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MINISTRY OF INFRASTRUCTURE

TECHNICAL SPECIFICATIONTSG-211-XXX: 2026
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Pursuant to Article 13 of the Roads Act (Official Gazette of the Republic of Slovenia, Nos 132/2022, 140/22 – ZSDH-1A, 29/23, and 78/23 – ZUNPEOVE) and Article 50(6) of the Railway Safety Act (Official Gazette of the Republic of Slovenia, Nos 30/18 and 54/21 and 16/26), the Minister of Infrastructure issues the following technical specification:

BRIDGE STRUCTURES

DRAINAGE OF BRIDGE STRUCTURES

TSPI – PGV.07.460: 2026

Minister of Infrastructure

Number:

Ljubljana,

This technical specification PGV.07.460: 2026 is issued having regard to the information procedure in accordance with Directive (EU) 2015/1535 of the European Parliament and of the Council of 9 September 2015 laying down a procedure for the provision of information in the field of technical regulations and of rules on Information Society services (OJ L 241, 17. 9. 2015, p. 1).

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1 Subject of the technical specification

The subject of the technical specification is the drainage of bridge structures on roads and railways, including drainage of bridge approach embankments, and drainage of bridge structures for pedestrians and/or cyclists.

The content of this TSPI cannot be interpreted and implemented in such a way as to prevent or condition the proper use of construction products placed on the market in accordance with the requirements of the Construction Products Act.

2 Definition of terms

Drainage / Entwasserung is the removal of water, whether surface water or seepage, from the surface of a structure or from the surrounding areas.

Channelling / Kanalisierung is the collection and removal of water from a building or paved surfaces via drainage pipes.

Surface water / Oberflächenwasser is rainwater that falls onto the upper surface of a bridge structure.

Seeping water / Sickerwasser is the part of surface water that seeps through individual parts of the road surface (asphalt layers, pavements, edge beams) to waterproofed surfaces.

Drain canal / Abflusskanal is the location to which water is drained from a bridge structure (road drainage system, river, lake, etc.).

(Bridge) drain / Brückenablauf is a component of the drainage system into which surface water flows.

Drainage pipe / Ablaufrohr is a component used to drain and channel water away from a building.

Pipe supports / Rohraufhängung are brackets and supports used to secure drainpipes to the structure.

Drainage spout / Tropftülle is a pipe with a specially designed spout, which is installed in the superstructure beneath the waterproofing layer.

Cleaning shaft / Reinigungsschacht is an opening in the drainpipe into which a cleaning nozzle is inserted during the cleaning process.

3 General advice

3.1 Scale

The drainage and channelling system of bridge structures shall refer to:

- Drainage of the upper surfaces of the structure.
- Drainage of seepage water from insulated surfaces and the release of vapour pressure.
- Drainage and ventilation of cavities.
- Drainage of bedding pads.
- Drainage of backfills.
- Connecting a building’s drainage system to the stormwater drainage system of a road or railway line.

The design of the transverse and longitudinal cross-section of the structure is based on the principles of proper drainage of the structure.

All drainage components must be designed in such a way that they can be easily inspected and replaced.

The elements of the bridge arrester shall be designed in such a way that they do not interfere with the most stressed parts of the main elements of the load-bearing structure and with the areas of the prestressing cables.

Bridge structures must have their own stormwater drainage system, which may be connected to the stormwater drainage system of the road or railway line, or directly to the receiving watercourse.

The dimensions and number of structural elements of the drainage system must be determined on the basis of a hydraulic calculation.

3.2 Surface water drainage

Surface water drainage from road and railway structures involves the drainage of stormwater from the upper surface of the structure and its controlled or uncontrolled discharge into the substructure or a receiving body (connection to the road/railway drainage system, soakaways, watercourses, etc.)

3.2.1 Facilities on roads

When designing the drainage system for road bridges, the first step is to analyse the need for stormwater treatment, in accordance with the Regulation on the emission of substances in stormwater discharged from public roads or the specific conditions set by the relevant authorities.

For structures on roads, the following guidelines are basically followed:

- Minimum one drain per 400 m2 of contribution surface.
- Where the transverse gradient is 2.5% and the longitudinal gradient of the alignment is ≥1%, the maximum spacing between drains is 25 m; where the longitudinal gradient is 0.5%, the maximum spacing is 10 m. Intermediate values may be interpolated linearly. As a general rule, gradients of less than 0.5% should be avoided. Where this is not possible, provision must be made in these areas for a reduced spacing between drains, asphalt grooving, linear drainage beneath the kerb, or other drainage methods.
- As a rule, hydraulic calculation of the drainage is required for larger bridges (more than 1500 m2 surface area).

As a general rule, smaller structures are drained by means of the transverse and longitudinal gradients of the carriageway surface, and drainage is provided as part of the road drainage system.

Anchoring to bridge structures is not recommended. Where this cannot be avoided, particular attention must be paid to the road’s camber and the effect of backflow, and appropriate measures must be put in place to prevent aquaplaning, such as grooving the asphalt wearing course or other suitable measures.

3.2.2 Structures on railways

3.2.2.1 Open drainage system

An open drainage system for a superstructure without outlets – i.e. drainage via the area behind the abutments – is permitted for superstructures up to a length of approximately 30 m; this also applies to structures without a longitudinal slope (horizontal structures).

In such cases, the clear spans of superstructures ≥15 m must be increased by the amount of deformation caused by quasi-static loads, whereby a quasi-static combination factor Ψ_2 = 0.20 is taken for the effect of rail traffic.

For structures where bridge decks are constructed without a longitudinal slope, the deck elevation specified above shall also be applied to spans of less than 15 m in order to prevent water from pooling.

For structures with steel rolled beams embedded in concrete (Filler Beam Deck), it is recommended that this deck elevation be implemented regardless of the span and/or longitudinal slope.

3.2.2.2 Closed drainage system

For buildings that do not meet the above requirements, a closed drainage system must be designed.

The transverse slope of the superstructure is at least 1.5 %.

Drainage axis – the position of the lowest point in the cross-section of the superstructure:

- Single-track structures: alongside the track centreline, outside the sleepers, set back from the track centreline by at least 1.90 m.
- Two-track structures: between the two tracks. Exceptionally, two drainage axes on the outer edge of both track axes. The minimum distance from the centreline of the track is 1.90 m.

When determining the position of the outlets, it is necessary to take into account the deformation of the superstructure (rheological effects in AB and PAB structures, deviations in the elevation and the actual deformation of the structure). It is therefore advisable to provide outlets both near the supports and in the middle of the spans. The maximum distance between the outlets is 30 m.

The minimum cross-section of a longitudinal exhaust pipe shall be 200 mm. The minimum longitudinal gradient is 0.9 %.

3.3 Drainage of seepage water

3.3.1 Facilities on roads

The surface water that seeps through the layers of asphalt and the joints between the kerbs and the asphalt, reaching the waterproofing, and the vapour pressure of the water that builds up between the waterproofing and the asphalt, must be drained away from the waterproofing in a controlled manner through the superstructure.

Seepage water is discharged through:

- The implementation of drainage channels along the curbs in the protective layer of waterproofing asphalt on the lower and higher side of the cross-section.
- Implementation of pipes for the drainage of seepage water.

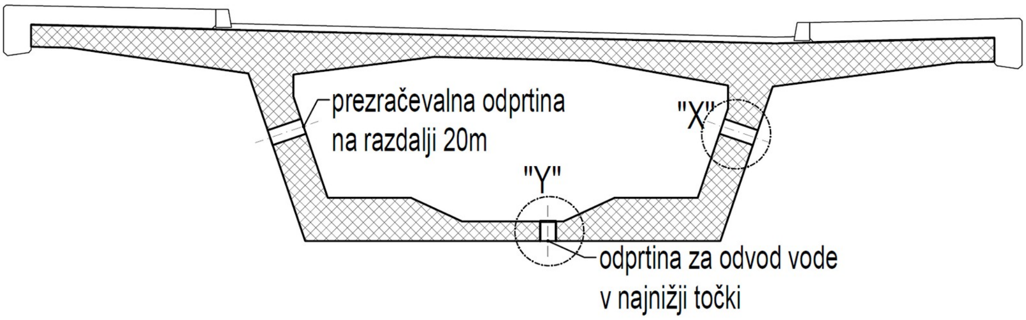
Seepage water pipes (CPV), in the event of the need to purify rainwater, shall be connected to the longitudinal storm drainage system of the building.

3.3.2 Structures on railways

There is no need to design additional drainage systems for seepage water at railway structures.

3.4 Drainage and ventilation of cavities

In order to prevent the formation of condensed water, all hollow parts of the structure shall be adequately and permanently ventilated. To this end, the boxes shall be equipped with ventilation openings at intervals of up to 20 m.



prezračevalna odprtina na razdalji 20m	ventilation opening at a distance of 20 m
odprtina za odvod vode v najnižji točki	a drain hole at the lowest point

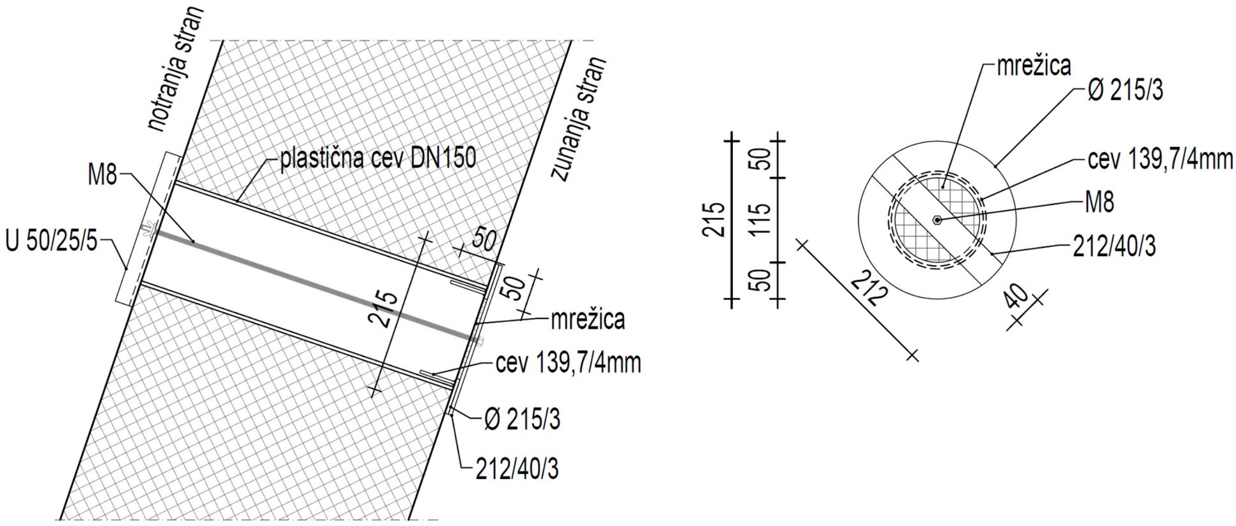
Figure 3.1: Position of the ventilation openings in the cross-section

In the case of box-shaped cross-sections, ventilation openings must be provided both in the web of the cross-section (in all webs) and in the bottom clab (Figure 3.1). Openings in the bottom slab must also be provided at the lowest point of the cross-section (e.g. in front of cross-beams or thickened sections of the bottom slab, etc.). For horizontal surfaces of the bottom slab, it is recommended to provide one opening in the bottom slab on each side of the cross-section (to allow for construction tolerances).

Ventilation openings in webs shall generally be carried out at an upper third of the height of the web to prevent the flow of precipitation.

All ventilation openings must be covered with mesh to prevent access by birds and other animals (Figure 3.2 and Figure 3.3).

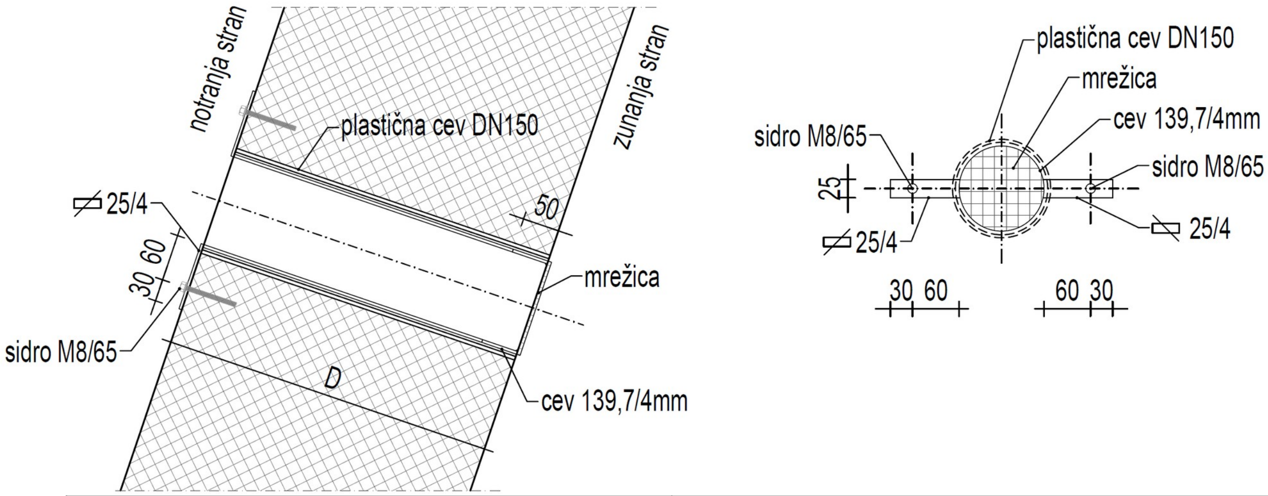
DRAINAGE OF BRIDGE STRUCTURES



Notranja stran	Internal side
M8	M8
U 50/25/5	U 50/25/5
Plastična cev DN150	DN150 plastic pipe
Zunanja stran	External side
Mrežica	Mesh
Cev 139,7/4mm	Pipe 139.7/4 mm
∅ 215/3	∅ 215/3

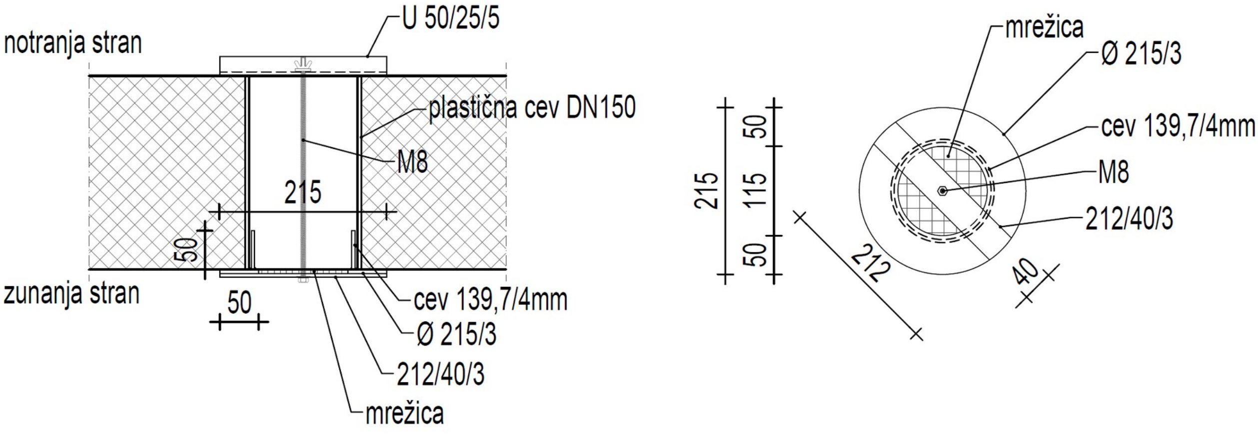
Figure 3.2: Detail ‘X’ – variant 1

DRAINAGE OF BRIDGE STRUCTURES



Notranja stran	Internal side
Sidro M8/65	
M8	M8
U 50/25/5	U 50/25/5
Plastična cev DN150	DN150 plastic pipe
Zunanja stran	External side
Mrežica	Mesh
Cev 139,7/4mm	Pipe 139.7/4 mm

Figure 3.3: Detail ‘X’ – variant 2



Notranja stran	Internal side
M8	M8
U 50/25/5	U 50/25/5
Plastična cev DN150	DN150 plastic pipe
Zunanja stran	External side
Mrežica	Mesh
Cev 139,7/4mm	Pipe 139.7/4 mm
∅ 215/3	∅ 215/3

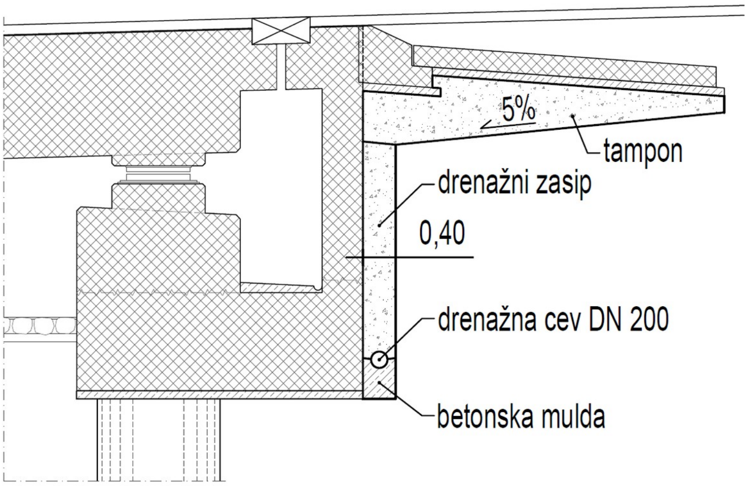
Figure 3.4: Detail ‘Y’

In the case of steel or composite bridge structures, where the box sections are designed to be airtight, ventilation of the interior of the section is not permitted.

