GUIDELINES FOR ROAD DESIGN, CONSTRUCTION, MAINTENANCE AND SUPERVISION

Volume I: DESIGNING

Section 2: DESIGNING BRIDGES

DESIGN GUIDELINES (DG 1.2.12)

Part 12: BRIDGE INSTALLATION

INTRODUCTION

Installations can be found on almost all bridges. They are particularly numerous on bridges situated in towns and settlements.

It is very important to study thoroughly the needs for installations already when planning and designing bridges, and to select such structure that enables an appropriate crossing.

Installations shall be led on bridges in such a way that they can be easily maintained and, if necessary, supplemented or removed as well.

Installations are inspected and maintained in accordance with the maintenance design. Any imperfection on the installations shall be made good in due time.

C O N T E N T S

1 SUBJECT OF DESIGN GUIDELINES

The present design guidelines deals with individual installations and determines their position on bridges.

Fundamental rules for leading installations on bridges and for transition of installations into the road body are presented.

2 REFERENCE REGULATIONS

The present design guidelines comprises

- JUS N.B2.741
- JUS N.B2.754
- JUS N.B4.901
- Guidelines for placing and fastening of installations on bridges *(Richtlinien für das Verlegen und Anbringen von Leitungen an Brücken, Ausgabe 1994);*
- ZTV-KOR 92
- ZTV-K-88;
- DIN 1076
- DIN 1998.

3 EXPLANATION OF TERMS

Installations are ducts or cables serving for transmission of materials or energy.

Earthing is a conducting connection between electric apparatus or metallic elements and earth. It serves as protection from lightning.

Cathodic protection is protection of steel elements of a structure from corrosion.

Monitoring means observation of structures from remote measuring places.

Inspection shaft enables control of installations placed in bridge walkways.

Passable inspection shaft serves for overcoming of height differences, for distribution of installations within the bridge (in plan), and for compensation of different expansions of the bridge superstructure and installations.

Chamber is a closed space, attached to abutment by means of hinges. Its function is the same as that of the passable inspection shaft. It is designed for a greater number of installations appearing particularly on urban bridges.

4 GENERAL

The basic purpose of up-to-date bridges on motorways, on categorized roads out of towns, and in particular those in towns and settlements, is to enable roads to cross natural and artificial obstacles. Moreover, their task is to enable transition of installations as well.

A distinction between the following installations shall be drawn:

- Installations for communal and urban needs, and
- Installations enabling an undisturbed use of bridges and roads.

Installations for communal and urban needs:

- Electric installations
- Telecommunication installations
- Water supply pipes
- Waste water pipes (sewer pipes)
- Water for remote heating (hot-water pipes)
- Gas conduits
- Oil conduits.

Installations enabling undisturbed use of bridges and roads:

- Drainage and piping of bridges
- Lighting
- Emergency call installation
- Traffic and signalling-safety installation
- Earthing
- Cathodic protection
- Monitoring
- Installations for heating of carriageways

For all installations listed above, technical regulations, instructions and recommendations are available, which shall be strictly adhered to in order to ensure faultless functioning of the installations.

It is of extreme importance to study the present and the future needs for installations very thoroughly already whilst planning and designing a bridge. In this manner, capacities of installations can be specified.

Bridge designers should select such bridge structures that offer sufficient space for leading of installations, since the needs for energy, water, gas, etc., generally increase.
Bridge structures not enabling an appropriate transition of installations shall be avoided.

Transition of certain installations on bridges shall be solved by special design.

Loads imposed by installations shall be adequately taken into consideration in design calculations. It shall be born in mind that capacities of installations can increase in the future; therefore, adding of installations shall be made feasible, and an appropriate bridge structure shall be foreseen for that purpose.

5 FUNDAMENTAL RULES FOR LEADING INSTALLATIONS ON BRIDGES

Installations are led on bridges only in case where other possibilities are unacceptable for technical and economical reasons.

Unless impracticable, installations shall be placed simultaneously with bridges. In extreme cases, special bridges enabling transition of installations are foreseen. This is particularly true for gas conduits, oil conduits, conduits for chemicals or any other conduits that might cause heavy damage on bridges in case of failure.
Installations must not be placed in load bearing concrete elements of superstructures and substructures.

Installations on bridges shall be led through protective ducts being wrapped up with isolating material as circumstances may require. These ducts shall be adequately fixed onto the load bearing structure and, if required, equipped with expansion joints.
Installations shall be led through the bridge in such a way that they can be maintained, supplemented or removed.

Some bridges are exposed to intensive traffic loading causing vibrations and major deformations. In such cases, an adequate bridge superstructure shall be designed to minimize the vibration and deformation phenomena. The installations must be placed away from ruts as much as possible. They are fastened to the load bearing structure by means of elastic connections.

Installations that fluids flow through can provoke special loads acting on the bridge structure. This should be taken into consideration in the bridge design.
Placing and fastening of installations on existing bridges is permitted only in case that this is allowed by static and constructive characteristics of a bridge, and that the bridge appearance is not essentially affected.

Any subsequent extensions of installations must not interfere with the bridge superstructure. All necessary permits shall be obtained.

The following basic guidelines shall be taken into consideration as well:

- Permission by the investor;
- Permission by the designer;
- Working out of drawings;
- Maintenance of the bridge and other installations must not be made difficult;
- Maintenance and replacement of installations shall be enabled.

Installations to be placed on bridges shall be arranged in such a way that:

- Traffic safety on bridges and below them is not reduced;
- Clear opening or flow-through profile is not diminished;
- Durability of a bridge and its equipment is not jeopardized;
- No damages on elements (e.g. reinforcing steel, pre-stressing steel, corrosion protection), installed equipment (e.g. drainage pipes), and on existing installations occur during subsequent placing and fixing of installations;
- Aesthetical appearance of a bridge is not affected;
- Inspection and testing of bridges are not hindered;
- Preservation of bridges and their equipment is not essentially aggravated.

For all types of installations a design shall be worked out where technical solutions, assembling instructions, and safety precautions are indicated. It is also necessary to prepare a common arrangement drawing of all installations showing their mutual position. Namely, certain installations must not be led together thus requiring an adequate spacing and protection.

