm.

Suitably adjusted bituminous sheeting shall be coiled up onto reel of an appropriate mass.

During a repeated slow unreeling the bituminous sheeting shall be uniformly heated over the entire width by means of several torches placed on the bridge superstructure or other source of heat. In the same time, the bituminous compound below the bearing fabric shall be melted. The temperature of the heating means (distance from the bituminous sheeting and application rate) shall be adjusted to outer conditions (air temperature, wind).

When bituminous sheeting is welded onto the bonding layer made of a reaction resin, the temperature of heating the substrate surface shall not be too high.
The manufacturer shall determine the basic conditions for heating of bituminous sheeting during welding. For heating of the bituminous compound on sheeting single torches may be used when approved by the supervising engineer and in exceptional cases only.

Under certain circumstances it is also allowed to stick suitable bituminous sealing sheeting onto a bituminous priming coat. For this purpose, a hot bituminous adhesive mixture shall be used. The temperature of this mixture during application shall be in accordance with the manufacturer's instructions. The bituminous adhesive compound shall be heated in a suitable boiler equipped with a stirring device. During heating, the compound shall be mechanically stirred and its temperature checked continuously. The consumption of the adhesive compound amounts to 1.5 – 2.0 kg/m^2, depending on the texture of the cement concrete surface.

During a repeated uncoiling (either during welding or sticking), a sufficient quantity of melted (plasticized) bituminous compound shall always be available in front of the bituminous sheeting on the reel, so that a crest can be formed.

Immediately after spreading out, the bituminous sheeting shall be uniformly pressed to the substrate. In this way, the sheeting is properly stuck over the entire width and the air is completely eliminated from the joint.

The bituminous compound (melted or adhesive) that flows out on the edges of the sheeting or has been pressed out from below the sheeting, shall be uniformly drawn out along the joint by means of suitable smoothing tools. Excessive pressed out quantity of the bituminous compound shall be

adequately removed. On the contrary, when on a certain portion of the joint the bituminous mixture has not come out or an insufficient sealing has been established, such spots shall be additionally sealed.

A transition of the bituminous sealing compound in the butt joint area into the upper asphalt mixtures shall be prevented by covering of that area with an approximately 20 cm wide adhesive strip. An eventually required additional sticking of those strips to the substrate shall be carried through by means of a careful heating of the joint area.

The average bond strength of bituminous sheeting shall amount to minimum 0.8 N/mm^2. At least three tests shall be carried out at 0°C. Any individual measured value must not be lower than 0.4 N/mm^2.

A general scheme of bridge waterproofing with single bituminous sheeting is shown in the figure 6.2. In the figure 6.3, this scheme is presented in greater detail, whereas waterproofing at the kerb is shown in the figure 6.4.