3.5 Drainage of the backfill behind the end abutment

3.5.1 Facilities on roads

Regardless of the road’s drainage system, a drainage bed made of stone aggregate of fraction 16/32 or drainage concrete, 40 cm wide, must be constructed behind the end abutment (Figure 3.5). At the lower end, it is terminated by a DN200 mm transverse drainage channel on a concrete gutter.



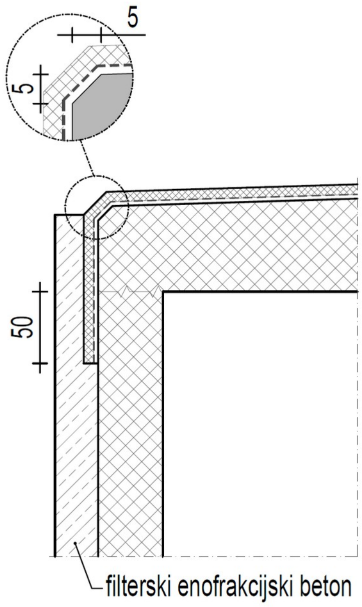
tampon	tampon
Drenažni zasip	Drainage backfilling
Drenažna cev DN 200	DN 200 drainage pipe
Betonska mulda	Concrete gutter

Figure 3.5: Implementation of drainage of the area behind the retaining walls using drainage backfill

A bed of permeable stone material is laid beneath the transition slab, with a 5 % gradient towards the drainage mat.

3.5.2 Structures on railways

The waterproofing in railway structures is extended to the wall through a working contact. Where fill concrete is used, the drainage concrete along the back wall of the retaining wall must be routed to the upper edge of the deck and connected to the lower transverse drainage, Figure 3.6. The waterproofing can also be finished in accordance with the details shown in Figure 4.35 in Section 4.2.5



Filterski enofrakcijski beton	Single-fraction filter concrete

Figure 3.6: Transition from the structure to the embankment and implementation of drainage for the upstream area in the upper section

The transverse drainage shall be min. DN150, minimum gradient 1 %, and allow cleaning from both sides.

3.6 Drainage of bed shelves and control corridor floors

The bedding pads must be laid at a gradient of 2 to 5 % towards the back-end. A collection channel made of DN50 mm PVC pipe is installed along the rear wall of the end retaining wall, with an outlet through the front walls of the retaining wall into the stormwater drainage system (e.g. sand traps at the verticals) or a free outlet down the embankment.

In the case of longer structures, the bottom surface of the inspection chamber for bearings and expansion joints is constructed at an angle or using sloped concrete, with the top surface sloping at a gradient of 5 % towards the collection pipe.

3.7 Connection of the drainage system of the bridge structure to the arrester (storm sewer)

Rainwater that requires treatment (controlled drainage) must:

- Connect to the road’s stormwater drainage system.
- Implement a self-contained system for the treatment and retention of rainwater.

Before connecting the bridge drainage system to the road drainage system, sand traps are installed. Sand traps for buildings, covering areas of up to 2000 m2, are generally made of DN1000 mm concrete pipes. For larger structures, it is necessary to dimension the sand traps and draw up a specific plan for them.

Where rainwater does not require cleaning, it may be drained:

- Via a free outlet into the substructure when crossing watercourses.
- By collecting bridge drainage and channelling it towards an abutment or pier, and discharging it into soakaways or ditches at other junctions.

3.8 Drainage of smaller bridge structures

Smaller road bridge structures whose length, together with parallel wing walls, is less than the required distance between the drains do not require their own drainage system. The drainage for these structures is provided as part of the road drainage system.

As part of the controlled drainage of the road, drainage inlets are installed in the road surface in front of and behind the structure.

In the case of uncontrolled drainage, drainage channels are constructed in front of and behind the structure, leading to a drainage channel or a seepage channel at the foot of the embankment.

We do not route the road drainage system across bridge structures. The road’s surface drainage system must be designed in such a way that:

- It leads away from the structure.
- A discharge into the receiving water body takes place upstream of the structure, with or without treatment, in accordance with the conditions.

4 Structural specifics of the individual elements of the drainage and channelling system

4.1 Facilities on roads

4.1.1 Drains

Drains are one of the most important elements of a drainage system. As a rule, they consist of three parts: a grating, a frame and a gully pot. The gully pot shall have an oblique (side) or vertical drain pipe with a minimum internal diameter of 125 mm. It must be fitted with mounting brackets that are welded to the concrete reinforcement.

The shape and type of the drain must be adapted to the bridge structure. Figures 4.1, 4.2, 4.3 and 4.4 show the different types of drains.

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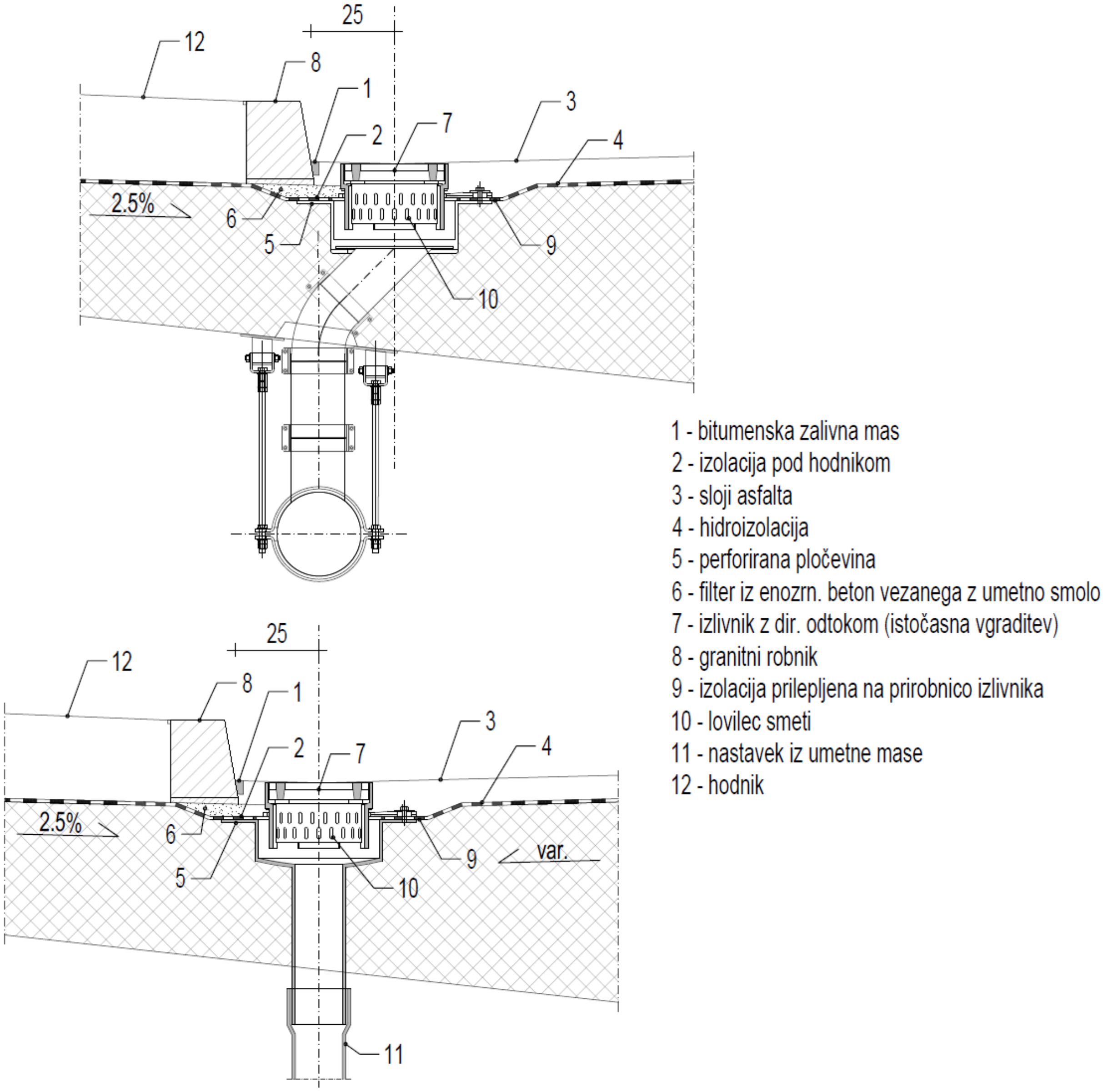


Bitumenska zalivna mas	Bituminous joint sealant
Izolacija pod hodnikom	Insulation under the corridor
Sloji asfalta	Layers of asphalt
Hidroizolacija	Waterproofing
Perforirana pločevina	Perforated sheet metal
Filter iz enozm. beton vezanega z umetno smolo	Filter made of resin-bound pervious concrete
Izlivnik z dir. Odtokom	Drain with direct discharge
Granitni robnik	Granite kerb
Izolacija prilepljena na prirobnico izlivnika	Insulation bonded to the drain flange
Lovilec smeti	Silt bucket

DRAINAGE OF BRIDGE STRUCTURES

Nastavek iz umetne mase	Plastic extension
hodnik	corridor

Figure 4.7: Drain with ground flow and vertical outlet

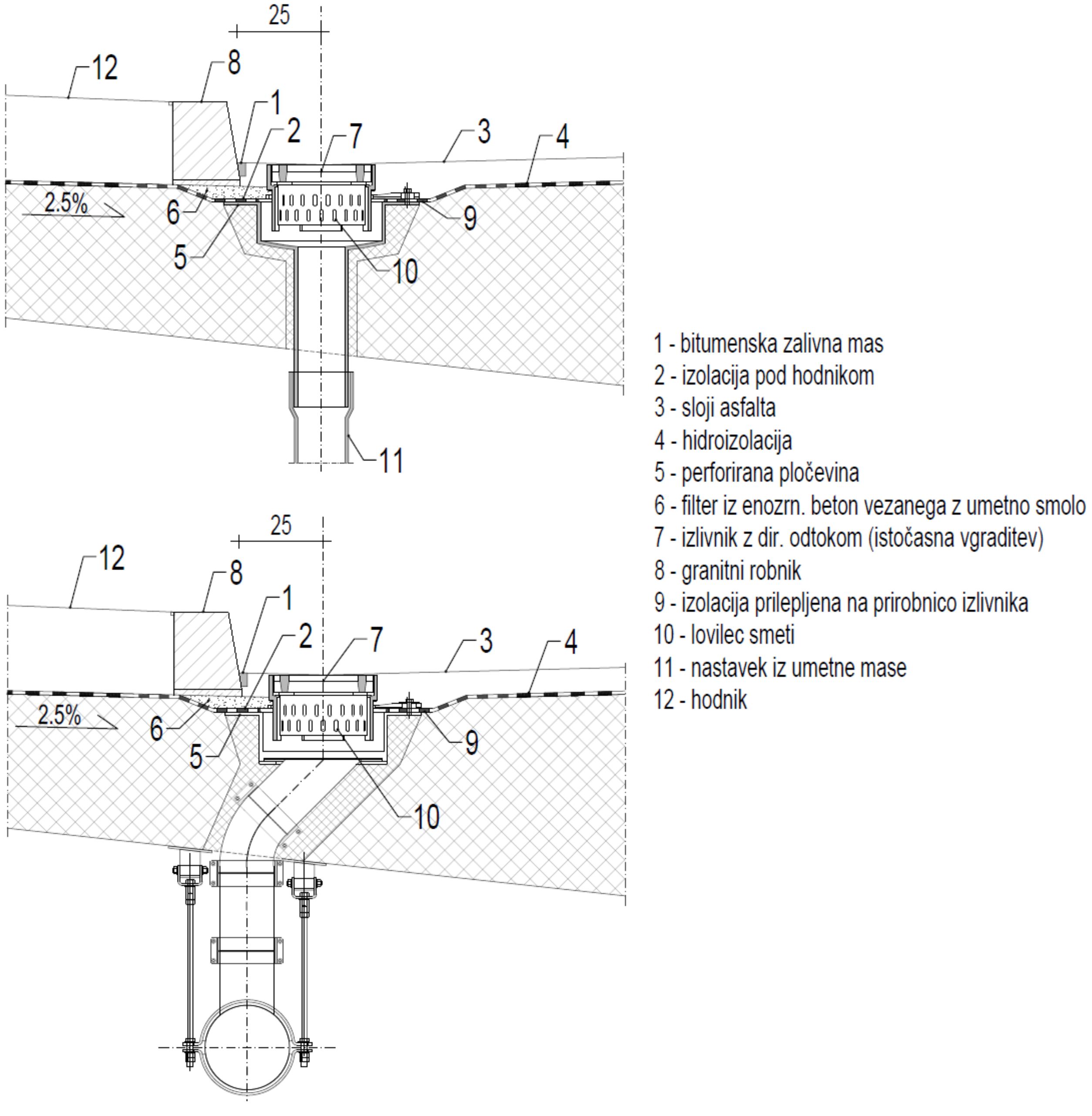
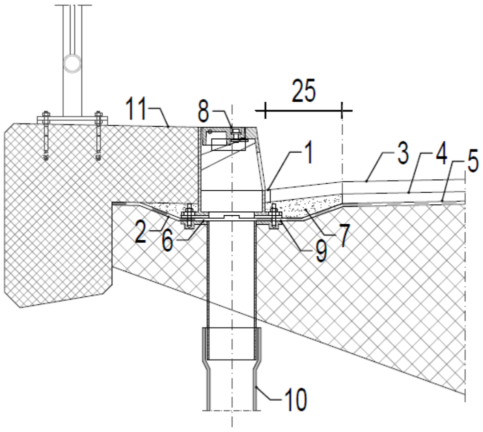


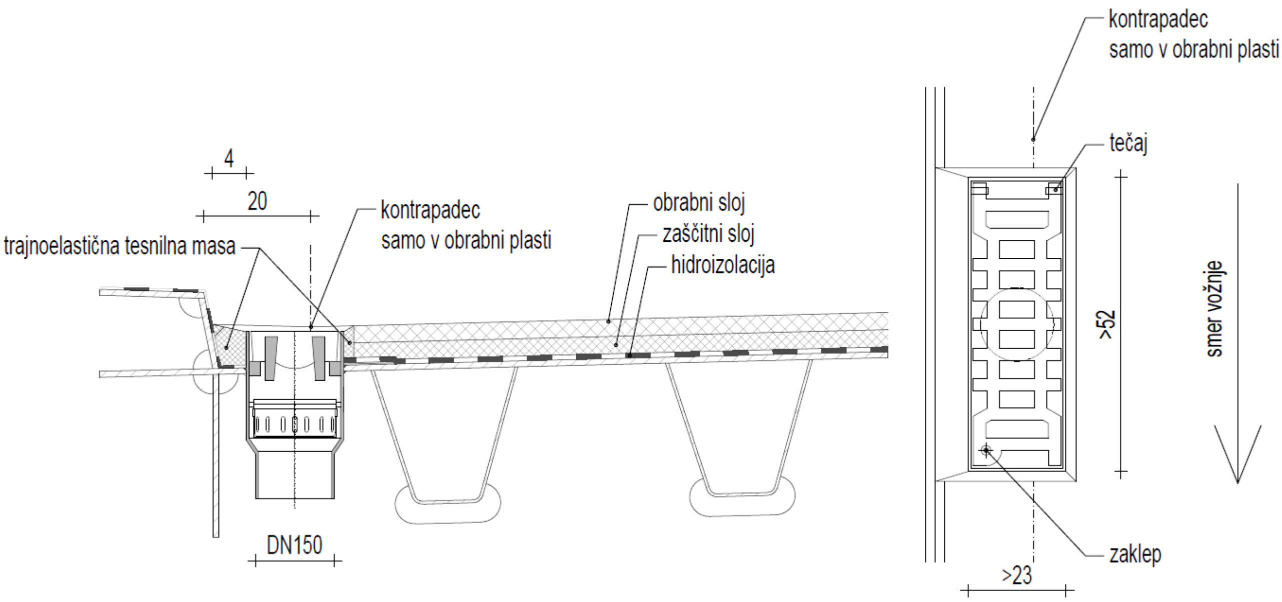
Figure 4.8: Retrofitting a drain during refurbishment works

DRAINAGE OF BRIDGE STRUCTURES



1 - bitumenska zalivna masa
2 - izolacija pod hodnikom
3 - obrabni sloj
4 - zaščitni sloj
5 - hidroizolacija
6 - perforirana pločevina
7 - filter iz enozrn. beton vezanega z umetno smolo
8 - izlivnik s stranskim vtokom
9 - izolacija prilepljena na prirobnico izlivnika
10 - nastavek iz umetne mase
11 - hodnik

Figure 4.9: Drain with lateral flow



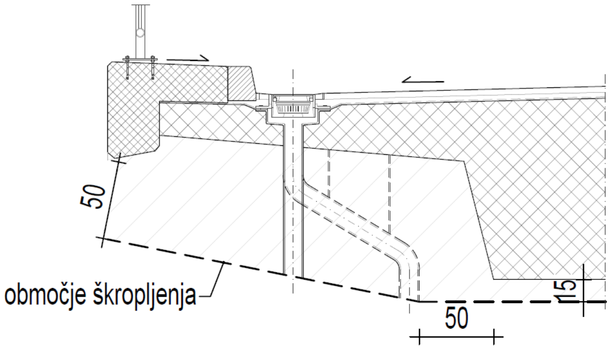
Trajnoelastična tesnilna masa	Permanently elastic sealant
Kontrapadec samo v obrabni plasti	Counter-slope only in the wearing course
Obrabni sloj	Wearing course
Zaščitni sloj	Protective layer
hidroizolacija	waterproofing
Tečaj	Hinge
Smer vožnje	Direction of travel
Zaklep	Lock

Figure 4.10: Design of the drain for steel bridges

Drains are installed on one or both sides of the roadway (depending on the cross-slope), at the lowest point of the cross-fall / counter-slope break. The cross-fall / counter-slope break must avoid the wheel track areas on the structure.