All metal elements of a bridge shall be earthed because of possible contact with electric installations or for stroke of lightning.

Installations shall be carried out in such a way that all electric currents are immediately cut off in case of bridge collapse.

Already in the bridge design stage, static and constructive requirements shall be taken into consideration whilst determining the position of installations. Undisturbed maintenance and inspection of structures as well as their eventual lifting (replacement of bearings, equalizing of settlements) shall be ensured.

On principle, placing of installations onto the visible bridge surfaces including piers and abutments is not allowed.

When installations are placed onto the external cantilevers, the appearance of a bridge can be improved by:

- Constructing cornices;
- Executing metal or concrete shutters;
- Harmonizing of colours of both, installations and structure;
- Constructing of an edge beam with a raised vertical end up to 1.0 m (figure 5.1);
- Ensuring that the lower edge of installations including suspensions, supports and eventual trapping devices is located higher than the lower edge of the superstructure.

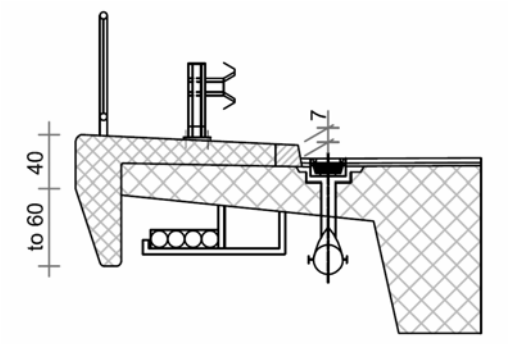

Fig.5.1: Edge beam with raised vertical end up to 1.0 m

5.1 Leading of installations in protective ducts in walkways

Ducts for installations may be placed in walkways under the condition that the walkway upper edge at the kerb is at least 18 cm above the asphalt level. When the walkway height at kerb is smaller (7 cm), the installations shall be led below the cantilever

5.2 Leading of installations in protective ducts in edge beams

Installations are placed in edge beams when the bridge length does not exceed 50.0 m and when bridges are designed in such a way that the carriageway slab is without cantilevers where installations could be placed, and, at the same time, the walkway height is insufficient (7 cm above the asphalt at kerb) to enable leading of installations in walkways.

This case is frequent when a bridge is designed as frame structure.
Into edge beams, three ducts of ∅ 125 mm or six ducts of ∅ 80 mm can be placed. The edge beam dimensions are adjusted to the number of ducts running in the particular edge beam (Fig. 5.1a and 5.1b).

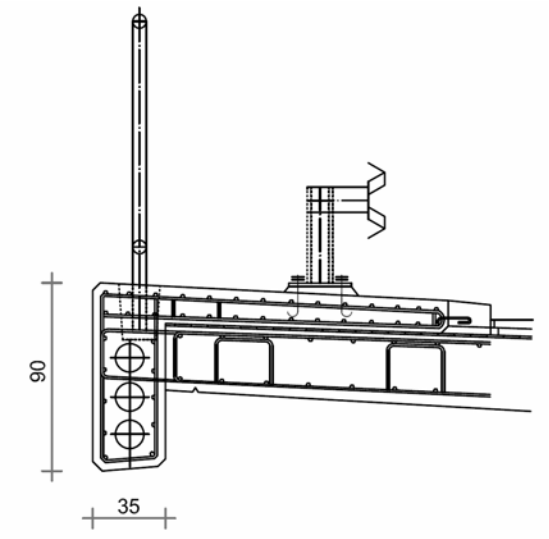

Fig.5.1a: 3 ducts of ∅125 mm in the edge beam

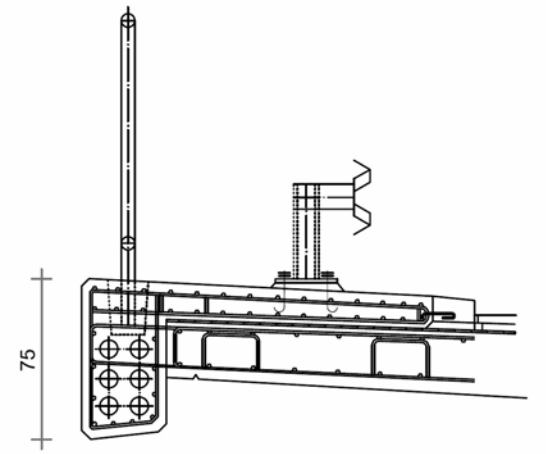

Fig.5.1b: 6 ducts of ∅ 80 mm in the edge beam

6 INSTALLATIONS FOR COMMUNAL AND URBAN NEEDS

6.1 Electric installations

Two types of electric installations can be placed on bridges:

- Low-voltage electric installation;
- High-voltage electric installation.

Electric installations can be disposed below superstructure cantilevers (figure 6.1), between reinforced concrete T-beams, or in the box interior in case of box superstructures (figure 6.4).

These installations may be placed above cantilevers, in walkways (figure 6.1) or in edge beams (figures 5.1a and 5.1b) only when another method of leading of installations would cause essential constructive and design imperfections, as well as when no shafts for inspection and hauling of installations are required (short bridges).

Protective ducts must not hinder building-in of steel reinforcement.

Electric installations shall be placed into plastic ducts or steel ducts protected from corrosion.

6.2 Telecommunication installations

Telecommunication installations can be disposed below superstructure cantilevers, between reinforced concrete T-beams, or in the box interior in case of box superstructures.

These installations may be placed above cantilevers, in walkways or in edge beams only when another method of leading of installations would cause essential constructive and design imperfections, as well as when no shafts for inspection and hauling of installations are required (short bridges).

Protective ducts must not hinder building-in of steel reinforcement.

Telecommunication installations shall be placed into plastic ducts or steel ducts protected from corrosion.

6.3 Water supply pipes and waste water pipes (sewer pipes)

Water supply pipes and waste water pipes are set in box girders in such a way that they are suspended on the upper slab (figure 6.4) or placed onto a suitably prepared base in the bottom slab (figure 6.4). A direct outlet shall be foreseen for the case of damaged installations. Both water supply pipes and waste water pipes may be placed in the box girder interior only when the latter is passable.