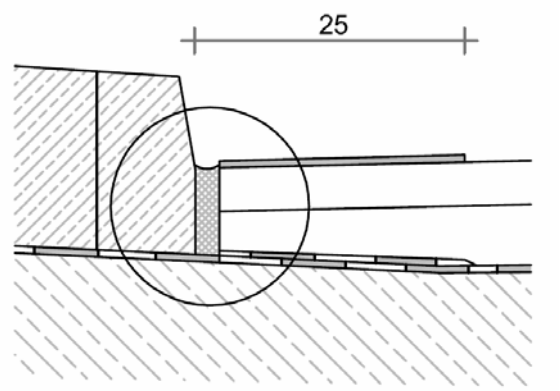


Fig. 6.2: Bridge waterproofing at the carriageway edge

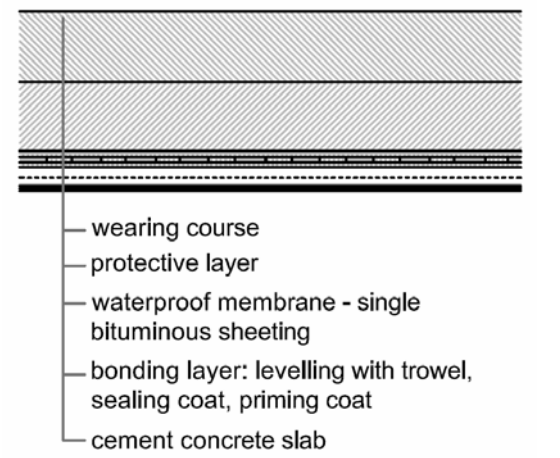
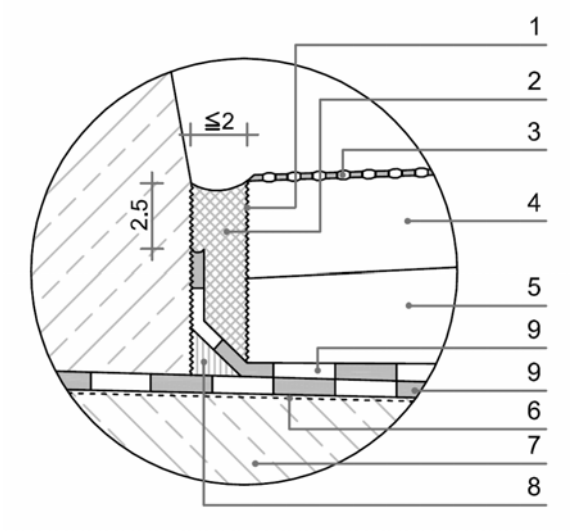


Fig. 6.3: Bridge waterproofing with single bituminous sheeting



Legend:
1 – priming coat
2 – joint sealing compound
3 – sealing coat
4 – wearing course
5 – protective layer
6 – priming coat, sealing coat, levelling with trowel
7 – cement concrete slab
8 – corner rounding off with bituminous compound or cement mortar
9 – waterproof membrane – bituminous sheeting

Fig. 6.4: Detail of waterproofing with bituminous sheeting at kerb

A common scheme of waterproofing at bridge gullies is shown in the figures 6.5 and 6.6, whereas a more detailed scheme in the figures 6.7 and 6.8. The longitudinal drainage groove shall ensure a complete evacuation of water that can sink to the waterproof membrane in the kerb area or in the area of the railing element.

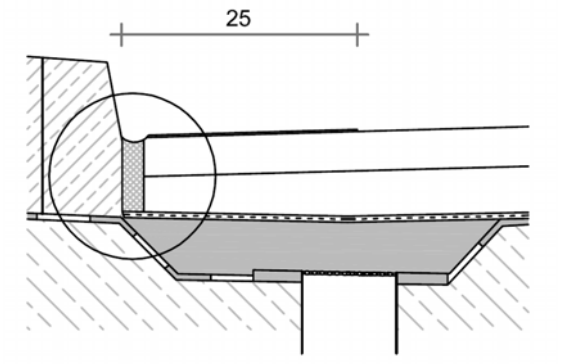
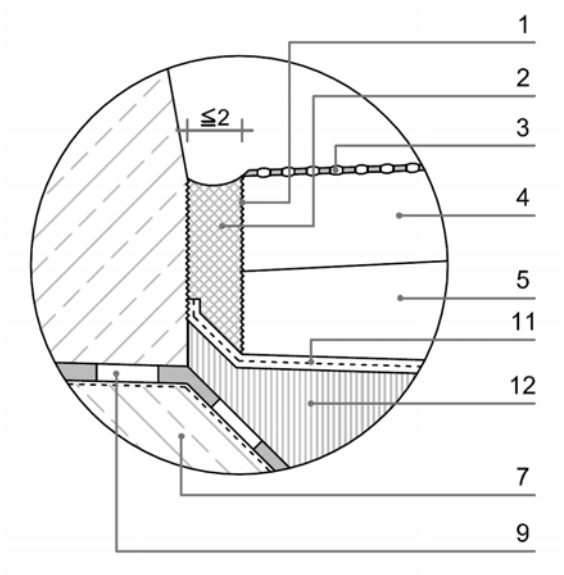


Fig. 6.5: Bridge waterproofing at gully



Legend:
1 – priming coat
2 – joint sealing compound
3 – sealing coat
4 – wearing course
5 – protective layer
7 – cement concrete slab
9 – waterproof membrane – bituminous sheeting
11 – protective felt
12 – drainage epoxy concrete

Fig. 6.6: Detail of bridge waterproofing at gully next to kerb

6.2.3.2 Double bituminous sheeting

In case of waterproofing with double bituminous sheeting (figure 6.7), the lower sheeting is generally stuck on the bonding layer by means of bituminous adhesive poured under the sheeting, whereas the upper sheeting is welded to the lower one.