The distances between the drains and the number of drains are determined by hydraulic calculation.

Free-flow drains may be used on bridge structures forming part of lower-grade roads, or on structures where, under specific conditions, channelled drainage is not required. In this case, the length of the pipe must be such as to prevent water from splashing onto the structure (Figure 4.5)



Območje škropljenja	Splashing area

Figure 4.11: Splashing area

Drains must be adjustable in height and tilt. The gully pot must be fitted with an 80 mm wide flange, to which the insulation is attached. There shall be a minimum of 8 cm of concrete below the bottom of the gully pot. The base of the pot must be sloped towards the axis to ensure a better flow of water and to facilitate the pouring of concrete underneath. It must be possible to adjust the connection angle of the transverse drain pipes to an angle of between 0° and 10°. The tendency of the gully pot on any side is then offset by the insertion of the frame into the pot. The frame must be fitted with stainless steel levelling bolts or wedges, which are used to precisely adjust the frame’s height and tilt. The frame of the drain must be designed on the outside in such a way that all the planned layers of asphalt can be connected directly to it. It must be possible for water that has seeped through and collected on the waterproofing to drain away. The upper edge of the drain frame must be mounted 10 mm below the plane of the wearing course of the asphalt.

The components of the drain must be made of high-quality grey cast iron. The drain components must be bituminised. The drain grate is designed to ensure safe passage for cyclists on roads with mixed traffic. The outer edge of the frame must be at least 1 cm away from the kerb. This joint is filled with an elastic bituminous compound. The grating must be installed in such a way that the lock is oriented in the direction of travel.

A lock made of stainless material must be provided for opening or lifting the grating.

The lower part of the drain shall be located together with the reinforcement and shall be concreted. Subsequent embedding in a predetermined opening is permitted only in special cases (e.g. reconstructions of structures, etc.).

The drainage capacity of the drain depends primarily on the type of grating (size, inlet area, shape of the grating bars), the surface area of the carriageway, the gradients, the design of the channel at the kerb, and the volume of water flowing into the channel, which must be at least 10 l/s.

There are two possible designs for the drain:

- Drain with top inlet.

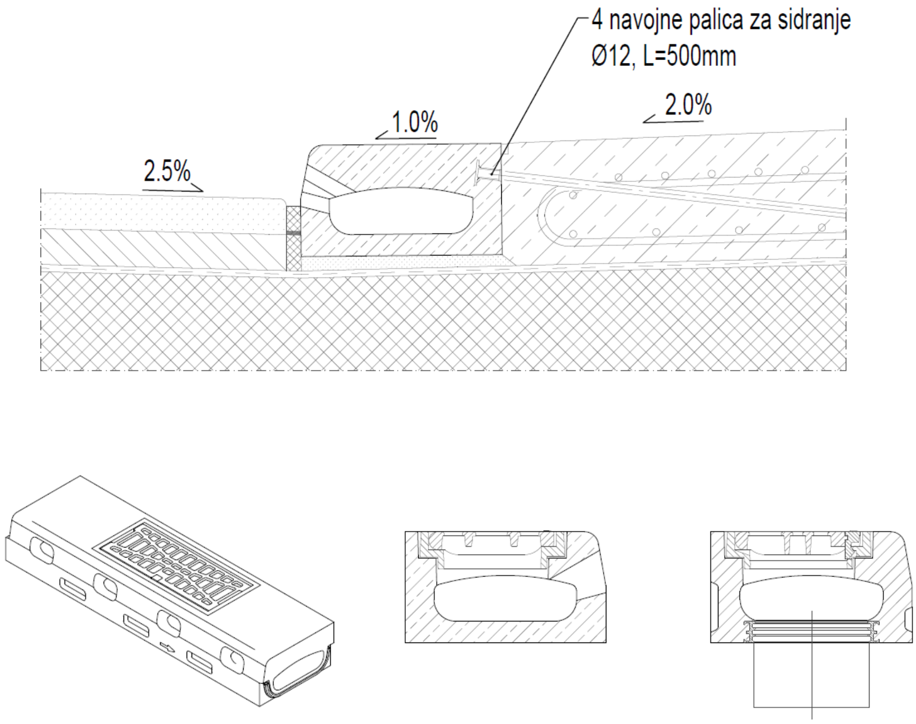
- Bridge drains with a side inlet may exceptionally be used on urban bridges or bridges with mixed traffic. Only typified drains may be installed, for which there is also a declaration of performance on the swallowing ability of the drain.

All installation materials for manholes, covers and grates must comply with the latest applicable standard. The standard currently in force is EN 124-2, which, as a general rule, specifies a minimum load class of D400 for road traffic loads. The covers must bear the designation of the applicable standard. The entire system must ensure loads and functionality in accordance with the manufacturer's instructions.

The fixing of covers and grates must be carried out in such a way as to prevent vandalism and accidental opening.

4.1.2 Linear drainage

In specific cases (extremely small gradients, spiral sections, crossings over traffic routes, and the like), drainage beneath the kerb may be provided using special perforated kerbs made of polymer-modified concrete (Figure 4.6). The shape of the kerb must conform to the requirements of the technical specification for kerbs.



4 navojne palica za sidranje ∅12, L =500mm	4 threaded rods for anchoring ∅12, L =500mm

Figure 4.12: Under-kerb drainage for buildings

4.1.3 Water drainage and channelisation pipes

The pipes used for draining channelised water are transverse drainage pipes, longitudinal collecting pipes and vertical (tray) pipes (Figures 4.7 and 4.8).

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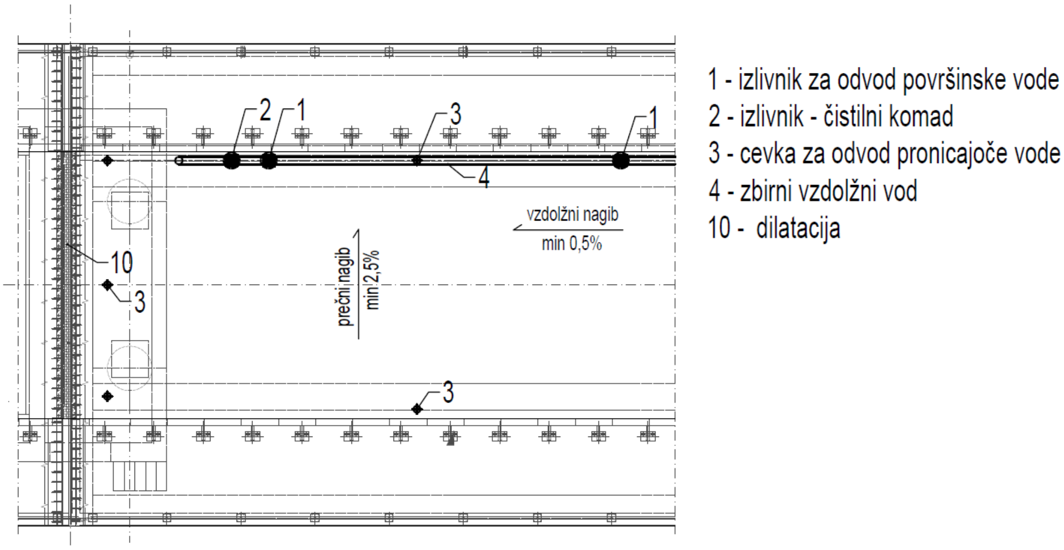
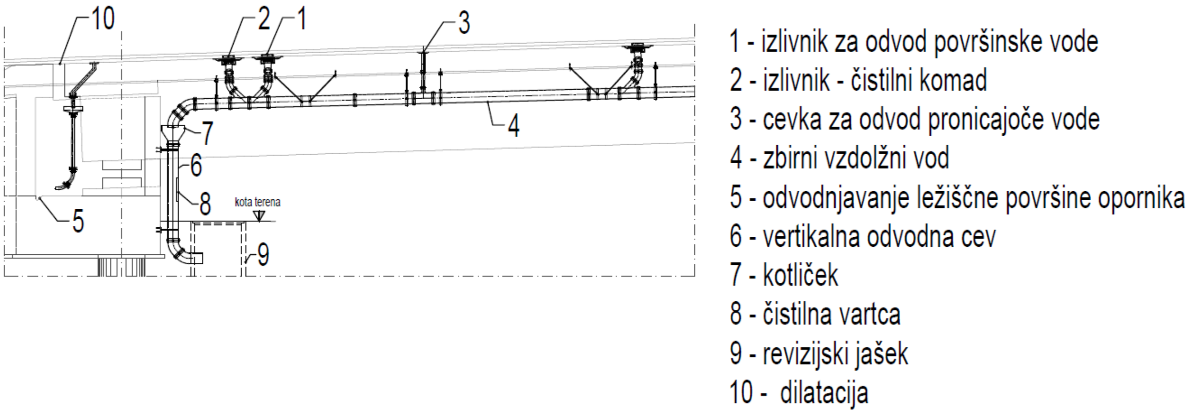


Prečni nagib	Cross slope
Vzdolžni nagib	Longitudinal slope
Min 2,5%	Min 2.5%
Min 0,5%	Min 0.5%

Figure 4.13: Pipe layout and the position of drains and CPVs

DRAINAGE OF BRIDGE STRUCTURES



Kote terena	Terrain angles
Izlivnik za odvod površinske vode	Surface water discharge outlet
Izlivnik – čistilni komad	Drain – cleaning piece
Cevka za odvod pronicajoče vode	Pipe for draining seepage water
Zbirni vzdolžni vod	Collector longitudinal pipe
Odvodnjavanje ležiščne površine opornika	Drainage of the bearing surface of the support
Vertikalna odvodna cev	Vertical drainpipe
Kotliček	Cistern
Čistilna vartca	Cleaning wrench
Revizijski jašek	Inspection chamber
dilatacija	expansion joint

Figure 4.14: Longitudinal section of the bridge drainage system showing the pipe routing at the abutment

The transverse drain pipe carries the water collected in the outlet into the longitudinal collection pipe at an angle of 45° to the floor plan and at an angle of 60° from above.

The internal diameter of the transverse drainage pipe shall be at least 150 mm and shall be determined by hydraulic calculation. The drop in the transverse pipe must be at least 5 %.

Collecting longitudinal pipes collect water from transverse drainage pipes (carriageway with double-sided transverse drop) or directly from drains (carriageway with single-sided transverse inclination).

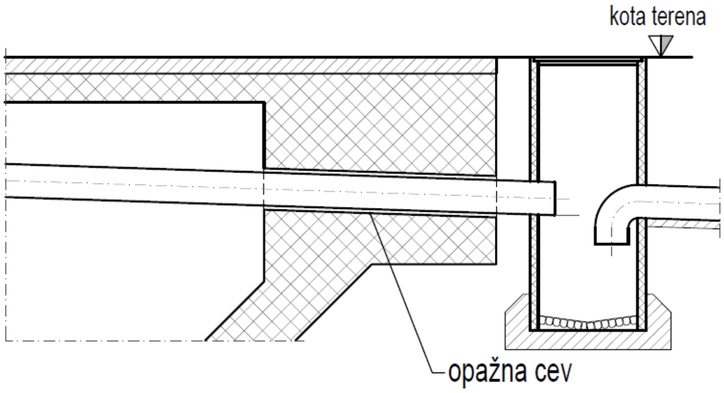
The minimum internal diameter of the longitudinal collector pipe must be 200 mm. The minimum inclination of the longitudinal collecting pipe shall be 1 %.

The collecting longitudinal tube shall not be concreted into the superstructure. When passing through cross-beams or other structural elements, it must be separated from them.

All changes in direction (bends) are made using shaped connectors with a maximum angle of 45°. 90° arc shall be executed with two phase fittings with an angle of 45° and an intermediate 20 cm long straight section of the pipe.

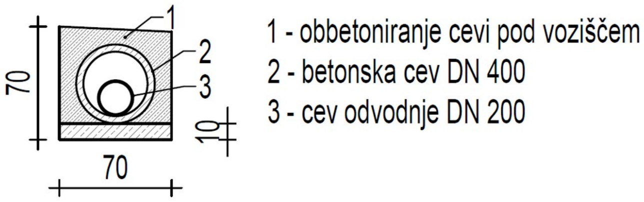
In the area of the end support, the collector pipe may be routed in the following ways:

- Continue through the embankment, e.g. in the case of short bridges (Figure 4.9), in which case the drainage pipe between the abutment's upstream face and the collection chamber must be routed through a concrete-encased pipe of a suitably larger cross-section (Figure 4.10).



Kota terena	Terrain angles
Opažna cev	Formwork pipe

Figure 4.15: Routing the pipe through the rear wall to the manhole

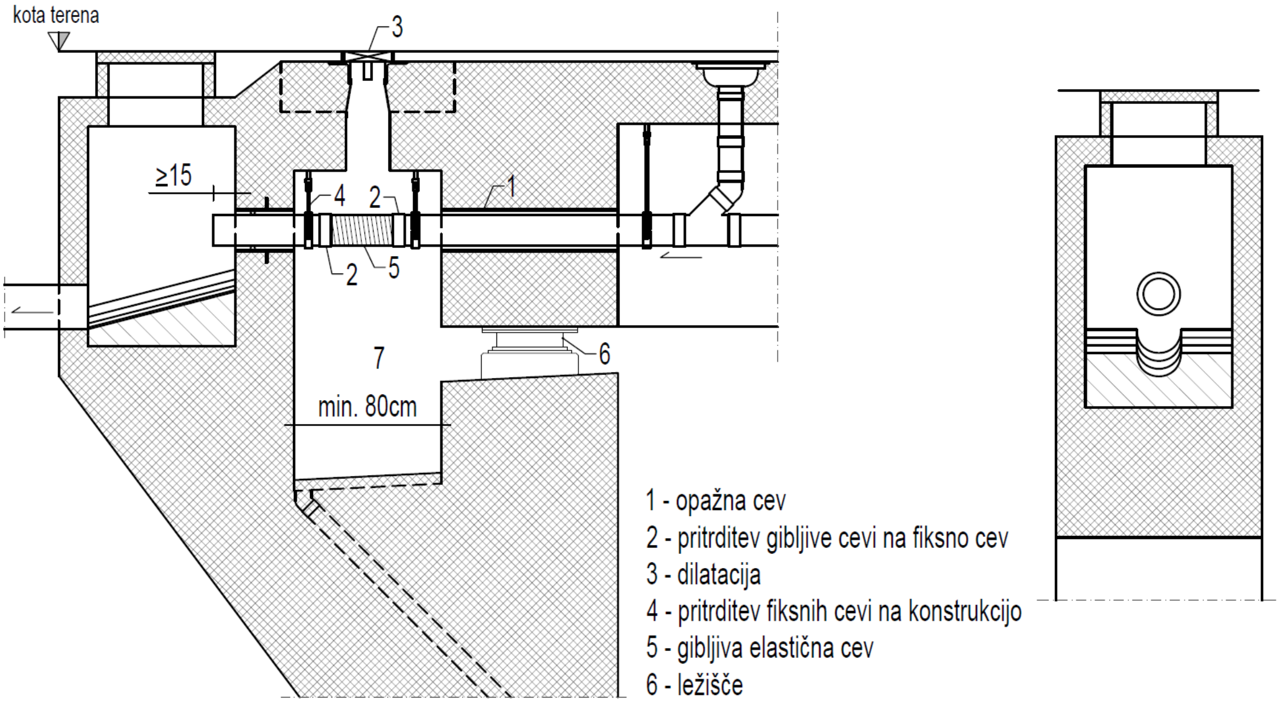


Obbetoniranje cevi pod voziščema	Enveloping of pipes under the carriageways
Betonska cev DN 400	DN 400 concrete pipe
Cev odvodnje DN 200	Drainage pipe DN 200

Figure 4.16: Concreting of pipes laid in the embankment beneath the road carriageway

- Through the retaining wall into the collection/inspection chamber on the backfill side of the retaining wall for longer structures where bearing surfaces and expansion joints are required, Figure 4.11.