When the cross section of a bridge superstructure is a slab, these installations are placed below the cantilevers (figure 6.5). In case of a slab with reinforced concrete T-beams, the installations are placed between T-beams (figure 6.1).

Water pipes shall be placed into protective ducts and adequately thermally isolated.

In water supply pipes and waste water pipes the water temperature is constant while the structure temperature varies continuously due to air temperature changes. Therefore, extensions of the pipes differ from those of the superstructure. These differences in length shall be appropriately surmounted. The pipes must not be rigidly connected to the structure. However, they shall be fastened on certain spots in order to prevent their movements particularly due to the traffic loading.

The weight of both, water supply pipes and waste water pipes filled with water shall be taken into account for the dead load and therefore included in the design calculation.

Leading of water piping shall be worked out in a special design, which has to be at designer’s disposal already in the conceptual stage of the bridge design. Only in this way, the designer can foresee in due time the required spaces for installation of air vents for the water pipes.

6.4 Water for remote heating (hot water pipes)

As a rule, water pipes for remote heating (hot water pipes) are suspended below the superstructure cantilever (figure 6.2) or at the reinforced concrete T-beam (figure 6.1) in case of a slab with reinforced concrete T-beams.

Hot water pipes shall be efficaciously isolated to prevent excessive thermal losses. These pipes are subjected to changes in length due to temperature differences. Therefore, these temperature changes shall be adequately surmounted.

The pipes must not be rigidly connected to the structure. However, they shall be fastened on certain spots in order to prevent their movements particularly due to the traffic loading.

The weight of water pipes for remote heating filled with water shall be taken into account for the dead load and therefore included in the design calculation.

When there is traffic below bridges that carry water pipes for remote heating, precautions ensuring safety of participants in traffic shall be taken in such a manner that trapping devices for hot water leaking out are installed.

6.5 Gas conduits

As a rule, high-pressure gas conduits must not placed into or onto bridges when the gas working pressure is greater than 16 bars.

Generally, gas conduits are placed below the outer cantilever of bridge superstructures (figures 6.1 and 6.4).

For safety reasons, placing of gas conduits in the box girder interior is not allowed.

In exceptional cases when superstructures are one-piece made of slab with reinforced concrete T-beams, or when superstructures are two-piece made of slab with reinforced concrete T-beams or box girders, gas conduits may be placed on the lower side (figure 6.6).

Leading of gas conduit shall be worked out in a special design, which has to be at designer's disposal already in the conceptual stage of the bridge design. Only in this way, the designer can foresee in due time the necessary openings.

6.6 Oil conduits

Oil conduits are not led on bridges. It is preferable to foresee a special bridge to bring an oil conduit over different hindrances. Such a bridge must fulfil all safety precautions in order to prevent pollution of environment in case of eventual unexpected oil outflow.