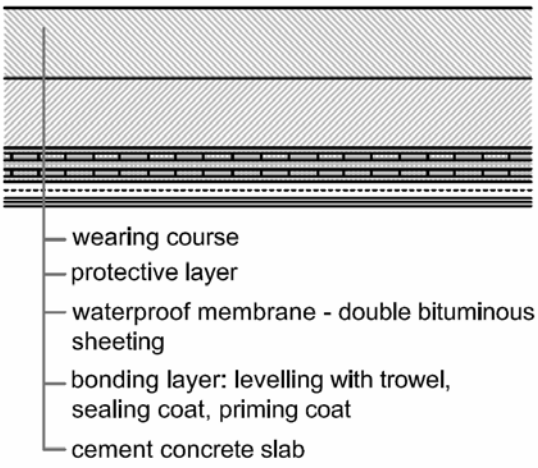


Fig. 6.7: Bridge waterproofing with double bituminous sheeting

To waterproofing with double bituminous sheeting the same conditions apply as to the waterproofing with single sheeting (refer to 6.2.3.1). Additional conditions apply to overlapping of the upper sheeting that shall be shifted with regard to the lower one by:

- ½ of sheeting width in longitudinal direction,
- at least 50 cm in transversal direction.

In case of waterproofing with double bituminous sheeting both layers shall be applied in the same direction (longitudinally as a rule).

6.2.3.3 Bitumen modified with polymers

Particularly for waterproofing of inclined cement concrete surfaces, sprayed waterproof membrane made of bituminous binder modified with polymers is suitable.

The consumption of the above mentioned material amounts to 2 – 3 kg/m^2, depending on the substrate roughness and the executed bonding layer.

As a rule, such binder applied by spraying in several layers of approximately 1 kg/m^2 to the substrate coated with a bonding layer, shall be adequately reinforced. For this purpose fabrics or meshes made of synthetic fibres and metal are appropriate. Such reinforcement of the sprayed bituminous waterproof membrane shall be applied prior to spray application of the upper layer of the modified bituminous binder.

The surface of the waterproof membrane made of modified bituminous binder shall be protected by means of suitable material, such as felt, profiled plastic foil, polystyrene, wooden slabs or brick.

6.2.4 Protective layers

To protect horizontal or slightly inclined waterproof membranes, asphalt mixtures of bituminous concrete, crushed gravel with bituminous mastic and poured asphalt are suitable. Under certain circumstances cement concrete can be used as a protective layer (“white tub”).

To protect waterproof membranes of greater inclinations, other suitable materials shall be used. Different felts, polystyrene, a profiled plastic foil, wooden slabs, brick etc. are recommended for this purpose.

For shorter bridges (of length up to 30 m), it is advisable to apply a mixture of poured asphalt as protective layer.

To protect waterproof membranes applied to vertical cement concrete surfaces of frame bridge structures, such material shall be used that prevents reliably any mechanical damage of the waterproof membrane.

When delivering materials to be applied as protective layers, vehicles must not damage the waterproof membrane.

The average bond strength of horizontal protective layer shall amount to minimum 0.8 N/mm^2. Any individual measured value must not be lower than 0.4 N/mm^2.

6.2.4.1 Asphalt protective layers

In general, asphalt protective layers may be applied to a dry substrate only. Prior the application of the protective layer the waterproof membrane must not be damaged to such an extent that a perfect waterproofing would be jeopardized.

The type of the asphalt mixture to be applied as a protective layer shall be specified in the design.

The thickness of the asphalt protective layer shall nowhere be smaller than 2.5 cm and greater than 5 cm (figure 6.1).

When a local deepening on the waterproof membrane is greater than 5 cm it shall be levelled with a suitable asphalt mixture enabling application of 1.5 to 4 cm thick layers. As a rule, the mentioned levelling shall be carried through before application of the asphalt protective layer.