DRAINAGE OF BRIDGE STRUCTURES

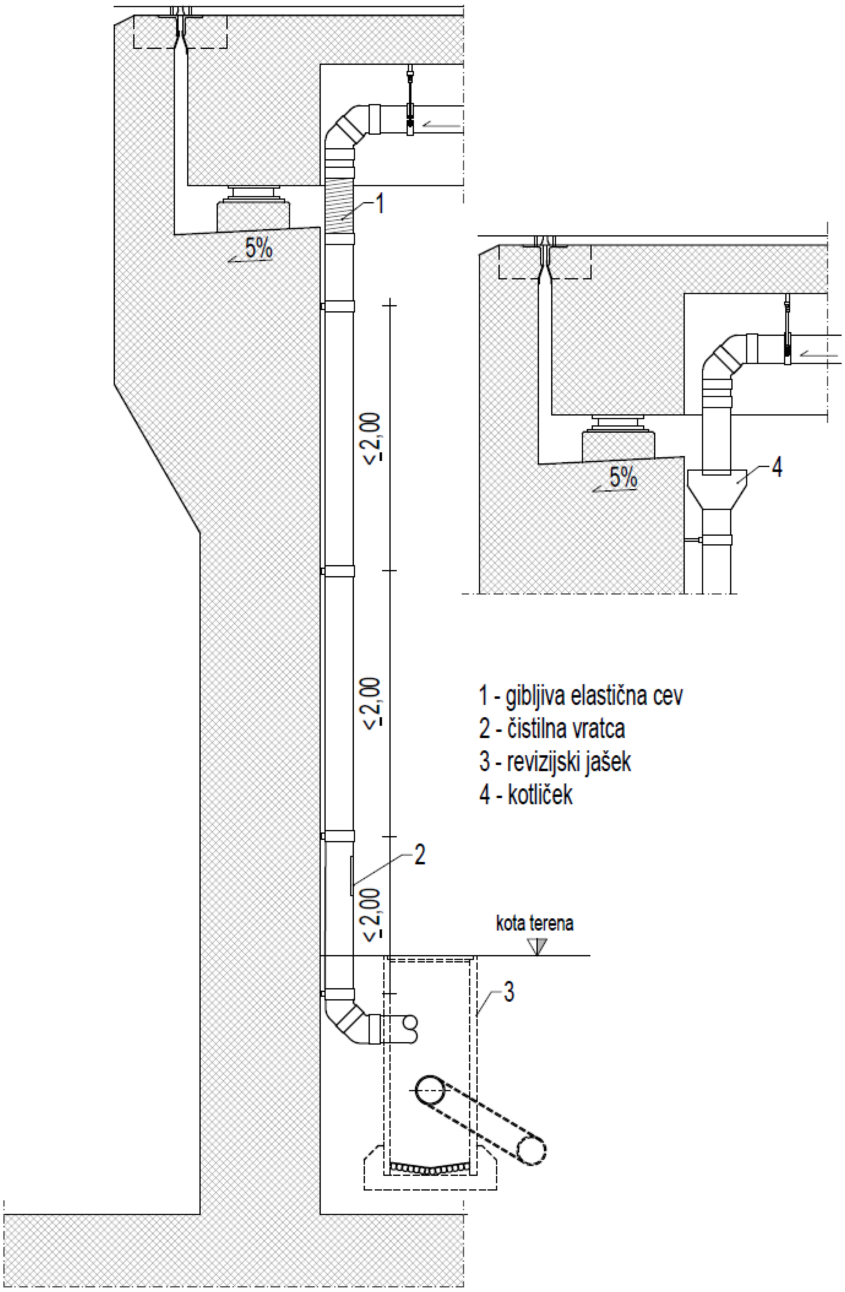


Kota terena	Terrain angles
Opažna cev	Formwork pipe
Pritrditev gibljive cevi na fiksno cev	Fixing of a flexible pipe to a fixed pipe
Dilatacija	Expansion joint
Pritrditev fiksnih cevi na konstrukcijo	Fixing of fixed pipes to the structure
Gibljiva elastična cev	Flexible elastic pipe
Ležišče	Bearing
Stranski dostop min. 80/120mm	Lateral access min. 80/120 mm

Figure 4.17: channelling stormwater through the rear wall of a retaining wall in structures with expansion joints at the end abutments

- With the vertical pipe pointing downwards in front of the support, Figure 4.12

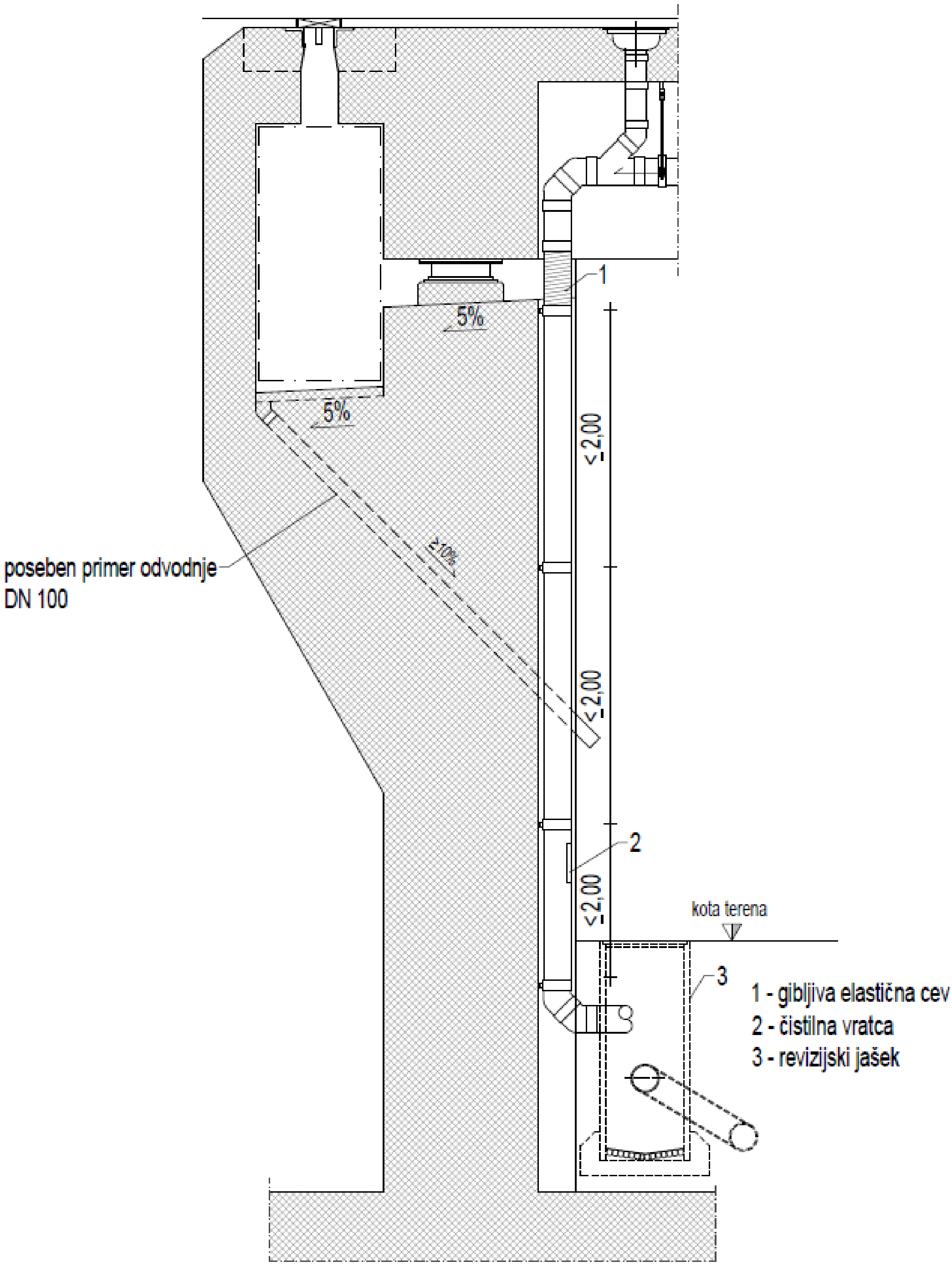
DRAINAGE OF BRIDGE STRUCTURES



Gibljiva elastična cev	Flexible elastic pipe
Čistilna vratca	Cleaning hatch
Revizijski jašek	Inspection chamber
Kotliček	Cistern

Figure 4.18: Vertical pipe routing in front of the support for structures without a chamber in the support, using an elastic compensation piece (left) or a gully pot (right)

DRAINAGE OF BRIDGE STRUCTURES

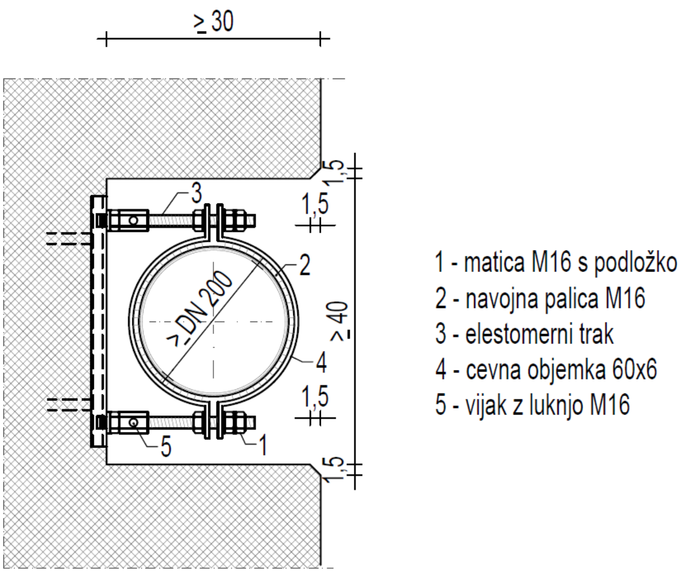


Poseben primer odvodnje DN 100	Special case of drainage DN 100
Kota terena	Terrain angles
Gibljiva elastična cev	Flexible elastic pipe
Čistilna vratca	Cleaning hatch
Revizijski jasek	Inspection chamber

Figure 4.19: Vertical alignment of the pipe in front of the supports for structures with a chamber in the upright, with possible connection of the drainage chamber to the vertical drainage system

In the case of integral structures, discharge is possible directly into the collection chamber without the need for a flexible elastic pipe.

The diameter of the vertical pipe must be matched to the diameter of the longitudinal pipe, so that the water gains sufficient momentum as it flows from the longitudinal collection pipe into the vertical drain pipe. Therefore, for vertical drainpipes of lesser height and smaller volumes of water, the same profile as that of the longitudinal pipe is specified. The vertical pipe may be routed freely alongside the support or in special grooves (Figure 4.14)



Matica M16 s podložko	M16 nut with washer
Navojna palica M16	M16 threaded rod
Elestomerni trak	Elastomeric tape
Cevna objemka 60x6	60x6 pipe clamp
Vijak z luknjo M16	Bolt with M16 hole

Figure 4.20: Routing a vertical pipe through a groove

For vertical pipes with a height of more than 10 m, it is reasonable to provide for ventilation at the upper end of the pipe. In this case, provision may be made for an open penetration funnel, which serves as a connection between the longitudinal and vertical piping. The funnel must be made of hot-dip galvanised sheet metal, stainless steel, cast iron or plastic.

Bend elements may only be fitted into vertical pipes at an angle of ≤ 60°. This prevents the pipes from becoming blocked.

Once the drainage system has been installed, the contractor must provide evidence of the reliability of the entire drainage system and its components. A 30-minute operational and leak test of the drainage system at maximum filling of the pipe with water shall be carried out and documented.

In the case of high-rise drainage pipes, it is advisable to test the longitudinal and vertical drainage pipes separately.

The system must be dimensioned for a pressure of at least 0.5 bar, which corresponds to a water column of a height of approx. 5.0 m.

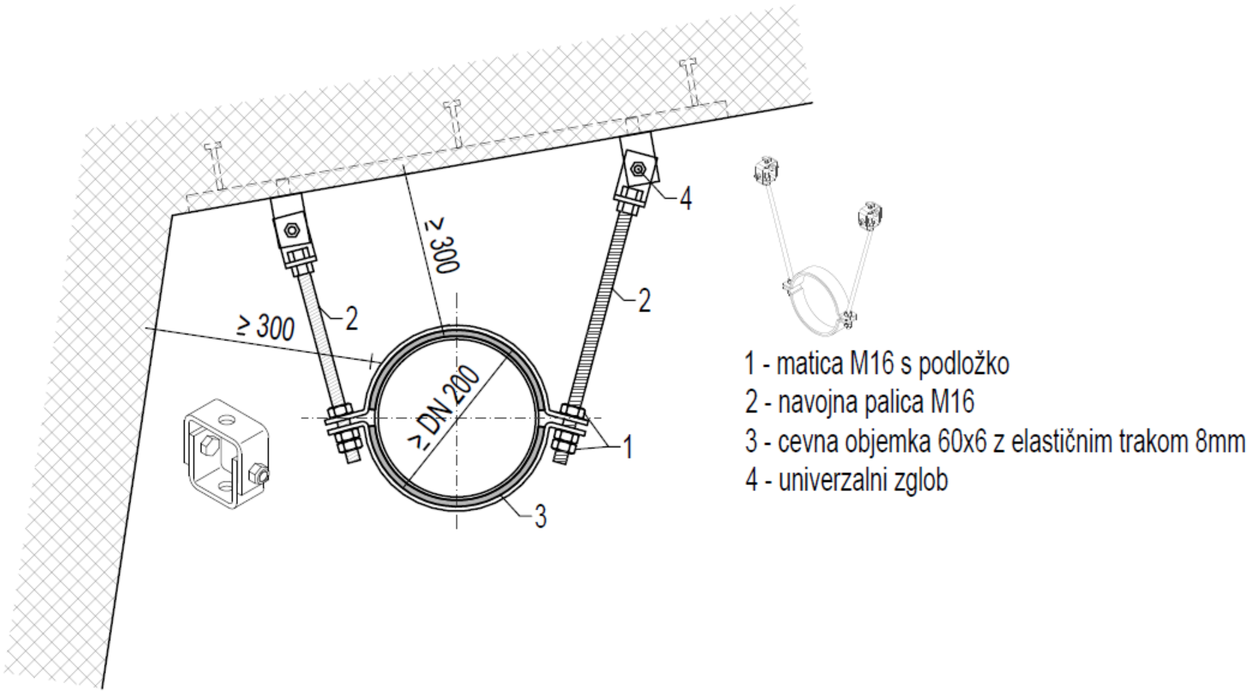
4.1.4 Conditions for the installation and fixing of pipes for water drainage and channelling to the building structure

The pipe fittings shall be suspension and support. These must be constructed and secured in such a way as to provide the pipes with sufficient support and allow for contraction and expansion. In principle, at least two pipe hangers must be provided for each pipe length to prevent a fall in the event that one fails.

The principle is followed that all the drains are exposed to the influence of the water spray of de-icing salt solutions, therefore only fasteners made of stainless steel may be used for fixing the pipes.

Supports and hangers used to secure drainage pipes to the bridge structure must be sufficiently rigid to ensure that the pipes are not damaged in the event of any structural vibrations.

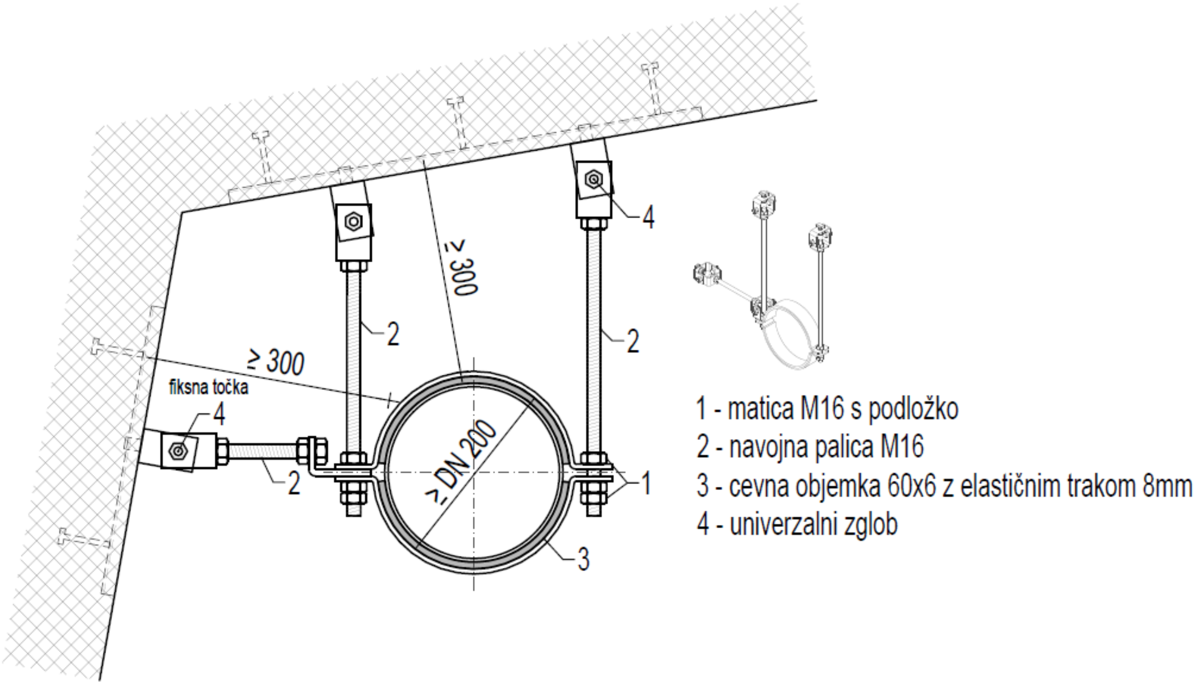
Supports and hangers must allow for height adjustment. Hangers are designed to be either movable or fixed (Figures 4.15 and 4.16). On the wing walls, they can be supported by steel brackets (Figure 4.17)



Matica M16 s podložko	M16 nut with washer
Navojna palica M16	M16 threaded rod
Cevna objemka 60x6 z elastičnim trakom 8mm	60x6 pipe clamp with 8mm elastic strip
Univerzalni zglob	Universal joint

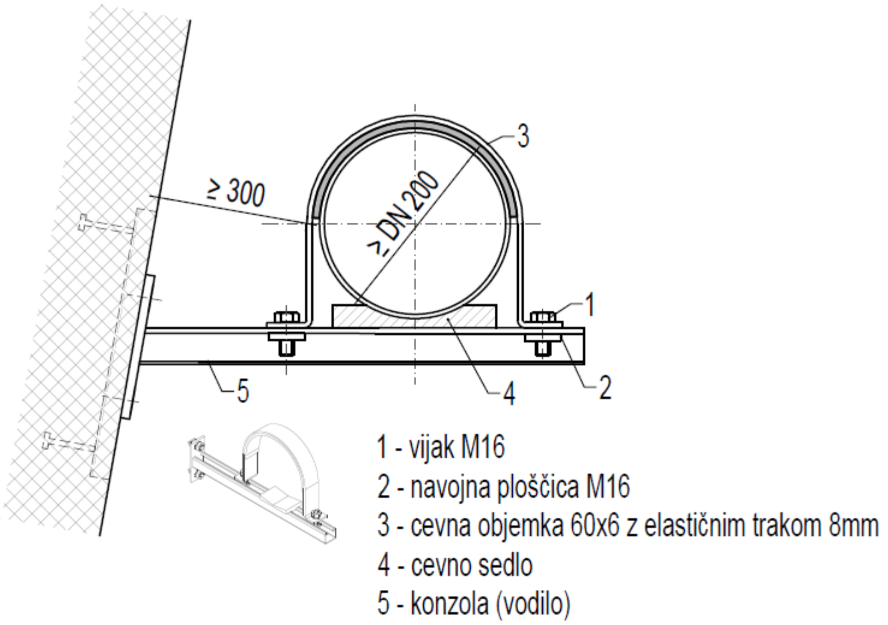
Figure 4.21: Longitudinally movable, transversely fixed suspension

DRAINAGE OF BRIDGE STRUCTURES



Matica M16 s podložko	M16 nut with washer
Navojna palica M16	M16 threaded rod
Cevna objemka 60x6 z elastičnim trakom 8mm	60x6 pipe clamp with 8mm elastic strip
Univerzalni zglob	Universal joint

Figure 4.22: Longitudinally movable, transversely fixed suspension



Vijak M16	M16 bolt
Navojna ploščica M16	M16 threaded plate
Cevna objemka 60x6 z elastičnim trakom 8mm	60x6 pipe clamp with 8mm elastic strip
Cevno sedlo	Pipe saddle
Konzola (vodilo)	Bracket (guide)

Figure 4.23: Routing the pipe on the bracket

The pipes are fixed in place at the junctions where the transverse drainpipes connect to the main longitudinal pipe.