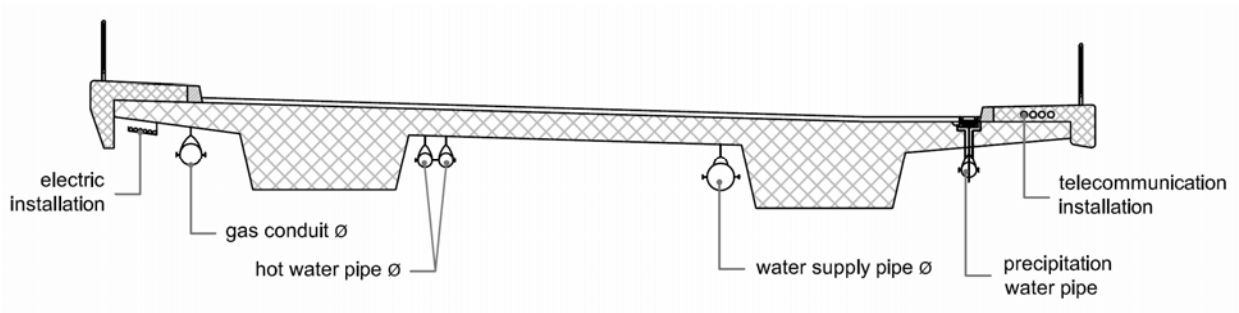

Fig. 6.1

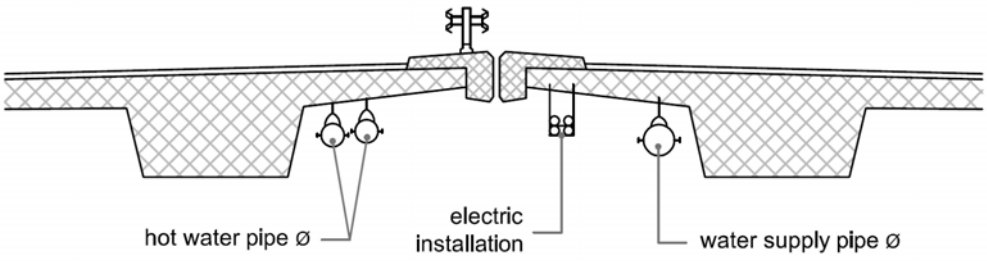

Fig. 6.2

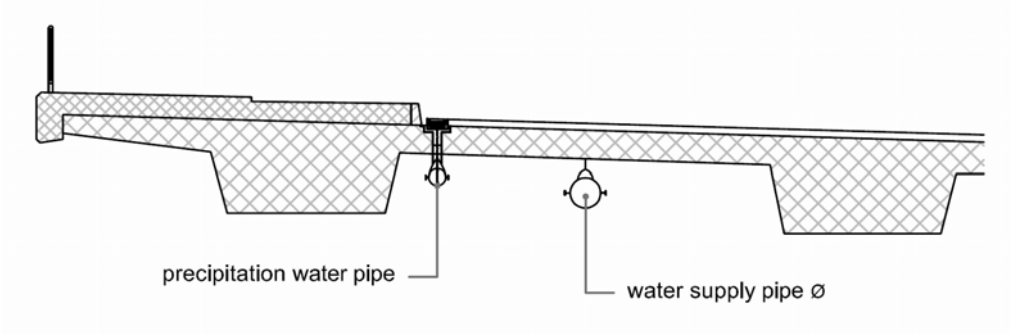

Fig. 6.3

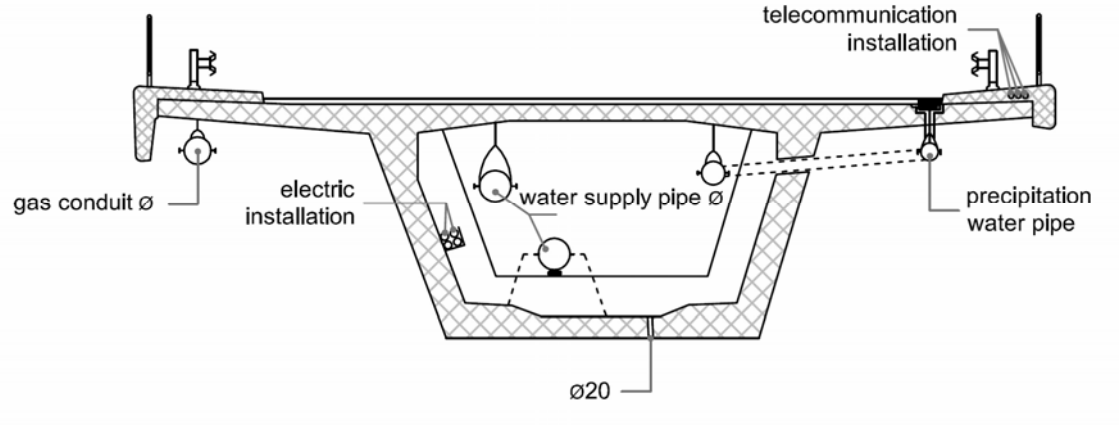

Fig. 6.4

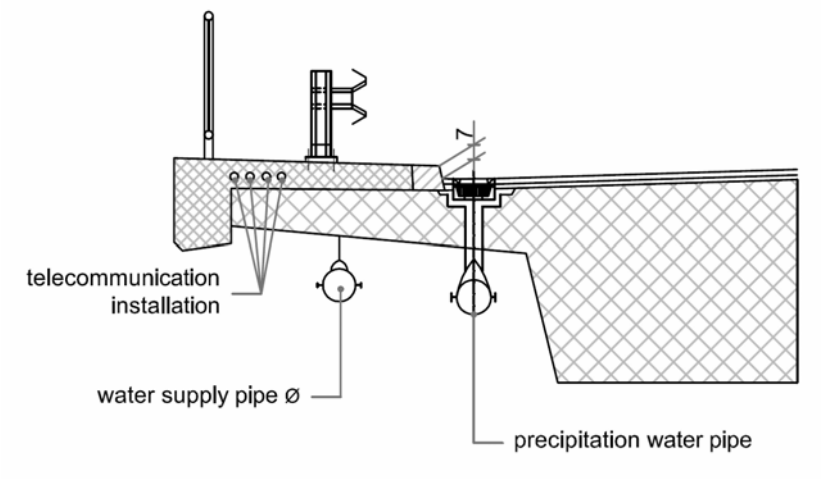

Fig. 6.5

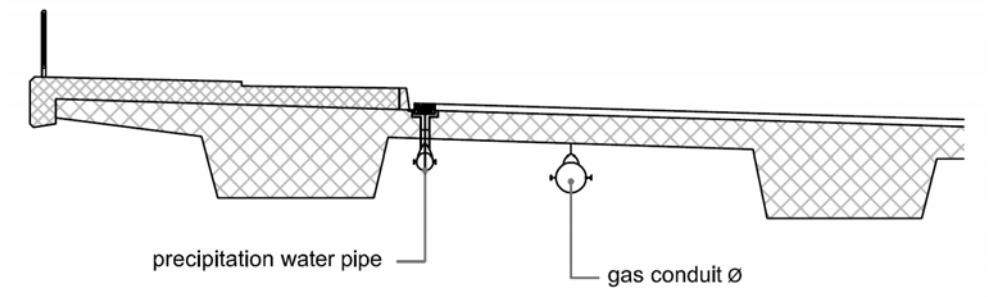

Fig. 6.6

7 INSTALLATIONS ENABLING UNDISTURBED USE OF BRIDGES AND ROADS

7.1 Drainage and piping of bridges

This subject is treated in DG 1.2.5

7.2 Lighting

Lighting is a type of installation that appears particularly on urban bridges and on bridges in the area of illuminated crossroads.

Electric installation that feeds the lighting system is placed in bridge walkways.
Protective ducts must not hinder building-in of steel reinforcement.
Electric installation shall be placed into plastic ducts or steel ducts protected from corrosion.
Inspection shafts are located at each candelabrum on the bridge as well as on both ends of the bridge.

Bridges on which lighting is foreseen shall be earthed.

7.3 Emergency call installations

Emergency call installations can be disposed below superstructure cantilevers, between reinforced concrete T-beams, or in the box interior in case of box superstructures.
These installations may be placed above cantilevers, in walkways or in edge beams only when another method of leading of installations would cause essential constructive and design imperfections, as well as when no shafts for inspection and hauling of installations are required (short bridges).

Protective ducts must not hinder building-in of steel reinforcement.

Telecommunication installations shall be placed into plastic ducts or steel ducts protected from corrosion.

7.4 Traffic and signalling-safety installations

Traffic and signalling-safety installations can be found on all bridges. Electric installation feeding the system of traffic control lights is placed into bridge walkways.

Electric installation feeding the remaining traffic and signalling-safety installations is placed below superstructure cantilevers, between reinforced concrete T-beams, or in the box interior in case of box superstructures.
Protective ducts must not hinder building-in of steel reinforcement.

Traffic and signalling-safety installations shall be placed into plastic ducts or steel ducts protected from corrosion.
Inspection shafts are located before both bridge ends when bridges are shorter than 50 m. In case of longer bridges, the inspection shafts are placed on the bridge itself at intervals of 30-40 m.