Asphalt protective layers are generally applied mechanically. For this purpose paving machines on wheels with tyres shall be employed. Exceptionally caterpillar paving machines may be used, however on condition that the waterproof membrane is adequately protected.

The maximum allowable unevenness on the surface of the mechanically applied asphalt protective layer measured with a 4 m long lath amounts to 6 mm.

During application of the protective layer, the bituminous compound must not pass from the waterproof membrane into the protective layer since this might have an adverse influence on the properties of the latter. Moreover, no displacement must occur in the waterproof membrane layers during application of the protective layer.

The protective layer shall be applied as soon as possible after application of the waterproof membrane. The temperature of the asphalt mixture of bituminous concrete to be applied to the bituminous waterproof sheeting shall not exceed 160°C, whereas the temperature of the poured asphalt shall not be greater than 250°C. It is recommendable to apply a minor quantity of asphalt mixture in advance followed by an immediate application of the remaining planned quantity. In this way it can be granted that the bituminous waterproof sheeting are not heated above the tolerable temperature.

A hot asphalt mixture can lie in front of distributing shaft on the paving machine 1 to 3 minutes, depending on the environment temperature. The same applies for stopping of the paving machine as well. The rate of application of the protective layer must not be smaller than 2 m/min.

Joints shall be executed hot-to-hot. The longitudinal joints of the protective layer must not be located in the area of ruts.

When the waterproof membrane is not soiled during application of the protective layer (e.g. with grains of scattered asphalt mixture), vehicles that deliver the asphalt mixture as well as the paving machine are allowed to drive on the waterproof membrane.

The void content in the applied protective layer shall not exceed 4% by volume (the compaction degree shall amount to minimum 98%). The same conditions apply to the asphalt mixture used for the levelling layer as well.

The joint on the protective layer of poured asphalt shall be executed hot-to-hot. In other cases the joints shall be carried through as openings and then sealed.

In case that a poured asphalt mixture is applied as a protective layer to which a wearing course of bituminous concrete or crushed aggregate with bituminous mastic is designed to be applied, approximately 1 kg/m^2 of crushed aggregate of 2/4 or 4/8 grain size distribution and completely coated with binder shall be pressed onto the protective layer surface.

6.2.4.2 Other protective layers

The methods of application of other materials intended for protective layers shall be adjusted to their characteristics. In particular it must be ensured that the waterproof membrane is adequately protected from damage during all working stages and in all conditions.

6.2.5 Wearing courses

A wearing course on a bridge shall grant the same driving conditions as that on the nearby road. Therefore they are generally made of similar materials.

When applying wearing courses on bridges, restrictions concerning the compaction by means of vibrating shall be taken into consideration. Other conditions for execution of wearing courses on bridges are similar to those for the roads.

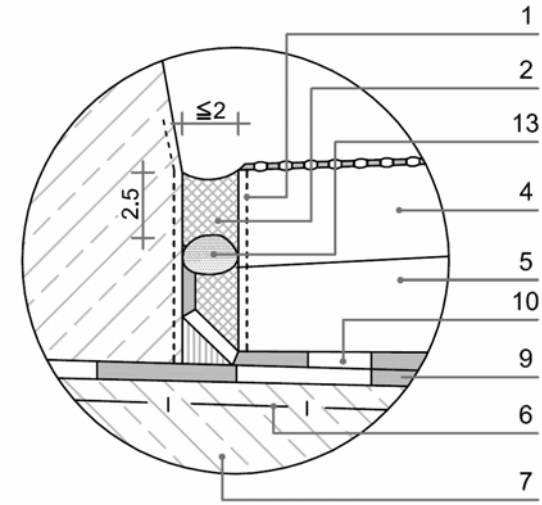
6.2.6 Sealing of joints of boundary surfaces

As a rule, the waterproof membrane shall be perfectly connected with the boundary surfaces of materials built in into a bridge. Therefore suitable joints of 15 – 20 mm width shall be foreseen on boundary surfaces. These joints shall be sealed with adequate bituminous mixtures or other approved sealing materials. The joint width shall be specified in the design whereas the depth of sealing is to be carried through in accordance with the manufacturer of the sealing material.