Anchoring of hangers and supports is carried out with the help of a special profile and bolts with T-head. When carrying out subsequent drilling and inserting steel inserts, care must be taken to avoid damaging the prestressed cables and reinforcement.

Hangers and supports for securing pipes must be corrosion-resistant and made of stainless steel.

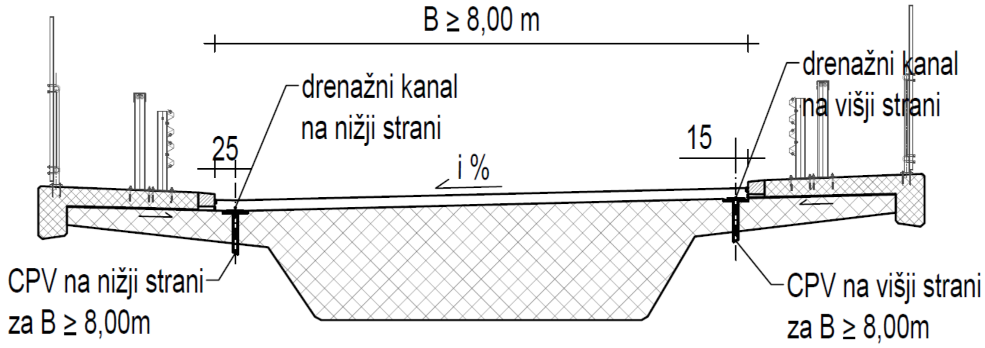
The spacing between supports or hangers depends on the type of pipe and the permissible pipe sag.

The differences in length between the structure of the bridge structure and the pipe line are determined based on the expansion coefficients of the materials and temperature differences: 40° when routing the pipe inside a box-shaped cross-section and 60° when routing the pipe outside the cross-section.

4.1.5 Elements for draining seepage water and venting

The pipes must be distributed over the entire waterproofed surface so that they are at the lowest point of the roadway, e.g., along the sidewalk (25 cm from the curb), spaced at intervals of approx. 3.0 to 10.0 m, depending on the longitudinal gradient of the roadway

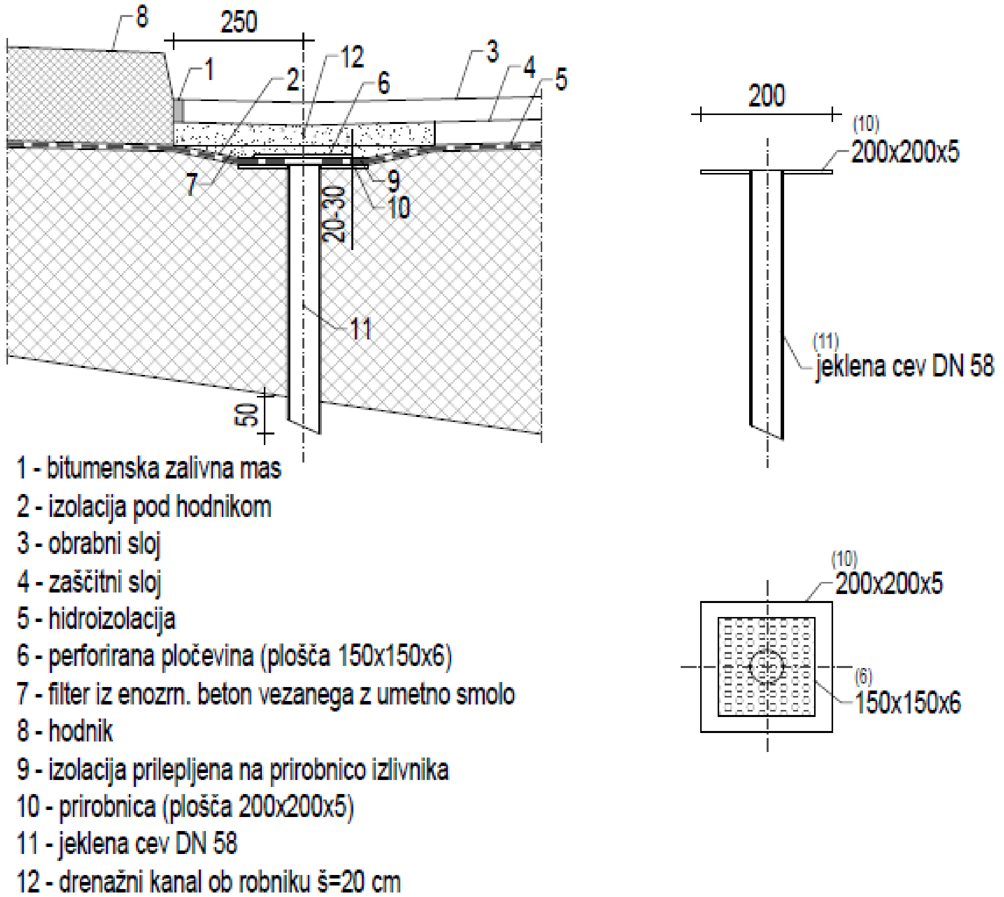
(Figure 4.18). Each pipe should serve up to 25 m2 of the building's floor area. At carriageway widths above 8.0 m, CPV shall also be installed at the upper edge of the carriageway transverse drop, at a distance of 6.0 to 10.0 m



CPV na nižji strani za B ≥ 8,00m	CPV on the lower side for B ≥ 8.00 m
Drenažni kanal na nižji strani	Drainage channel on the lower side
Drenažni kanal na višji strani	Drainage channel on the higher side
CPV na višji strani za B ≥ 8,00m	CPV on the higher side for B ≥ 8.00 m

Figure 4.24: Installation of CPV and a drainage channel for larger structures

DRAINAGE OF BRIDGE STRUCTURES



Jeklena cev DN 58	DN 58 steel pipe
Bitumenska zalivna mas	Bituminous joint sealant
Izolacija pod hodnikom	Insulation under the corridor
Obrabni sloj	Wearing course
Zaščitni sloj	Protective layer
Hidroizolacija	Waterproofing
Perforirana pločevina (plošča 150x150x6)	Perforated sheet metal (plate 150x150x6)
Filter iz enozm. Beton vezanega z umetno smolo	Filter made of resin-bound pervious concrete
Hodnik	Sidewalk
Izolacija prilepljena na prirobnico izlivnika	Insulation bonded to the drain flange
Prirobnica (plošča 200x200x5)	Flange (plate 200x200x5)
Jeklena cev DN 58	DN 58 steel pipe
Drenažni kanal ob robniku š=20 cm	Drainage channel along the kerb, width 20 cm

Figure 4.25: Detail of the seepage water pipe (CPV) and installation

The deepening of the upper surface of the concrete of the superstructure in the CPV area shall be carried out at a depth of 2-3 cm at a surface of 40 x 40 cm. Figure 4.19 shows a detail of the CPV installation

A longitudinal drainage layer, 3 cm thick and 20 cm wide, consisting of 4–8 mm gravel bound with epoxy resin, is laid between the CPV and the drains, over the waterproofing. In the CPV area, the drainage layer should be extended above the groove for installation of the CPV (Figure 4.20 and Figure 4.21).

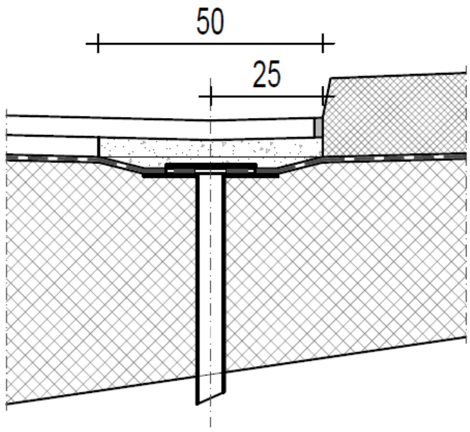


Figure 4.26: A longitudinal drainage channel in the protective asphalt layer on the lower side of the deck

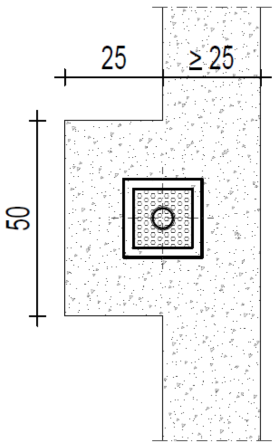


Figure 4.27: extension of the drainage channel at the CPV points on the lower side of the deck

In the case of bridge structures crossing other road links, water from the CPV directly above the carriageway must be channelled into a collective sewer pipe, and only this pipe must be connected to the collective pipe for the drainage of surface water.

Immediately before lower expansion joint according to the longitudinal gradient, the CPV must be installed at intervals of 3.0 to 4.0 m. The seepage water along the expansion joint should be channelised if the free water outflow would present any disturbance under the structure (Figure 4.22 and Figure 4.23).

DRAINAGE OF BRIDGE STRUCTURES

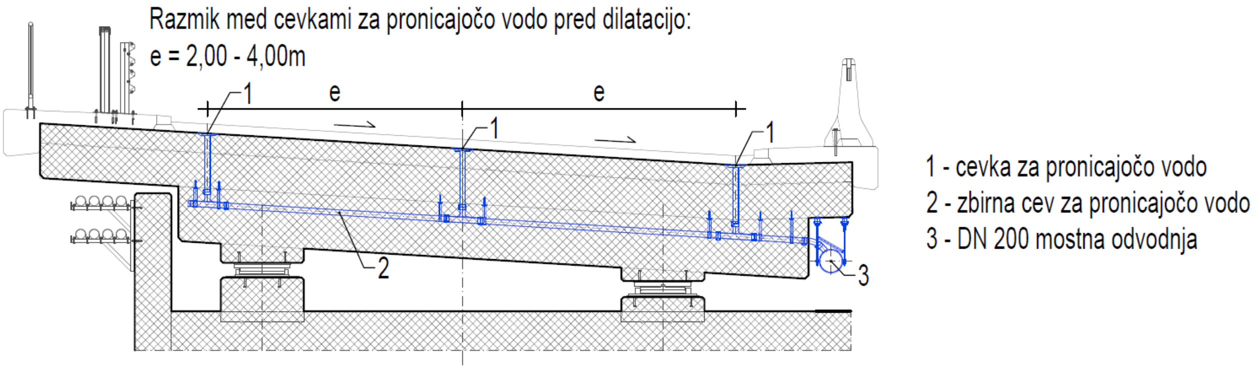
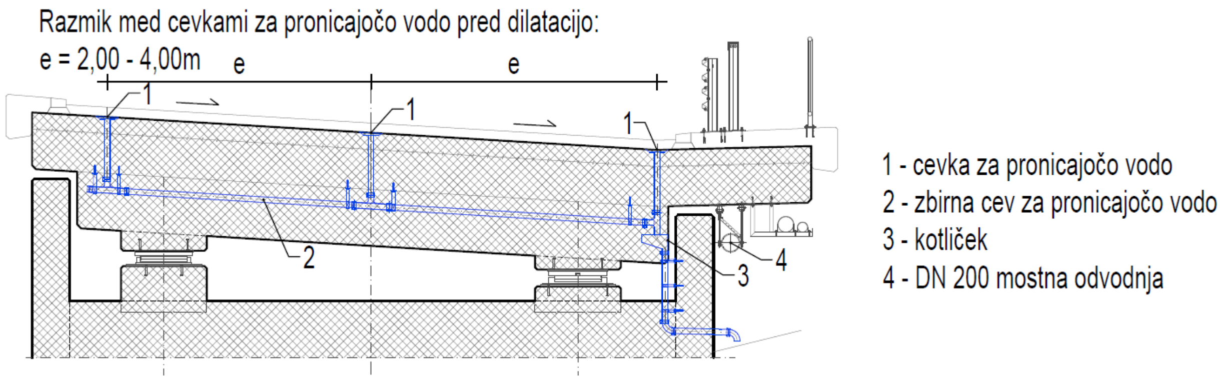


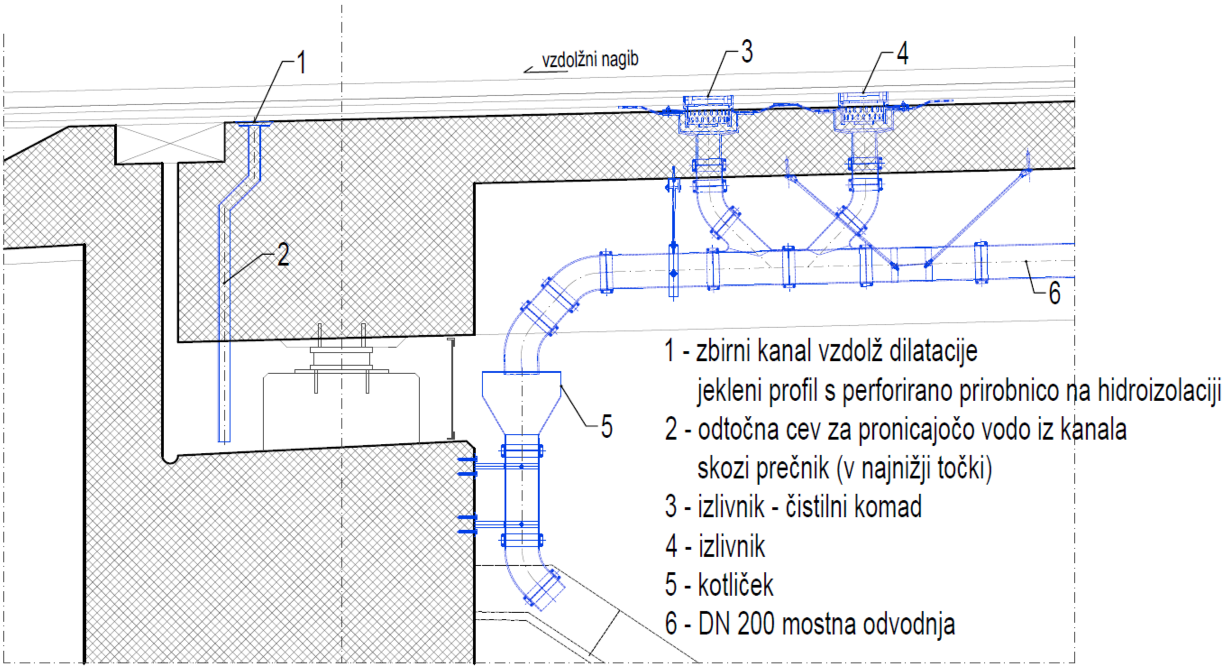
Figure 4.28: Drainage of the CPV prior to expansion joint, with water collected in the longitudinal bridge drainage system



Cevka za pronicajočo vodo	Seepage water pipe
Zbirna cev za pronicajočo vodo	Collector pipe for seepage water
Kotliček	Cistern
DN 200 mostna odvodnja	DN 200 bridge drainage

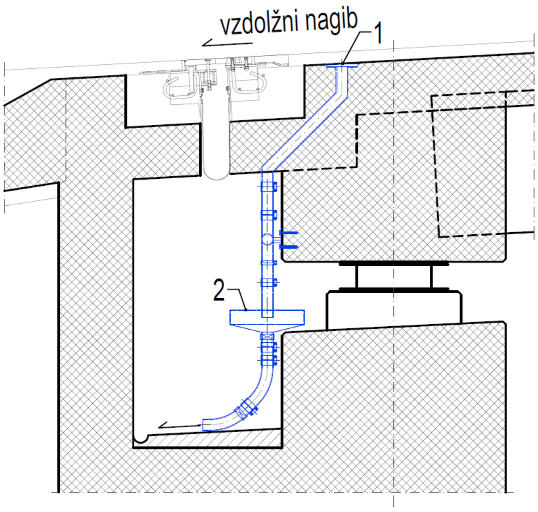
Figure 4.29: Drainage of CPV before expansion joint with free flow to the terrain

DRAINAGE OF BRIDGE STRUCTURES



Vzdolžni nagib	Longitudinal slope
Zbirni kanal vzdolž dilatacije jekleni profil s perforirano prirobnico na hidroizolaciji	A drainage channel running along the expansion joint, comprising a steel profile with a perforated flange on the waterproofing
Odtočna cev za pronicajočo vodo iz kanala skozi prečnik (v najnižji točki)	Drain pipe for seepage water from the channel through the crossbeam (at the lowest point)
Izlivnik – čistilni komad	Drain – cleaning piece
Izlivnik	Drain
Kotliček	Cistern
DN 200 mostna odvodnja	DN 200 bridge drainage

Figure 4.30: example of CPV drainage before expansion joint for structures without a maintenance chamber



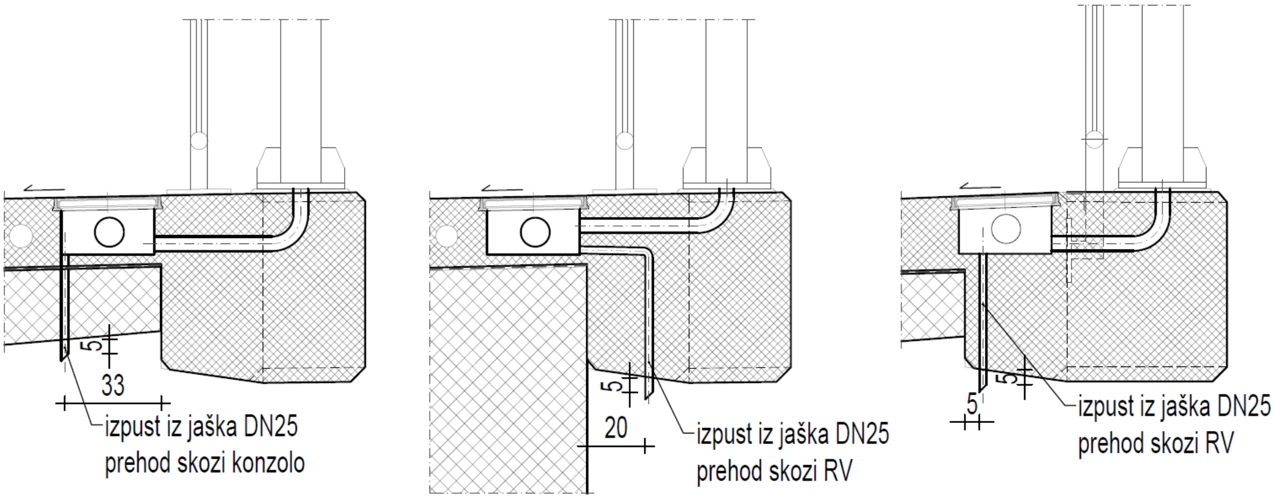
Vzdolžni nagib	Longitudinal slope
Cevka za pronicajočo vodo	Seepage water pipe
Kotliček	Cistern

Figure 4.31: an example of a free drainage into the maintenance chamber

In structures with inspection galleries in the end abutments, seepage water is channelled into a chamber and from there out of the structure (Figure 4.25). In structures without inspection chambers, seepage water collects along the upstream face of the end abutment and is discharged transversely into the embankment (Figure 4.24). Regardless of whether the CPV is installed at the lowest point of the bend, points that cannot be drained must be avoided.