7.5 Earthing

When electric installations, lighting or traffic and signalling-safety installations requiring feeding with electric energy are placed on a bridge, all steel elements of the bridge shall be earthed (Fig.7.1).

Metal handrails on bridges where no electric installations are placed shall be earthed as well due to possible strokes of lightning.
When a metal handrail on a bridge is connected with the walkway reinforcement, the designer shall investigate whether the handrail has to be earthed or not. Earthing details shall be worked out by specialized designers.

7.6 Cathodic protection

Cathodic protection is protection of structural steel elements from corrosion. It is particularly applied to steel elements in water or ground. It is often used for pipelines and tanks buried in earth. Recently, cathodic protection is used in reinforced concrete structures as well.

Cathodic protection is based on the following principle: by means of controlled electric current running between an anode and a steel element (cathode) to be protected from corrosion, reduction of potential and therefore prevention of metal dissolving is achieved.

Cathodic protection can also be carried through by fastening of self-sacrificing electrodes on structural steel elements to be protected from corrosion. These electrodes are made of magnesium, zinc or aluminium having a lower electrochemical potential than the structural steel elements. Steel being a more precious metal is preserved on account of the less precious metals, which oxidize and consequently decay instead of steel.

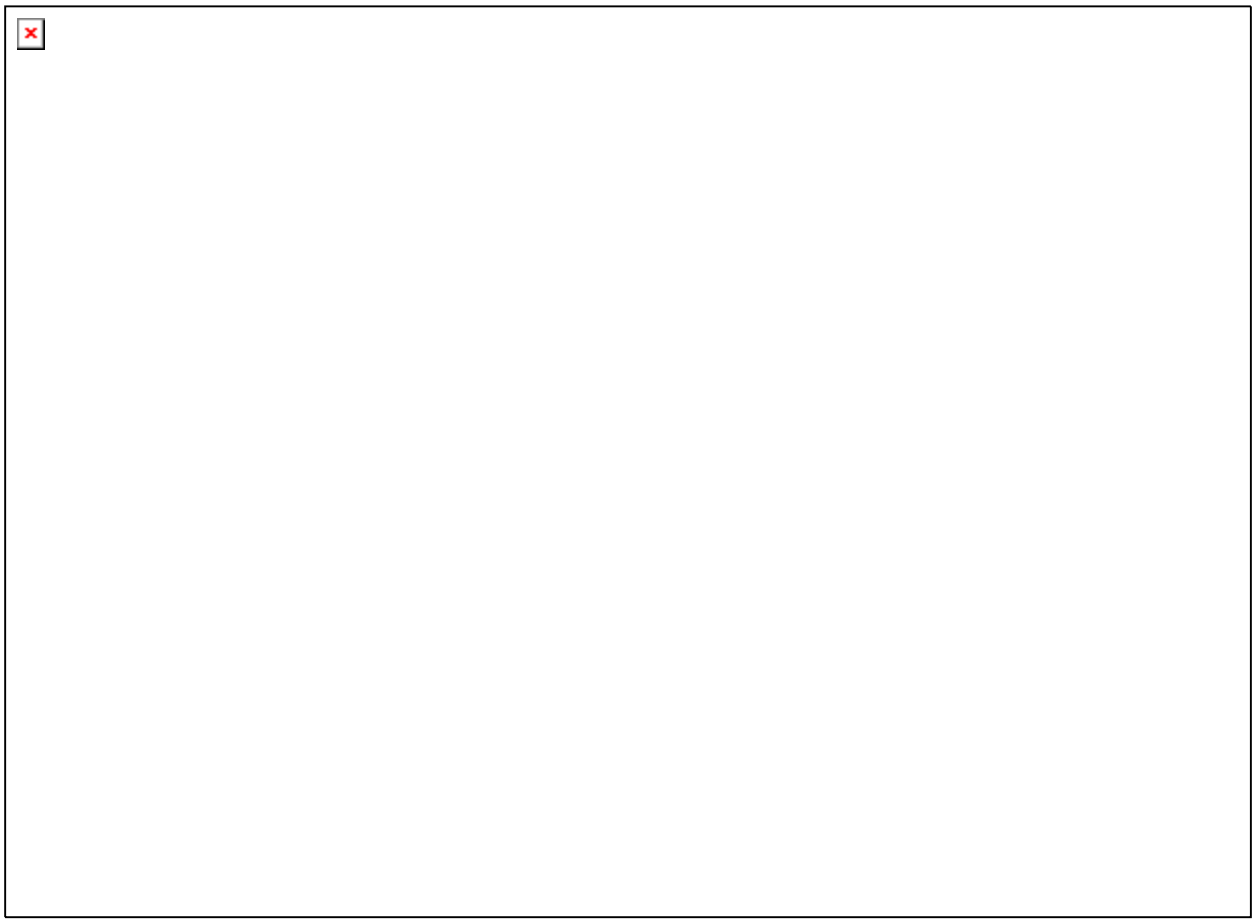

Fig. 7.1: Earthing
- bridge with piers
- bridge without piers

In reinforced concrete structures, pre-stressing steel is protected by means of cathodic protection. The electric current density recommended for the cathodic protection amounts to 5-20 mA/m^2. The hydrogen brittle failure occurs at electric current density values that are much higher than those required for cathodic protection.

The execution of cathodic protection shall be subject of a special design to be worked out by cathodic protection experts in cooperation with the bridge designer.

7.7 Monitoring

Monitoring is convenient especially for large and important bridges situated in severe climatic conditions or in an aggressive environment.

The need for monitoring as well as the execution method for each individual structure shall be defined by the client on the basis of design specifications.

Monitoring means observing of condition of a structure from a remote measuring location. The following can be monitored:

- Load bearing capacity of the structure;
- Corrosion rate;
- Environmental factors.