The joints between the boundary surfaces of both protective layer and wearing course, and the adjacent materials on the carriageway shall be executed apart. At kerbs the joint at the protective layer shall be sealed with an adequate bituminous sealing compound over the entire height, whereas the joint at the wearing course shall be sealed up to few millimetres above the wearing course. In certain conditions it is possible to insert a suitable sealing inlay (e.g. a strip of profiled rubber – figure 6.8) up to a height of 2.5 cm below the wearing course surface. However, this must not be accomplished on the carriageway surfaces.

Prior to application of the joint sealing compound all surfaces in the joint shall be perfectly dry and clean. As a rule, they shall be coated with an adequate primer, which must be in such a condition that subsequent works are enabled. The protection of kerbs with a priming coat or a joint sealing mixture shall extend by at least 2 cm above the wearing course level.

When required the joint sealing bituminous compound shall be heated to the working temperature specified by the manufacturer. This shall be carried through in suitable boilers by means of indirect heating and mechanical stirring. A repeated heating of bituminous joint sealing compound is allowed on condition that its characteristics established after application comply with the requirements stated in the table 5.8.



Legend:
1 = priming coat
2 = joint sealing compound
4 = wearing course
5 = protective layer
6 = priming coat, sealing coat, levelling with trowel
7 = cement concrete slab
9 = waterproof membrane – bituminous sheeting
10 = waterproof membrane – bituminous sheeting
13 = sealing inlay

Fig. 6.8: Detail of sealing at kerb by means of sealing inlay

In case that the bituminous joint sealing compound shrinks up excessively upon cooling it shall be repeatedly applied to fill up the joint completely.

When bituminous strips are used to seal the boundary surfaces of both protective layer and wearing course, these strips shall be placed in accordance with the maker's instructions and prior to application of asphalt protective layer or wearing course (bituminous concrete, poured asphalt or crushed aggregate with bituminous mastic).

Boundary horizontal surfaces on the wearing courses at joints sealed with a joint sealing compound shall be sealed with an appropriate coat in a width of approx. 25 cm measured from the kerb (figure 6.2). As a basis for such sealing, levelling with a trowel is suitable. It shall be applied to the priming coat consisting of bituminous emulsion or bituminous adhesive. By an additional spraying of modified bituminous binder (1 – 1.5 kg/m^2) and by spreading of crushed gravel of grain size distribution of 2/4 mm (up to 2.5 kg/m^2), a perfect waterproofing of the surface is granted.

6.3 Quality of execution

6.3.1 General

Prior to commencement of application of all materials, machines and devices that might affect the quality of bridge waterproofing, their suitability to ensure the required characteristics shall be verified.

Beside general and special technical conditions provided by the client, all conditions and instructions by the manufacturers of the waterproofing materials, machines and devices shall be taken into consideration.
The following tests shall be carried through on the materials intended for waterproofing:
- preliminary conformity (applicability) tests,
- internal control tests, and
- external control tests.

For testing of asphalt mixtures used to execute protective layers and wearing courses all those provisions apply that are stated in the technical specifications for materials and procedures for the carriageway structures.

When appropriate, a test comprises the following:
- taking, marking, preparation and transportation of samples to the testing institution;
- storing;
- execution of tests;
- test report;
- preserving of proving samples.

6.3.2 Preliminary conformity tests

Preliminary conformity tests are carried through to prove suitability of materials and methods for the foreseen intention of use specified in the description of works and the bill of quantities.

On the contractor's request, an authorized institution shall prove the conformity of materials and procedures by issuing an adequate certificate. The contractor is obliged to submit such certificate to the client in due time before starting the works. The certificate shall comprise all characteristics required in 5 and 6.2. The contractor must not commence any application works until he has obtained an approval by the client for each material or method foreseen.
The costs of the preliminary conformity testing of materials and procedures shall be entirely born by the manufacturer or contractor.