The fixed fixing of the drainage pipe of the seepage water along the expansion is not allowed over the expansion itself, because the movement of the expansion joint leads to damage to the sewage system.

Drainage of service shafts in corridors is carried out at the lowest point of the shaft using a DN25 mm pipe (Figure 4.26).



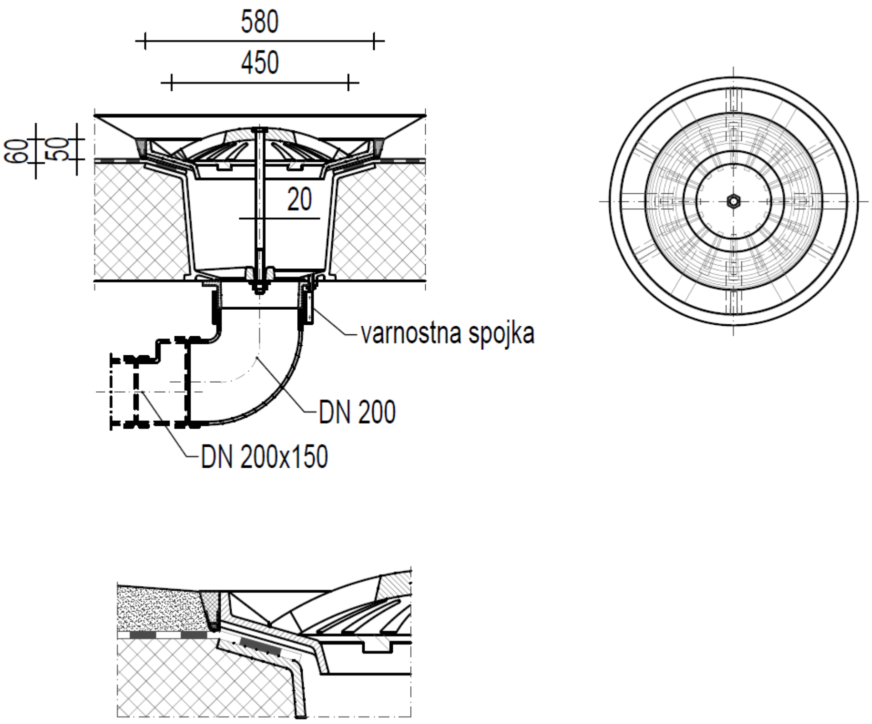
Izpust iz jaška DN25 prehod skozi konzolo	Outlet from the DN25 shaft, passing through the bracket
Izpust iz jaška DN25 prehod skozi RV	Outlet from the DN25 shaft, passing through the RV

Figure 4.32: Drainage of a shaft via a corridor console – methods of implementation depending on the shaft's location and the structure beneath it

4.2 Structures on railways

4.2.1 Drains

For drains on railway bridge structures, the cast iron drains shall be used. The drain grating has an external diameter of 450 mm and a thickness of 30 mm, with 16 drainage slots, each approximately 100 mm long and 18-20 mm wide, of cast iron. The grating is secured using an M20 bolt.



Varnostna spojka	Safety clutch
DN 200	DN 200
DN 200x15	DN 200x15

Figure 4.33: Drains on railway bridge structures

A drainage funnel is formed in the protective concrete waterproofing, sloping towards the drain.

The joint between the protective concrete and the grating is sealed with a layer of polyester felt 200-300 g/m2, which is resistant to oils and bitumen, with a thickness of approx. 25 mm, filled at the bottom with quartz sand of a grain size of 1–2 mm to a depth of 10 mm and filled at the top with a permanently elastic filling material (Figure 4.27).

4.2.2 Drainage of sidewalks and channels

It is necessary to prevent the retention of water in the sidewalks and channels of the railway bridge structure.

4.2.2.1 Drainage of sidewalks and channels on concrete bridges

To drain service sidewalks and edge beams into the track bed trough, the upper surface of the sidewalk or edge beam must be constructed with a cross-slope of 2.5 % towards the drainage axis. Openings are to be provided in the wall of the edge beam in accordance with the following requirements:

- Dimensions min. 80 x 80 mm or Φ 80 mm.
- Spacing max. 5.0 m.

- The slope of the openings is 3.5 %.

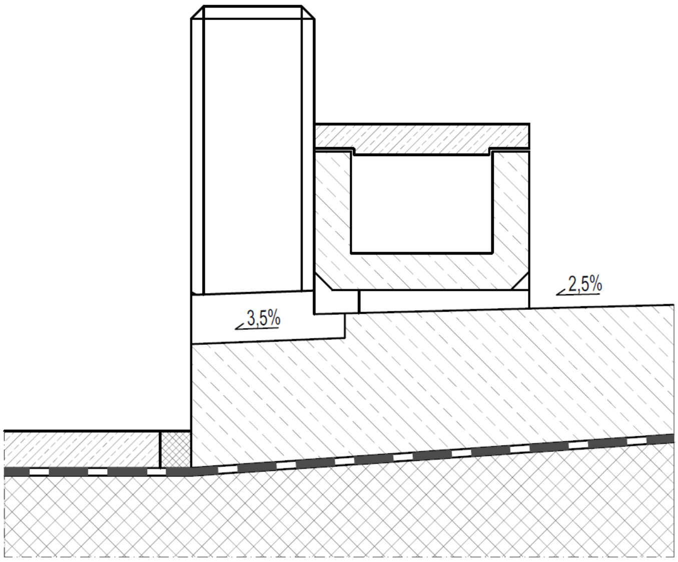
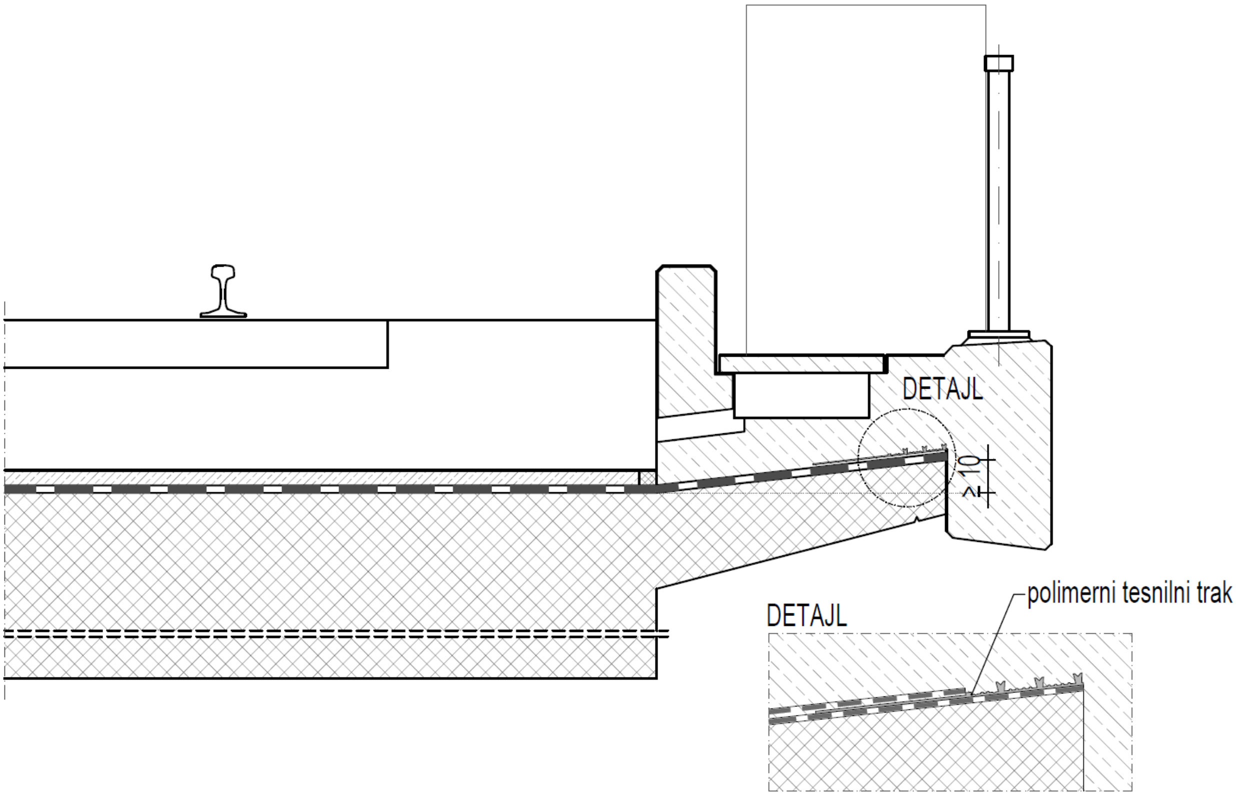


Figure 4.34: Drainage of sidewalks via channels



DETAJL	DETAIL
Polimerni tesnilni trak	Polymer sealing strip

Figure 4.35: Installation of a bracket on reinforced concrete or prestressed reinforced concrete railway bridge structures, with a waterproofing termination detail using polymer sealing strip

The bracket under the sidewalk should have a slope in direction of the track ballast. The height of the outer edge of the upper surface of the bracket shall be at least 10 cm higher than the upper surface of the track ballast. The completion of the waterproofing at the end of the bracket is carried out with an additional polymer sealing strip (Figure 4.28).

At the end of the bracket, a polymer sealing strip is installed on the waterproofing below the monolithic part of the edge beam (Figure 4 .35).

4.2.2.2 Drainage of sidewalks and channels on steel bridges

In the case of steel superstructures, service sidewalks are generally constructed from open grating, and the bases of cable trays are also water-permeable.

The provisions apply only to new structures with a closed superstructure, i.e. an orthotropic steel deck and an upper track structure comprising a ballast bed or a track on a rigid subgrade, where water needs to be collected and drained. For existing structures with an open superstructure, the above provisions do not apply. Where the service route and cable trough are outside the supporting structure, it is not necessary to collect and drain water from the service route and cable trough (Figure 4.30)i.

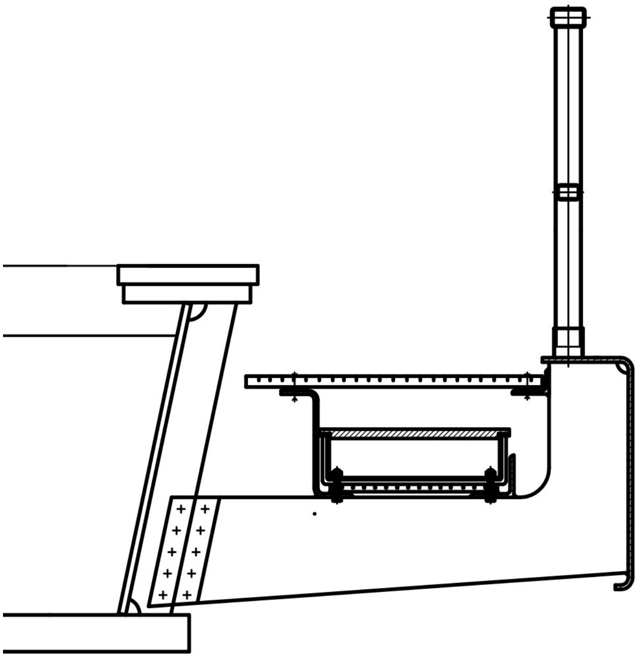


Figure 4.36: A service route outside the supporting structure, e.g. on brackets

However, where the supporting structure extends beyond the service route and cable trough, and the cross-beams and orthotropic steel deck extend beneath the service route and cable trough, rainwater must be collected and drained via the bridge’s drainage system.

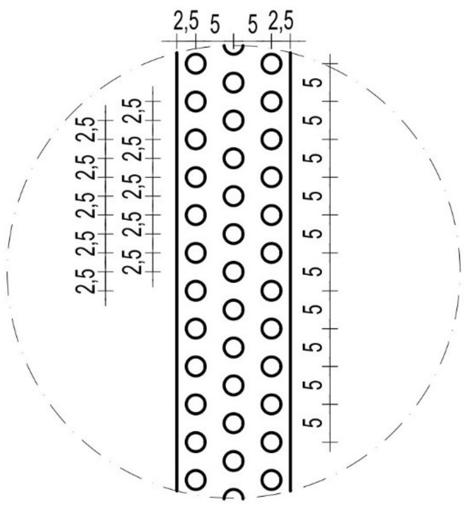
4.2.3 Special considerations regarding the use of sub-ballast mats beneath the track bed

Where a noise-reducing mat made of elastic synthetic materials is laid beneath the track bed (to meet requirements for noise reduction or to increase the durability of the ballast), this must be carried out in such a way that it does not impede the drainage of the structure.

Execution in drains shall be made according to the following procedure:

- Installation of a sub-ballast mat on a structure with a 0.8 x 0.8 m opening in the drain area.
- Production of a 1.0 x 1.0 m sheet from a sub-ballast mat with holes cut out in accordance with the drain hole pattern.
- A cut-to-size piece of sub-ballast mat measuring 1.0 x 1.0 m is placed over the drain and trimmed around the area extending beyond the 0.8 x 0.8 m opening so that it fits precisely into the opening.
- The joint of the two parts of the sub-ballast mat into a whole shall be carried out by gluing the flipping straps across the contact edges of the latter.

Where the sub-ballast mat extends beyond the retaining walls onto the cement-stabilised backfill, holes with a diameter of 22 mm must be drilled in the noise-reducing mat in the area of the drainage walls behind the retaining walls to ensure drainage behind the retaining wall



(Figure 4.31)

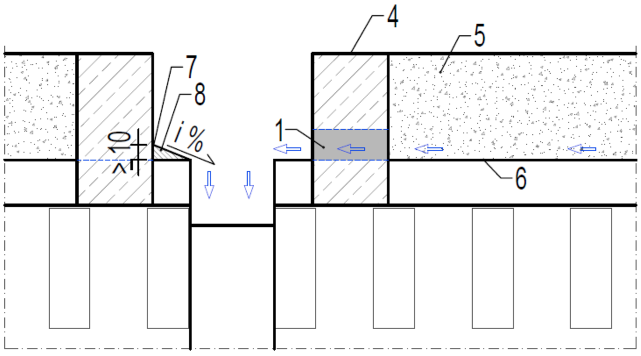
Figure 4.37: Perforation of the sub-ballast mat in the area where the backfill drainage is being carried out

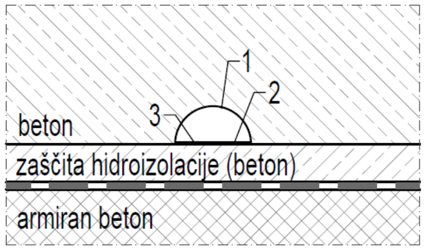
4.2.4 Rail drainage on rigid base

Track construction on a rigid base must not interfere with the intended method of drainage of the superstructure and after hydraulic calculation of the intended catchment areas per drain (Figure 4.33).

To this end, a DN200 half-pipe made of high-density polyethylene (HDPE) must be laid at the level of the protective concrete waterproofing, prior to the installation of the sloped concrete, in the area of the drains (Figure 4.32).