By monitoring of load bearing capacity of a structure, bridge stability is observed during its construction and service. Static and dynamical parameters of the bridge are measured, which are essential factors to determine its safety and serviceability. A permanent monitoring of the bridge condition is particularly important in case of exceptional loads (heavy transports, strong winds, earthquake). Load cells to monitor the load bearing capacity of the bridge structure are connected with the measuring station where structural responses are recorded by means of computers. In this way, relative deformations, temperature of the structure, and magnitude of accelerations are monitored. Using these data, structural stresses as well as magnitudes and velocities of structural displacements can be calculated.

Monitoring of corrosion means observing the corrosion rate of structural steel elements built-in in concrete, buried in ground or placed in ducts, such as anchors, pre-stressing steel, and steel reinforcement. Cells to monitor the corrosion are installed at critical locations of the bridge structure.

On the basis of data won by means of the monitoring systems and regular inspections of bridges, adequate arrangements can be made in due time in order to prevent structural damages and decay.

7.8 Installations for heating of carriageways

For major bridges situated in severe climatic conditions it is recommendable to study the possibility of placing installations for heating of the bridge carriageway. This can be achieved either by gas or electric current. Maintenance of such bridges is easier since salting of carriageways and removing of snow is not required. Moreover, damages of the bridge structure due to the salt action are avoided.

Constructive solutions of installations for heating of carriageways shall be worked out in a special design. In case that such installations are foreseen, the thickness of the asphalt layer shall be increased.

8 DISTANCES BETWEEN INSTALLATIONS

The clear spacing between installations and structural elements shall amount to minimum 2xD (twice the pipe diameter) to enable maintenance works.

The horizontal distance between telephone installations and electric power installations of voltage up to 1 kV shall amount to at least 0.3 m.

The horizontal distance between telephone installations and electric power installations of voltage above 1 kV shall amount to at least 0.5 m.

When the required spacing cannot be achieved, protective measures being valid for electric power installations shall be taken into consideration.

9 FASTENING OF INSTALLATIONS

In case of necessity, suspending structures and their actions on the bridge shall be verified by appropriate calculations. All suspending devices shall be protected from corrosion.

Suspending structures can be fastened subsequently by screwing them on concrete (figure 9.1). However, it is also possible to build-in suitable profiles during bridge construction.
The distance between fastened installations amounts to approximately 2.0 m. However, it depends on the duct diameter, stiffness, and material.

Steel reinforcement must not be damaged with devices for fixing of installations.
Installations must never be rigidly fastened to the superstructure.

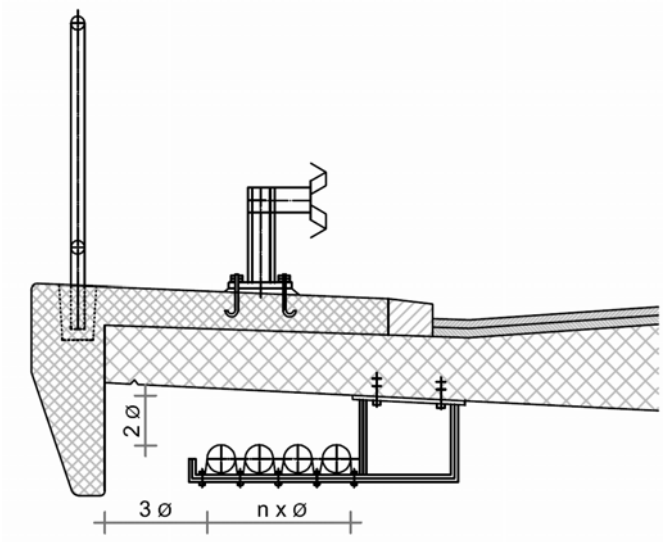

Fig. 9.1: Detail of fastening of installations below cantilever

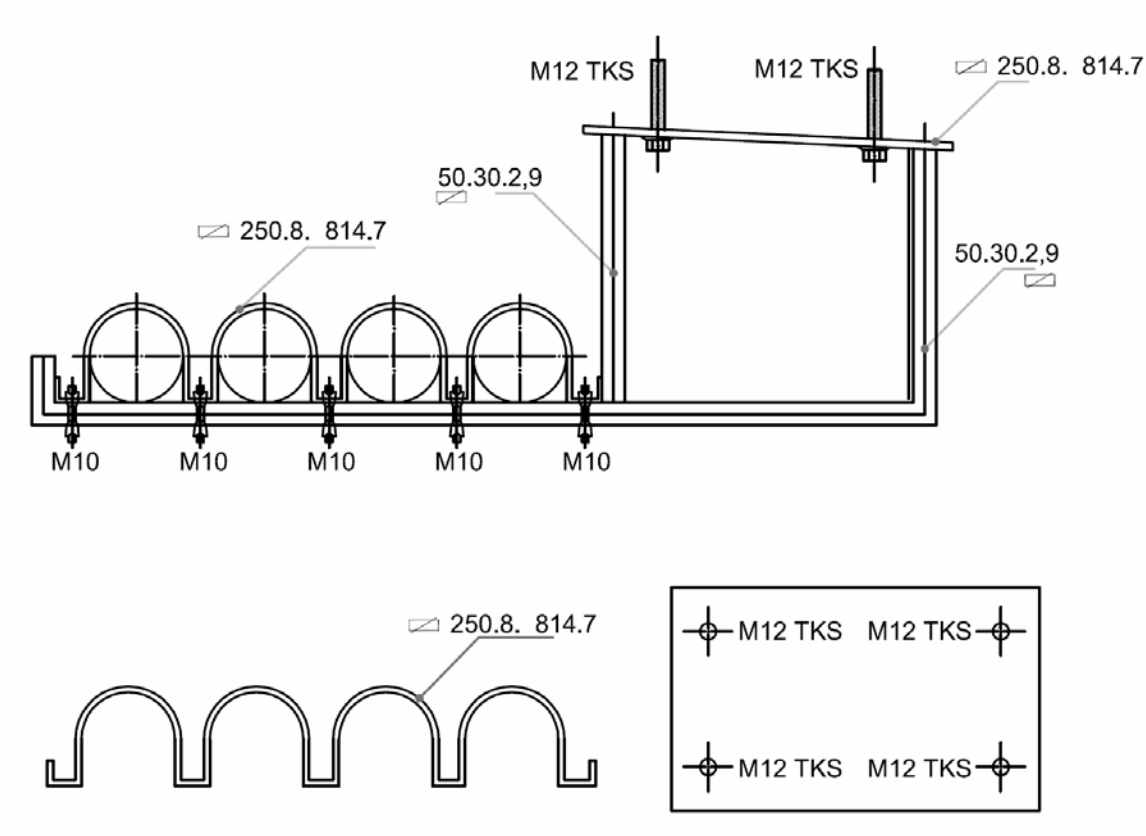

Fig. 9.2: Workshop drawing of suspension for four ducts

In areas where chamber walls are bored through, installations shall be elastically placed down onto the base. Moreover, they must be flexible longitudinally and transversally as well.
The size of openings in the walls shall be sufficient to enable transition of ducts and protection around them.