6.3.3 Internal quality tests

Testing within the framework of internal quality control during construction shall be carried through by a qualified contractor or laboratory authorized by the contractor to find out whether the quality of the materials and the executed works comply with the contractual conditions.
As a rule, the extent of the internal quality testing shall be determined by programme being a constituent part of the contract documents.
The contractor is obliged to report regularly the results of the internal tests to the client. In case that the established quality deviates from the required one, the contractor shall immediately take adequate measures.
Depending on the waterproofing method, the following shall be tested:
For materials:
- forms of delivery and labels on containers (e.g. batch number),
- condition and storage of packing and its content in accordance with the working instructions,
- mixing in a prescribed ratio by means of adequate stirring equipment until a perfect homogeneity is attained,
- production date and allowable duration of storage,
- eventually required adding of other substances (e.g. solvents),
- mineral admixtures and mixture of grains for spreading with regard to composition, grain size and humidity.

For execution:
- external conditions, i.e. air temperature, substrate temperature, material temperature, dew point, and relative air humidity at least twice a day until it can be proven that these conditions cannot affect the quality of executed works,
- moisture content of substrate (cement concrete slab),

- bond strength of the prepared substrate surface,
- procedure of application of reaction resin or bituminous binder to the priming coat,
- respecting of workability time,
- appearance of surface of individual layers with regard to uniformity, coverage and deficiencies,
- respecting of time intervals between consecutive operations,
- condition of applied priming coat, levelling with trowel and eventual bonding layer prior to continuation of contractual works,
- material consumption for priming coat,
- appearance and quality of prepared surface,
- roughness depth of prepared surface,
- thickness of waterproof membrane during application,
- void content in waterproof membrane,
- bond strength of waterproof membrane,
- condition of eventual bonding layer,
- adhesion strength of welded bituminous sheeting,
- sticking together of waterproof membrane and substrate as well as eventual blisters and open pores below waterproof membrane and/or protective layer of poured asphalt,
- temperature during application of protective layer,
- spreading with regard to the type and quantity of grain mixture and a correct choice of the time when spreading is carried through.

As a rule, the contractor shall submit adequate evidence for the quality of materials and execution of waterproofing for all materials and procedures and for each bridge.

All the costs of the internal quality control of materials and procedures within the contractual provisions shall be entirely born by the contractor.

6.3.4 External quality tests

In general, authorized institutions shall carry through the external control testing.

The external quality tests are intended to supervise the correctness of the internal control testing and to establish the quality of materials and executed works in view of contractual provisions. The results of the external quality tests represent a basis for taking over of the works carried out.

Taking of samples as well as site testing shall be carried through in the presence of both the bridge contractor and the client. In case that the contractor is not present despite of the fact that he has been apprised on time, taking of samples and execution of testing may be performed during his absence as well.

As a rule, the contractor is obliged to assist the authorized institution during taking samples and/or carrying through of the external control testing.

When representatives of the client or the authorized institution are present during the internal control testing, the client may consider such testing as the external one.

Special proving samples of all the materials (in a separate package) shall be taken for eventually required subsequent verifying.

All the samples taken for the external control testing shall be adequately recorded and thoroughly preserved.

After application of the waterproof membrane and the protective layer of poured asphalt it shall be verified by suitable testing whether any unstuck spots such as voids or blisters are present between the particular layer and the substrate.

All the costs of the external control tests within the framework of the contractual provisions shall be entirely born by the client.

The costs of eventual additional testing required either by the client or the contractor shall be born by the party placing the order.

6.3.5 Types and extent of tests

Prior to commencement of the works the contractor is obliged to submit conformity certificates, issued by an authorized institution, for all the materials (as a rule already stored) to be applied for bridge waterproofing.
A minimum extent of external control tests of materials to verify their conformity is indicated in the table 6.1.
In due time prior to commencement of works the contractor shall submit to the client for approval the compositions of asphalt mixtures intended to execute the protective layer and the wearing course, as well as the results of the demonstrative application of those asphalt mixtures.

During the works testing planned within the framework of the internal and external control shall be carried through. A minimum extent of such testing is specified in detail in the table 7.1. On the basis of the results of those tests, the supervising engineer is free to modify the extent of testing.