DRAINAGE OF BRIDGE STRUCTURES





1 - polovična plastična cev DN200
2 - tanko lokalno polnilo za izravnavo, zaščitna betonske površine pod vsako polovično cevjo
3 - polnilo za beton (hrapava podlaga)
4 - varovalo gramoza
5- gramozno nasutje
6 - izravnalni beton
7 - podlaga mora biti hrapava
8 - polnilo za beton debeline min. 3 cm

Beton	Concrete
Zaščita hidroizolacije (beton)	Protection of waterproofing (concrete)
Armiran beton	Reinforced concrete
Polovična plastična cev DN200	Half-length plastic pipe DN200
Tanko lokalno polnilo za izravnavo, zaščitna betonske površine pod vsako polovično cevjo	A thin layer of levelling compound to protect the concrete surface beneath each half-pipe
Polnilo za beton (hrapava podlaga)	Concrete filler (rough substrate)
Varovalo gramoza	Gravel barrier
Gramozno nasutje	Gravel backfilling
Izravnalni beton	Equalising slump concrete
Podlaga mora biti hrapava	The surface must be rough
Polnilo za beton debeline min. 3 cm	Filler for concrete with a minimum thickness of 3 cm

Figure 4.38: Installation of transverse drainage through a rigid track bed and a detail of the drainage of the gravel ballast at an expansion joint

DRAINAGE OF BRIDGE STRUCTURES

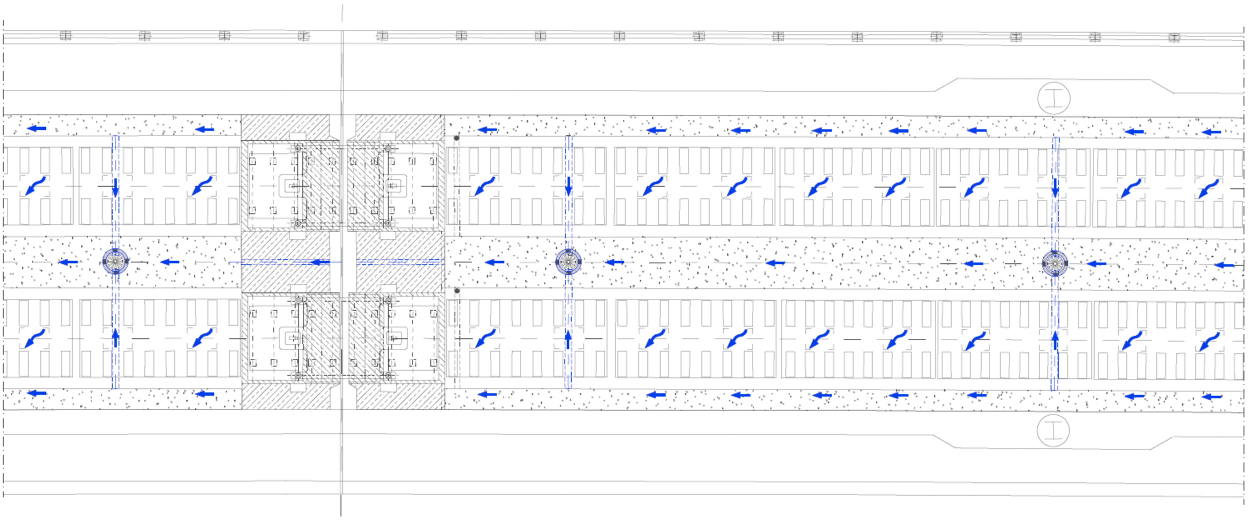


Figure 4.39: The principle of draining rainwater from a structure with a track on a rigid sub-base

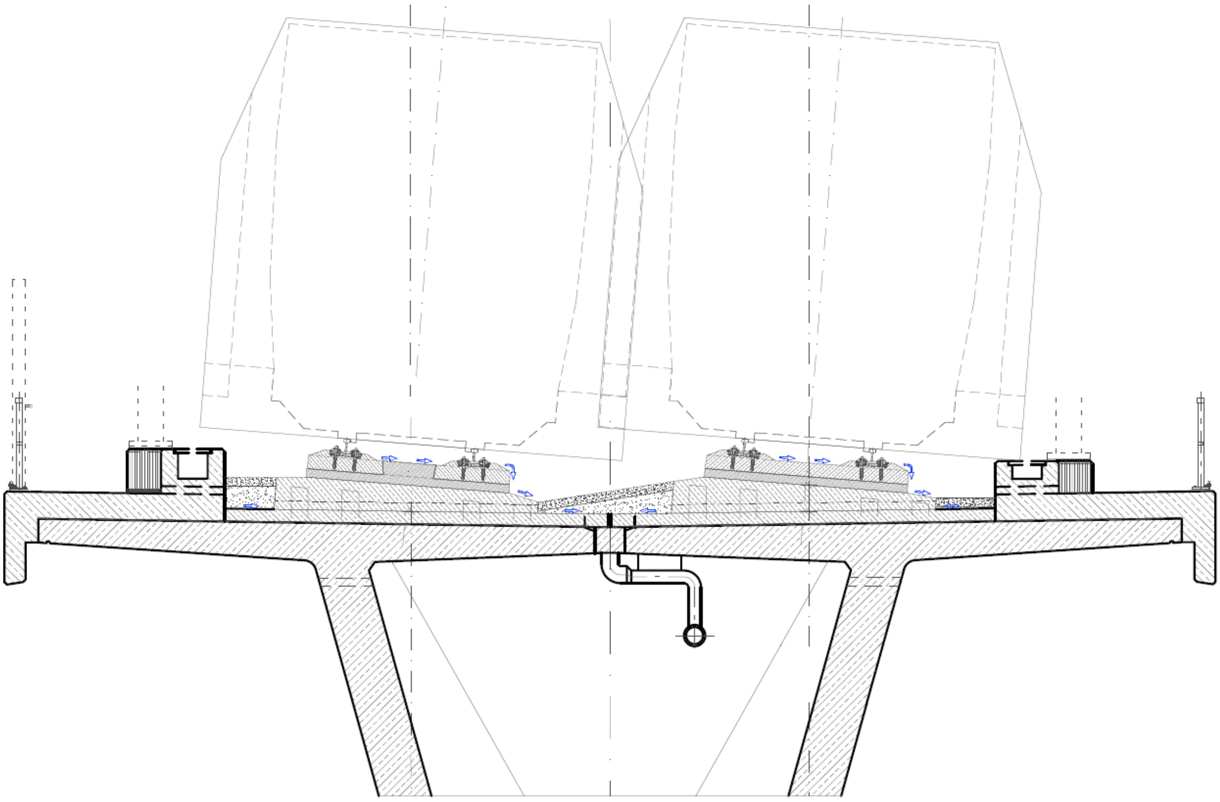
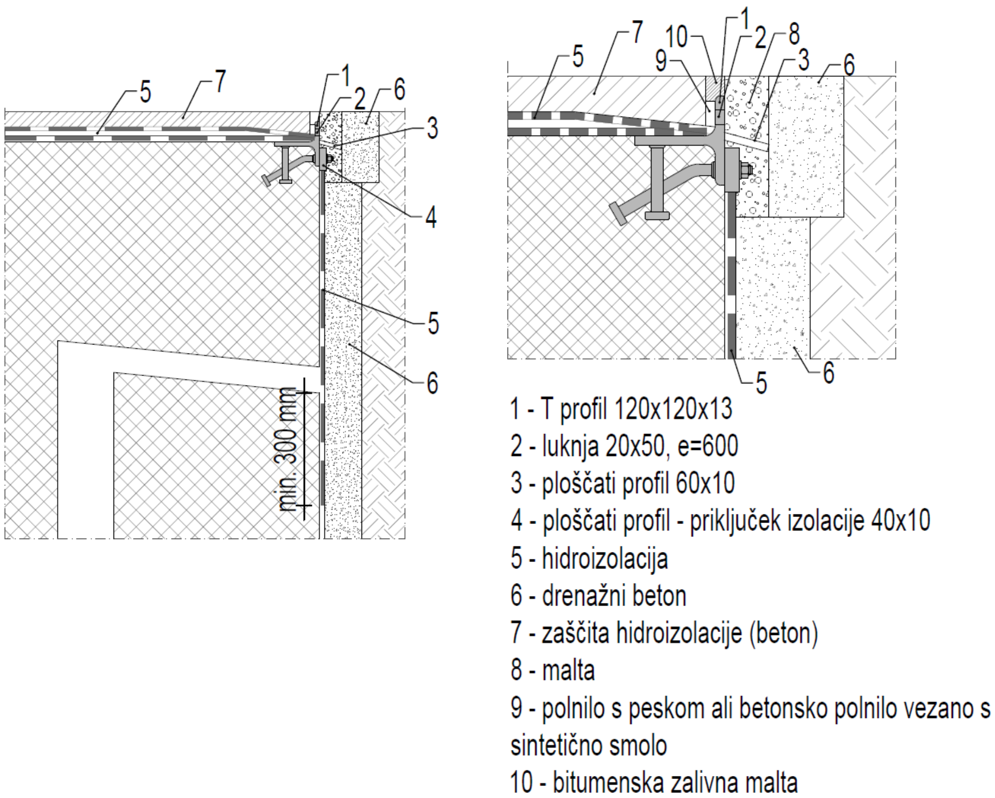


Figure 4.40: Design of a transverse storm drain on a structure with a multi-track line

Similarly, for structures with decks comprising several braking units, the area behind the track on a rigid sub-base (the area between the sidewalks/channels and the track, or between the tracks) must be drained in accordance with the detail shown in Figure 4.34.

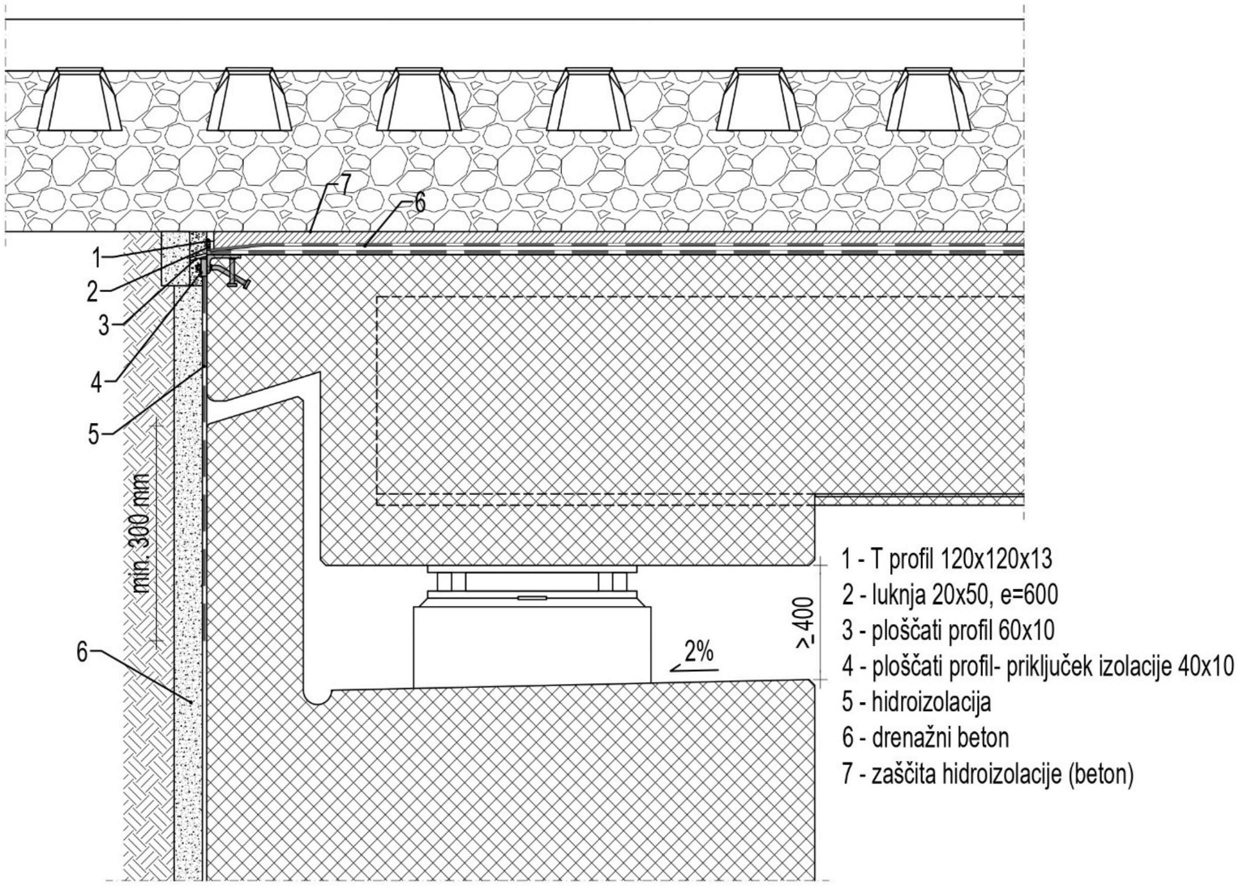
4.2.5 Special features of superstructures constructed using the side-push method

In the case of superstructures constructed using the side-push method, for short closures a solution is adopted without a bridge expansion joint or with a low-lying joint between the superstructure and the abutment (Figure 4.35 and Figure 4.36).



T profil 120x120x13	T-profile 120x120x13
4luknja 20x50, e=600	4hole 20x50, e=600
Ploščati profil 60x10	Flat profile 60x10
Ploščati profil – priključek izolacije 40x10	Flat profile - insulation connection 40x10
Hidroizolacija	Waterproofing
Drenažni beton	Drainage concrete
Zaščita hidroizolacije (beton)	Protection of waterproofing (concrete)
malta	mortar
Polnilo s peskom ali betonsko polnilo vezano s sintetično smolo	Sand-based fill or concrete fill bonded with synthetic resin
Bitumenska zalivna malta	Bituminous joint sealant mortar

Figure 4.41: Example of completion of waterproofing



T profil 120x120x13	T-profile 120x120x13
Luknja 20x50, e=600	Hole 20x50, e=600
Ploščati profil 60x10	Flat profile 60x10
Ploščati profil – priključek izolacije 40x10	Flat profile - insulation connection 40x10
Hidroizolacija	Waterproofing
Drenažni beton	Drainage concrete
Zaščita hidroizolacije (beton)	Protection of waterproofing (concrete)

Figure 4.42: Example of completion of waterproofing

4.2.6 Protection of the drainage system against stray currents

In the event that the longitudinal and vertical lines of the drainage system are constructed of conductive materials (e.g. cast iron or stainless steel), the drainage elements must be connected to the earthing of the bridge structure.

5 Materials

5.1 General

When selecting the drainage material, special attention must be paid to:

- Energy losses in pipes (pipe roughness).
- The load on the drainage system during cleaning and maintenance.
- Abrasion resistance.
- Resistance to climatic conditions and the effects of UV radiation.
- Resistance to stresses caused by winter maintenance operations.
- Resistance to ageing (brittleness, colour fastness, etc.).
- Ensuring colour consistency across the entire drainage system.
- Volume stability and resistance to system deformation, primarily due to temperature changes.
- Mutual compatibility of materials.

5.2 Material characteristics of typical drainage materials

Table 5.1: Material characteristics

Characteristic value	Cast iron	GRP	HDPE	Stainless steels
E modulus (radial) [N/mm²]	170,000	8,000	150 to 200	
E modulus (longitudinal) [N/mm²]	170,000			200000
Roughness k [-]	0.01	0.01	0.01	0.01
Pipe stiffness [N/mm2]		10,000		
Radial tensile strength [N/mm2]	550	30 to 50		
Longitudinal tensile strength [N/mm2]	420	15 to 20	8 to 10	490 to 690
Recommended support distance [m]		3		3.3

5.2.1 Plastics

High-density polyethylene pipes must be manufactured in accordance with SIST EN 13244-1, and polypropylene pipes in accordance with ISO 15874.

The color of HDPE pipes is generally black. They are also available in grey, in a concrete-coloured finish.

The deformation module depends on the temperature and voltage state of the pipe.

The difference in the coefficient of thermal expansion between concrete or steel and plastic requires the implementation of special structural solutions when installing the drainage system.

5.2.2 Glass-reinforced polyester – GRP

GRP pipes are manufactured using glass fibres and polyester resin in accordance with the EN 14364 standard.

The requirements for GRP pipes are as follows:

- Pipes and elbows shall be manufactured in accordance with SIST EN 1447.
- The couplings are also made from GRP.
- The seals shall be made of EPDM material.

5.2.3 Cast iron pipes – cast iron

Pipes and elbows of ductile cast iron with jointing by flanges or couplers shall be executed in accordance with SIST EN 598.

Cast iron pipes and elbows without fittings shall be executed in accordance with SIST EN 877.

The external surface protection of pipes to be joined using couplings shall be carried out as follows:

- Electrolytic or thermal zinc coating, with a minimum thickness of 200 g/m2, 30 microns thick.
- A primer coat of two-component epoxy coating, 120 microns thick.
- A double-layer topcoat using a two-component polyurethane coating, with a minimum thickness of each layer of 80 microns, in a dark grey colour.
- Total thickness of protective layers min. 310 microns.

The internal protection of the coupling pipes with couplings shall be carried out by means of cement mortar application.

5.2.4 Fixing material

The durability of the fixing material depends to a large extent on the environmental conditions and maintenance requirements of the drainage system. It can be assumed that all pipes on the underside of bridges are exposed to the influence of brine from the water spray.

Only anchors suitable for concrete tension zones, made of austenitic stainless steel as specified in Table 5.2, may be used.

Table 5.2: Types of stainless steel for use in the drainage systems of bridge structures

Short name according to SIST EN 10088-1	Material No
X5CrNiMo 17-12-2	1.4401
X2CrNiMo 17-13-2	1.4404
X6CrNiMo 17-12-2	1.4571

6 Hydraulic calculation

6.1 General

The dimensions of the individual structural elements of the drainage system are determined on the basis of a hydraulic calculation, which forms an integral part of the drainage design/plan for the bridge structure. The chapter provides the definitions of input parameters and the forms necessary for the dimensioning of individual exhaust elements.