The function of installations must not be disturbed during lifting of the superstructure. As circumstances require, separable connections shall be foreseen.
At bridge expansion joints, particularly at transition between the superstructure and the abutment, ducts for installations shall be equipped with expansion joints.

10 TRANSITION OF INSTALLATIONS FROM BRIDGES TO ROADS

10.1 Bridges on motorways

In general, bridges on motorways contain only those installations that enable an undisturbed use of the bridge and the road. They are described in paragraph 4.
Bridge drainage and piping is always present.

It can pass over to the road body in different ways:

- It can continue into the road body via a shaft; in case of shorter bridges, no shafts are required;
- It can come down in front of the abutment;
- It can pass through the hollow abutment.

Other installations on motorway bridges such as emergency call installations or traffic and signalling-safety installations pass over to the road body via shafts situated in road shoulders or central reserves.

10.2 Bridges in towns and settlements

Bridges in towns and settlements often enable numerous installations for communal and urban needs to overcome different hindrances. These installations pass over to the road body via inspection chambers located in the abutment area and fixed to the abutments by means of hinges.

11 INSPECTION SHAFTS AND INSPECTION CHAMBERS

The following types of inspection shafts and chambers are considered:

- Inspection shafts on bridge structures serving for inspection of installations in the walkways on bridges of considerable lengths;
- Passable shafts at both bridge ends serving for overcoming of the height difference, for distribution of installations over the bridge in plan, and for compensating of different extensions of the superstructure and the installations.
- Chambers behind abutments in case of urban bridges carrying a great number of installations.

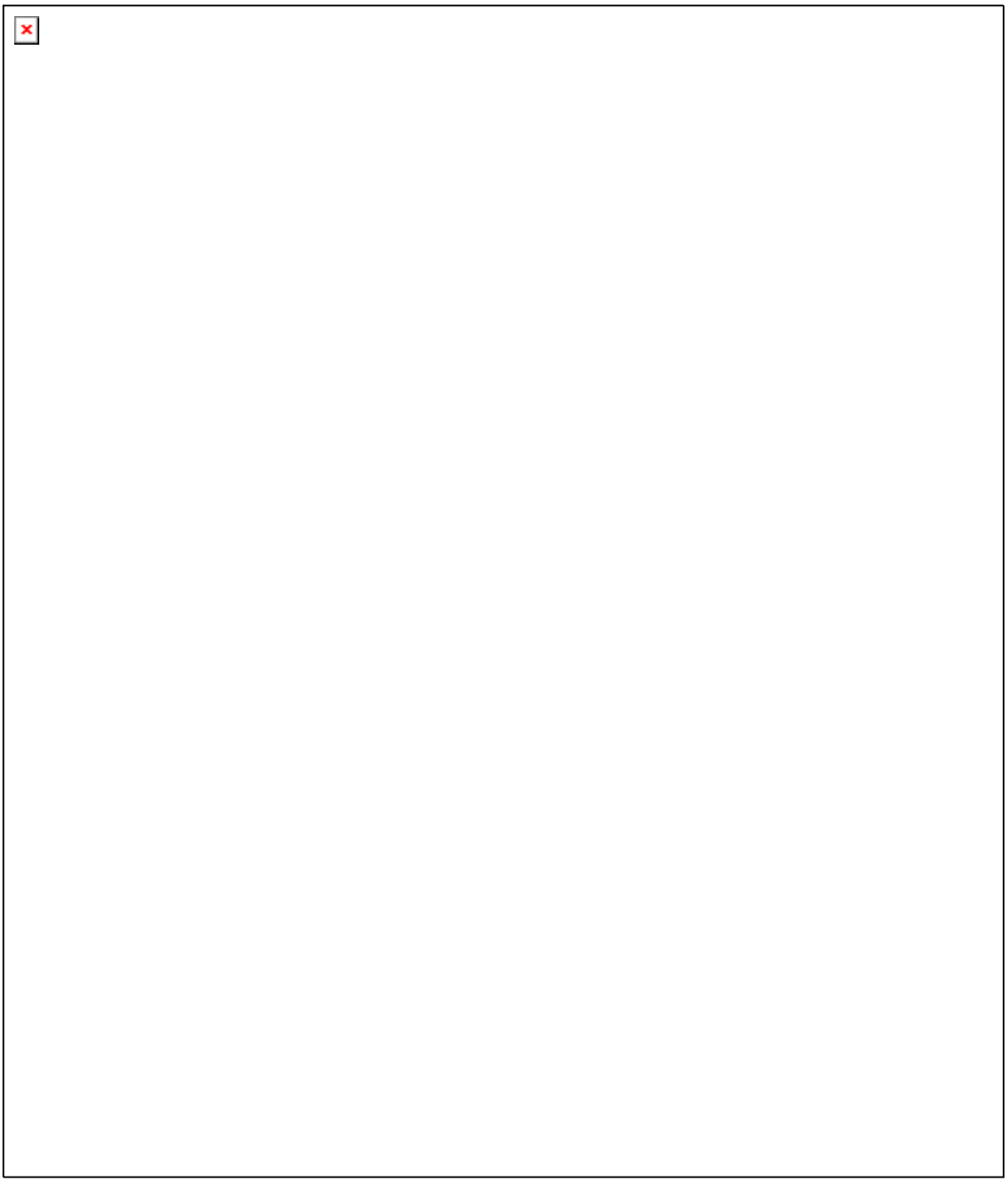

Fig. 11.1: Inspection shaft with metal cover

11.1 Inspection shafts on bridge structures

When installations are present on a bridge, inspection shafts are located in the walkway area. Such shafts shall be foreseen on bridges longer than 50.0 m.