Table 6.1: Minimum extent of external control testing to verify the conformity of waterproofing materials

Type of material	Test per initial quantity
- solution of bituminous binder, bituminous emulsion	from each batch
- modified bituminous binder	from each batch
- bituminous adhesive	from each batch
- bituminous sheeting	from each batch
- bituminous joint sealing compound	from each batch
- bituminous joint sealing strip	1,000 m
- epoxy resin	from each batch
- sand for spreading	20 t
- felt	10,000 m^2

The contractor is obliged to keep a record of the climatic conditions during the execution of the waterproofing works. The same condition applies to taking of samples and material consumption as well.
The contractor cannot proceed with the next working stage until the supervising engineer has approved the previous stage.

6.4 Quality assessment

After completion of individual working stages and/or complete works, statistic analyses of the results of both internal and external control testing shall be performed. This applies to the following:
- all input basic materials and asphalt mixtures,
- applied waterproof membrane, and
- asphalt mixture applied as wearing course.

The performers of both internal and external control shall elaborate statistic analyses of the control testing results. The comparisons of results of the statistic analyses are the basis to assess the quality conformity and to introduce eventual corrective measures.
An institution authorized for the external control shall elaborate an assessment of conformity of control testing results with the requirements.

7. MEASURING AND ACCEPTANCE OF WORKS

7.1 Measuring of works

The works carried through shall be measured in accordance with the general technical conditions and calculated in square metres.

All the quantities shall be measured according to actually executed extent and type of works specified in the bill of quantities.

7.2 Acceptance of works

The applied waterproofing is taken over by the client's engineer after receiving from the contractor a written notice of completion of works.

The contractor is obliged to submit in due time all data and reports of conformity issued by the internal control division as well as a final conformity assessment prepared by the external control testing institution.

The client's engineer takes over the applied waterproofing in accordance with the requirements of this design standard as well as with eventual additional requirements stated in the particular contract documents.

In case that deficiencies and unattained minimum quality requirements are established during taking over, the contractor is obliged to make them good at his own expense including all the costs of additional measurements and testing to be carried through after reconditioning.

For all the works not complying with the quality requirements of this design standard or the contractual specifications, and that have not been reconditioned by the contractor, the latter is not entitled to any payment. In such cases, the client is allowed to prolong the guarantee period to at least 5 years for all the works depending on the unsatisfying performance that had not been improved by the contractor.

Table 7.1: Minimum extent of internal and external control during waterproofing works

Type of testing	Per initial quantity	
	Internal control	External control
Substrate surface		
- survey of condition	250 m^2	1 x daily
- measurements of: evenness	250 m^2	-
roughness depth	250 m^2	1 x daily
bond strength	250 m^2	-
Bonding layers		
- climatic conditions	all the time	-
- characteristics of reaction resin coating	500 m^2	2,000 m^2
- characteristics of bituminous binder	-	per batch
- quantity of bituminous binder coating	250 m^2	1 x daily
Waterproof membranes		
Bituminous sheeting		
- climatic conditions	all the time	-
- characteristics of bituminous sheeting	2,000 m^2	per batch
- characteristics of bituminous adhesive	2,000 m^2	per batch
- method of sheeting application	all the time	1 x daily
- quantity of bituminous adhesive	2,000 m^2	1 x per bridge
- measurements of bond strength		3 x per bridge
Bitumen modified with polymers		
- climatic conditions	all the time	-
- characteristics of modified bitumen	2,000 m^2	1 x per bridge
- thickness of layer	1,000 m^2	2,000 m^2
Protective layers and wearing courses of asphalt mixtures of bituminous concrete and crushed gravel with bituminous mastic		
- climatic conditions	daily	-
- characteristics of asphalt mixture	1 x per bridge/1,000 m^2	1 x per bridge/2,000 m^2
- thickness of layer	1,000 m^2	2,000 m^2
- compaction of layer	1,000 m^2	-
Protective layers and wearing courses of poured asphalt mixtures		
- characteristics of asphalt mixtures	each boiler	1 x per bridge/2,000 m^2
- thickness of layer	1,000 m^2	2,000 m^2