6.2 Amount and outflow of water

Of all types of precipitation, rain and downpours are the most significant for drainage and sewerage systems; depending on the time of year, geographical location and current weather conditions, they vary in intensity and frequency. The effects of other forms of precipitation (snow, fog) are not significant for the drainage system.

The volume of rainwater runoff from a given catchment area is:

$$Q\,odt.=\varphi * q'_{T(n)} * F \qquad (6.1)$$

φ = runoff coefficient (the ratio between the amount of rainfall falling on the catchment area and the amount of water that runs off into the drainage system). For bridge structures = 1.0.),

q' = unit precipitation intensity [l/s*ha],

F = catchment area to which the rainfall run-off is applied [ha].

The unit intensity of rainfall is equal to the amount of precipitation per unit of time per unit of area. Determined with the aid of rainfall intensity data:

$$q' = i * f = 166{,}6 * i \, [l/s * ha] \qquad (6.2)$$

$$i = \frac{h}{t} \qquad (6.3)$$

i = intensity of precipitation [mm/min],

h = precipitation depth [mm],

t = duration of the downpour [min].

The data have been obtained on the basis of observations made over several years using measuring instruments and have been statistically processed (return periods for extreme rainfall: https://crossrisk.eu/sl/climate. From this data for the given frequency n, determine the link between the one-year precipitation intensity q' and the duration of the rainfall T:

$$q' = q' T(n) \qquad (6.4)$$

Due to the increasing frequency of extreme rainfall events and climate change, it is recommended that data from rainfall monitoring stations be increased by 20–25 %.

Precipitation frequency *n* refers to the number of times a given amount of precipitation is reached or exceeded during a specified duration of precipitation or downpour.

In order to ensure traffic safety and in view of the recent frequency of extreme rainfall events, it is necessary to ensure reliable drainage of the bridge structures for the calculated one-hour rate of downpours with a duration of *T* = 10 min and a frequency of downpours *n* = 0.1.

The values for standard rainfall intensities are taken from official meteorological data for the site's location.

From a hydraulic point of view, the drainage and sewerage system of the bridge structure must be designed such that the time taken for water to collect and drain away is less than or equal to the duration of the design rainfall event:

$$T \leq T_r \qquad (6.5)$$

$$T = \frac{L}{v} \qquad (6.6)$$

The time taken for water to flow from the inlet to the outlet along a length of *L* at a velocity of *v*.

6.3 Determination of the required number of drains and the required spacing between them

6.3.1 Facilities on roads

The permissible size of the catchment area of a bridge structure, which, for drainage purposes, is allocated to a single drain F_{izl}, is determined by:.

- the longitudinal gradient of the drainage at the edge of the structure,
- transverse inclination, which is min. 2.5 – 3 %,
- unit precipitation intensity (q'),
- permissible width of the watercourse at the edge of the structure (š),
- swallowing ability of the drain.

The width of the watercourse at the edge of the structure (š), which the driver must not cross with their vehicle even during heavy downpours, may be:

- 1.50 m on bridge structures with a 2.50 m wide hard shoulder,
- 1.00 m on all other structures.

Size of the catchment area that falls on one drain:

$$F_{izl} = e_{izl} \times b \qquad (6.7)$$

e_{izl} = the distance between the drains,

b = the width of the bridge drainage surface which falls on one drain.

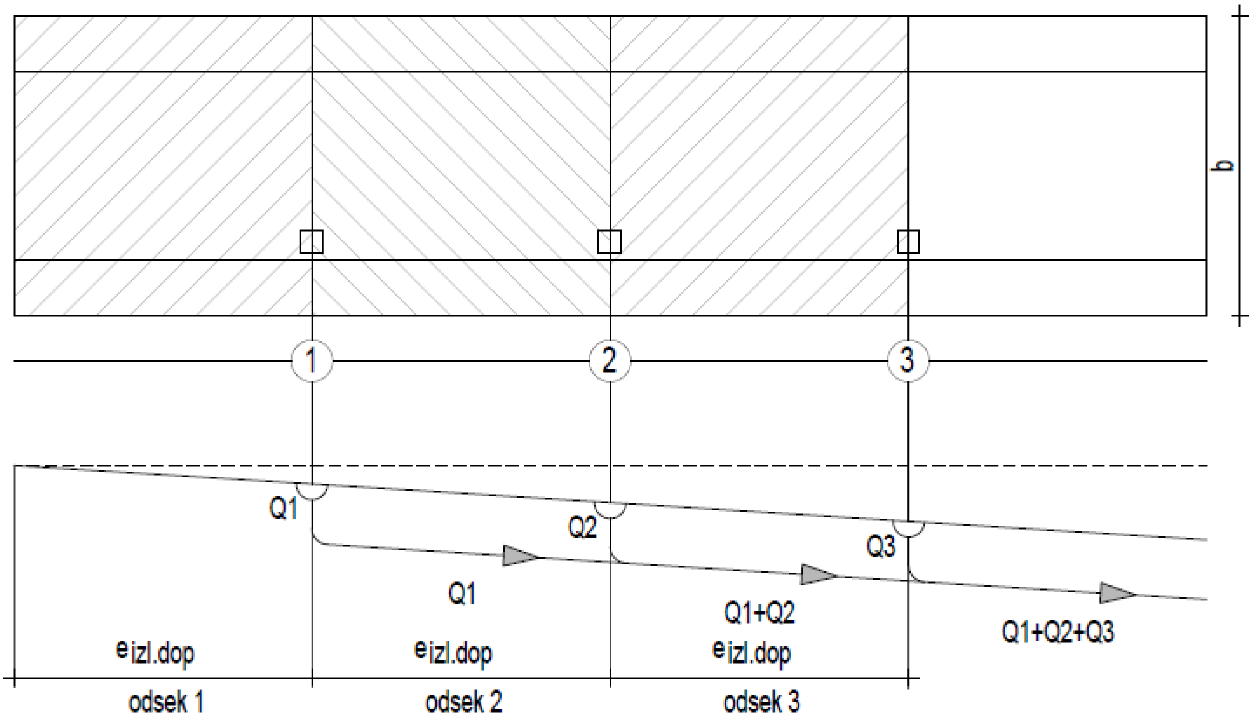


Figure 6.43: Surface falling on one drain

The spacing between the drains is determined by the permissible inflow rate $Q_{izl.dop}$ [l/s], which may fall on a single drain, or by the drain's intake capacity.

$$Q_{izl,dop} \geq Q_{¿=\varphi \times q^{\mathrm{I}} \times F_{izl}¿} \qquad (6.8)$$

The drain must be designed to handle a flow rate of at least 10 l/s, provided it is correctly installed on a carriageway with a cross-slope of 3% and a longitudinal slope of 3.50%. Where transverse and longitudinal gradients are smaller, a lower drainage capacity must be taken into account when determining the drainage area of an individual drain. This prevents the width of the watercourse at the edge of the carriageway from exceeding 1.50 or 1 m.

At each drain, some of the inflowing water flows past the drain grating; however, with hydraulically favourable gratings and longitudinal slopes of less than 5 %, this volume is small when the water flow does not exceed the outlet's capacity.

On steeper gradients (> 5%), a considerable proportion of the water flows over the grate even when the inflow is below the drain's intake capacity. This amount depends mainly on the construction of the drain grating and must be demonstrated in the test. The Qizl.dop values are given in Table 6.1, taking into account the transverse slope of the carriageway, the longitudinal slope of the carriageway edge and the location of the drain outlet (at the edge of the traffic lane or hard shoulder).

Table 6.3: Permissible absorption capacities of drains

Longitudinal slope in % at the edge of the bridge structure in the line of the drains	Cross slope 2.5 %. Drains at the edge of the 2.50 m wide hard shoulder	Drain at the edge of the traffic lane	Cross slope 3.0 %. Drains at the edge of the 2.50 m wide hard shoulder	Drain at the edge of the traffic lane
1.0 – 1.5	10	3.5	10	5.5
1.6 – 2.5	10	5.0	10	7.5
2.6 – 3.5	10	6.5	10	9.5

3.6 – 4.5	10	7.5	10	10
4.6 – 5.0	10	8.5	10	10
5.0 swallowing ability of the drain, taking into account its reduction due to the impact of a high longitudinal inclination				

The values are taken from the Swiss guidelines. For the last drain on the structure, viewed in the direction of the water flow, half the permissible inflow rate must be taken into account. This prevents water from draining away from the building through the expansion joint.

6.3.2 Structures on railways

In railway structures, the water flow width does not have a significant impact on traffic safety, so a value of 10 l/s can be taken as the swallowing capacity of the drain, regardless of the slope and location of the drain.

6.4 Dimensioning of drainage pipes

The dimensioning of the collecting pipe shall be carried out on sections from the drain to the drain. It is calculated with the full pipe profile. The following equations shall be used for the dimensioning of pipes:

$$Q_c = v \times S \qquad (6.9)$$

Q = flow volume [m3/s],

S = pipe cross section [m2],

v = the speed of water in the pipe [m/s],

which is calculated according to the De Chezy's form with an inserted Manning friction coefficient – Strickler's form:

$$v = \frac{1}{n_G} \times R^{\frac{2}{3}} \times i^{\frac{1}{2}} \qquad (6.10)$$

n_G = Manning's roughness coefficient, which depends on the type of pipe material

$$k = \frac{1}{n_G} \qquad (6.11)$$

k = according to tables and manufacturers' data, this ranges from 75 to 90, with local losses in bends and joints already taken into account.

Table 6.4: Roughness coefficients for different materials

material	n_G
brass and glass	0,009 – 0,015
wood	0,010 – 0,013
Cast iron - ductile	0,011 – 0,015
Iron	0,012 – 0,015

galvanised	0,013 – 0,017
Ceramics	0,011 – 0,017
concrete	0,012 – 0,018
PVC	0,009 – 0,012
GRP	0,010 – 0,012

Contributing amount of water per drainage pipe:

$$Q = \frac{q' \times F_{odv}}{10{,}000} \qquad (6.12)$$

Q' = unit precipitation intensity,

F_{odv} = catchment area falling on the pipe.

Tables or diagrams from any relevant literature dealing with the hydraulic design of pipelines may be used for the calculation. These are designed for different materials or pipe surface roughness. As a rule, the information from the pipe declaration of conformity (CE marking) shall be used in the dimensioning of pipes.

Table 6.3 gives the values for solid circular pipe cross-sections with diameters of DN150, DN200, DN250 and DN300 mm, which are commonly used in drainage and sewerage systems for bridge structures.

Table 6.5: Values for v and Q for circular pipes according to De Chezy's formula for velocity, with the friction coefficient C according to Streckler-Manning, taking into account the roughness coefficient nG = 0.013

i [%]	DN150		DN200		DN250		DN300	
	v [m/s]	Q [l/s]	v [m/s]	Q [l/s]	v [m/s]	Q [l/s]	v [m/s]	Q [l/s]
10	2.72	48.1	3.30	103.7	3.83	188.0	4.32	305.7
9	2.58	45.7	3.13	98.3	3.63	178.3	4.10	290.0
8	2.44	43.0	2.95	92.7	3.42	168.1	3.87	273.4
7	2.28	40.3	2.76	86.7	3.20	157.3	3.62	255.7
6	2.11	37.3	2.56	80.3	2.97	145.6	3.35	236.8
5	1.93	34.0	2.33	73.3	2.71	132.9	3.06	216.1
4	1.72	30.4	2.09	65.6	2.42	118.9	2.73	193.3
3	1.49	26.4	1.81	56.8	2.10	103.0	2.37	167.4
2	1.22	21.5	1.48	46.4	1.71	84.1	1.93	136.7
1	0.86	15.2	1.04	32.8	1.21	59.4	1.37	96.7
0.9	0.82	14.4	0.99	31.1	1.15	56.4	1.30	91.7
0.8	0.77	13.6	0.93	29.3	1.08	53.2	1.22	86.5
0.7	0.72	12.7	0.87	27.4	1.01	49.7	1.14	80.9
0.6	0.67	11.8	0.81	25.4	0.94	46.0	1.06	74.9
0.5	0.61	10.8	0.74	23.2	0.86	42.0	0.97	68.4

6.5 Practical example of calculation

Input data:

- Estimated duration of the downpour: T_r: 10 min
- Frequency of downpours: n = 0.1 (10 years)
- Measurement site: Ljubljana
- Rainfall height: h = 20 mm
- Unit precipitation intensity: q' = 333.2 [l/(s*ha)]
- Facility without a hard shoulder
- Facility width: b = 15.0 m
- Length of the drainage surface: L = 52.0 m
- Transverse slope: 3.0 %
- Longitudinal slope: 1.0 %

Bearing in mind that the drain is located at the edge of the traffic lane, and taking into account the longitudinal and transverse slope, we can refer to the table to determine the permissible drainage capacity per drain:

$$q_{izl,dop} = 5.5\, l/s$$

Determination of the spacing between drains:

$$e_{izl,dop} = \frac{10{,}000\, x\, Q_{izl,dop}}{q' \times b}$$

$$e_{izl,dop} = \frac{10{,}000 \times 5.5}{333.2 \times 15}$$

$$e_{izl,dop} = 11.00\,m$$

The distance between the drains is 11.0 m.

Determination of the diameters of drain pipes:

- Pipe diameter: D = 200 mm
- Cross-sectional area: S = 0.0314 m2
- Flow rate at i = 2%: v = 1.22 m/s
- Conductivity of the full profile (from the table): Q_{dop}. = 46.4 l/s

$$Q_{dej} = S \times v = 0.0383 \frac{m^3}{s} = 38.31 \frac{y}{s}$$

$$Q_{dej} = 38.31 \frac{y}{s} < Q_{dop} = 46.4 \frac{y}{s}$$

The maximum contribution volume of water inflow Qd from the total drainage surface for a given case shall be:

$$Q_d = \frac{q' \times L \times b}{10{,}000} = \frac{333.2 \times 52 \times 15}{10{,}000} = 25.98 \frac{y}{s}$$

This is less than the conduction capacity of the selected pipeline on the last section. The procedure can be carried out by performing several iterations of conductivity calculations for each pipe diameter.

Table 6.6: A tabular presentation of the calculation for the given example

Section	$L_{ods.}$ [m]	b [m]	$F_{ods.}$ [m²]	$Q_{odt.}$ [l/s]		DN [mm]	i [%]	v [m/s]	Q_{cevi} [l/s]	$T_{odt.}$ [s]	
				drain	total					section	total
1 – 2	11	15	165	5.5	5.5	200	2	1.48	46.4	7.5	7.5
2 – 3	11	15	165	5.5	11.0	200	2	1.48	46.4	7.5	15.0
3 – 4	11	15	165	5.5	16.5	200	2	1.48	46.4	7.5	22.5
4 – 5	11	15	165	5.5	22.0	200	2	1.48	46.4	7.5	30.0
5 – 6	11	15	165	5.5	27.5	200	2	1.48	46.4	7.5	37.5

7 Maintenance of the drainage system

7.1 General

Inadequate design, construction and/or maintenance of the drainage system on bridge structures can have a significant impact on the quality of the basic materials used and lead to various types of damage to the bridge structures. These over time lead to a significant reduction, in particular of sustainability, but also of the load-bearing capacity and/or stability of the individual structural elements and therefore of the structure as a whole.

Most damages resulting from inadequate drainage are related to excessive water logging of stormwater from the roadway. It often contains substances that are harmful to basic structural materials, such as concrete and steel, which further accelerates the deterioration of these basic structural materials.

In practice, the most common damage is caused by the presence of chlorides in the water, which usually originate from the winter gritting of roads. Consequently, road bridge structures are more susceptible to this type of damage.

Water logging due to inadequate drainage is one of the key causes of damage occurring in reinforced concrete, prestressed, steel, and composite bridge structures. As a result, they often fail to reach their designed service life.

Due to the aforementioned presence of aggressive substances in the water that seeps from the carriageway through the structural elements of bridge structures, damage is primarily caused by corrosion of the reinforcement or steel components. These are particularly common where water logging occurs in (old) bridge structures where the protective layer of concrete over the reinforcement is too thin.

7.2 Accessibility of the drainage system

All parts of the drainage system must be accessible at all times for cleaning, maintenance and inspection.

Longitudinal drainage systems installed between the main decks must be accessible by means of special maintenance equipment.

A manhole/sand trap must be provided at each lower end of the vertical drainpipe; this also serves to facilitate the inspection and cleaning of the vertical drainpipe.

7.3 Cleaning and maintenance of the drainage system

The drainage system must be designed in such a way as to allow for regular maintenance and cleaning.

The cleaning of longitudinal collecting drains is carried out through the cleaning shafts. The distance between cleaning shaft must not exceed 70 m.

Cleaning shafts must be directed upstream to the water flow in order to be able to pipe high pressure flushing in the opposite direction of water flow.

Cleaning shafts shall be fitted with a cover so that they do not receive any water from the carriageway that will interfere with the direction of water flow in the exhaust pipe. They are usually positioned immediately behind the drains on the lower side.

8 Bridge structure drainage and channeling system design

The design of the drainage system is an integral part of the bridge structure design.

The manner of drainage (controlled drainage, drains position, etc.) shall be provided for in the lower stages of the project documentation. This is because the manner of drainage has a significant impact on the design of the cross-section of the bridge superstructure.

The detailed design shall include the following:

- Preparation of the drainage layout at an appropriate scale (plan view, longitudinal section, cross-section).
- Presentation of characteristic details (pipe slopes, positions of fixed and movable suspensions, locations of cleanouts, manholes, etc.).
- Execution of a hydraulic calculation, if required based on the size of the structure.

9 Literature

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Rules on the Lower Structure of Railway Lines

DRAINAGE OF BRIDGE STRUCTURES