Inspection shafts are always situated in walkways when lighting is present on a bridge. In such cases, they are placed at each candelabrum. The size of inspection shafts depends on the number of ducts passing through.

Inspection shafts are not permitted in the carriageway slab area.
Inspection shafts are shallow in the walkway area. Dewatering of these shafts shall be ensured. They shall be closed with metal covers (figure 11.1).

The maximum allowed diameter of pipes/ducts to be placed in the walkways amounts to ∅ 11.0 cm.

11.2 Passable inspection shafts

Passable inspection shafts are walled-in spaces closed with reinforced concrete covers.

Inspection shafts shall be foreseen at both bridge ends when different installations have to be placed on the bridge. Inspection shafts shall be carried through in those places where direction of installations is changed (e.g. change of position in plan, of height, etc.) or different valves appear.

Dewatering of passable inspection shafts shall be arranged. The shafts are closed with reinforced concrete covers (figure 11.2).
In figure 11.2, standard passable inspection shafts are shown. However, these shafts can be bigger as well.

11.3 Inspection chambers

When a greater number of installations are placed on a bridge, it is more reasonable to foresee an inspection chamber at both bridge ends.

In the inspection chambers, installations are distributed, their height differences are overcome, and their length discrepancies compensated. Eventual new installations can be introduced through those chambers as well.

Dimensions of inspection chambers depend on the number of installations; however, chambers shall not be smaller than 2.0 x 2.0 m.

Opening in the walls of inspection chambers shall be carried through in the area of bearing blocks and shall be watertight. These openings shall allow eventual rotation of bearings without imposing constraints, and ensure that the installations do not come in contact with protective ducts.

Inspection chambers are connected to abutments by means of hinges.

Fig. 11.2: Passable inspection shaft with concrete cover for ducts placed in walkways

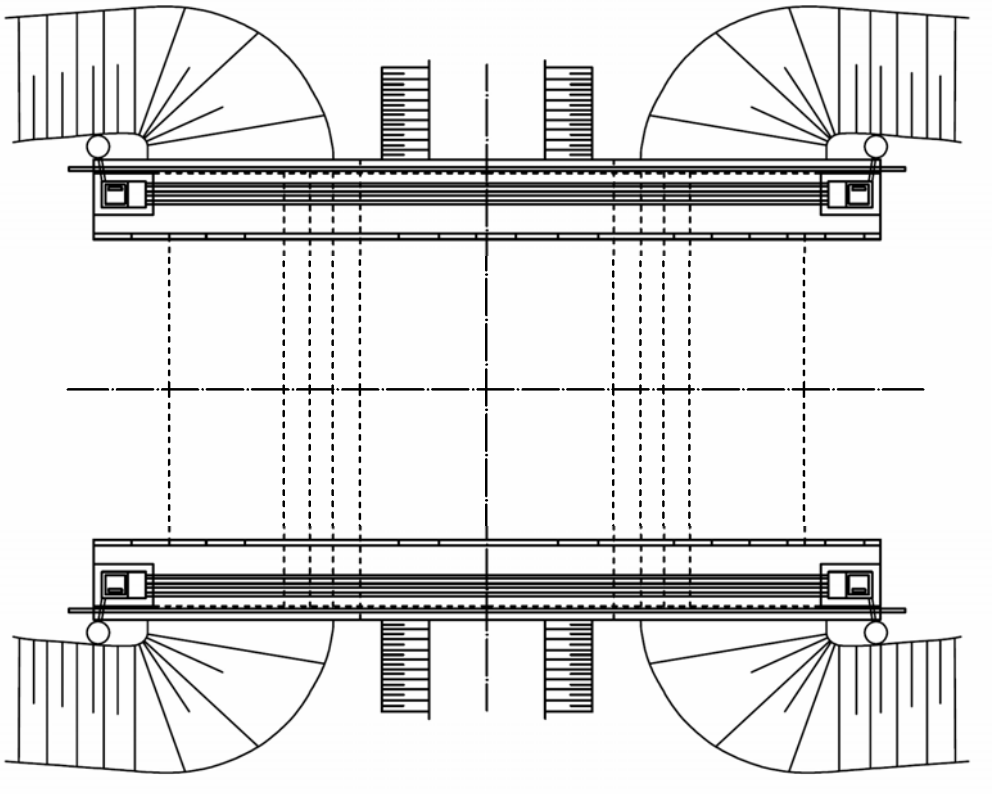

Fig. 11.3: Position of passable shafts in plan

12 MAINTENANCE, INSPECTION AND REPLACEMENT OF INSTALLATIONS IN BRIDGE LOAD BEARING STRUCTURES

Leading of installations on bridges, their position, and method of fastening shall be such that an undisturbed maintenance, inspection and replacement are enabled.

In case of box superstructures, installations are placed in the box interior. The latter shall be passable thus enabling a simple control over the installations.

Installations fixed to bridge cantilevers or located between reinforced concrete T-beams are accessible by means of specially manufactured ladders or, in exceptional cases, from a special inspection vehicle adequately equipped to enable an access to the bridge superstructure lower side.

The valid regulations require preliminary tests to prove a safe operation of certain installations (pressure tests for water supply pipes and waste water pipes). These tests shall be carried through before the bridge is handed over for traffic.

Managers of installations shall work out maintenance designs for individual installations, carry through regular inspections, and simultaneously make good eventual deficiencies and damages of the installations. These activities shall be performed in accordance with relevant standards.

Devices for fastening of installations shall be tested and inspected as well. The devices that are fixed directly to the bridge shall be inspected by the bridge owner, while the devices on the installations themselves by the managers of those installations.

All inspections of the installations shall be announced in due time. Records of executed inspections and tests of installations located on the bridge shall be kept.