GUIDELINES FOR ROAD DESIGN, CONSTRUCTION, MAINTENANCE AND SUPERVISION

Volume I: DESIGNING

Section 2: DESIGNING BRIDGES

DESIGN GUIDELINES (DG 1.2.6)

Part 6: BEARINGS FOR BRIDGES

INTRODUCTION

In case that a rigid connection between the bridge superstructure and the bridge supports (piers, abutments) cannot be carried through, bearings shall be foreseen to enable a transfer of selected forces and moments.

The present DG 1.2.6 deals with an overall topic of designing, installation, and maintenance of bridge bearings. The up-to-date and most frequently applied bearings on bridges are discussed in detail.

C O N T E N T S

1. SUBJECT OF DESIGN GUIDELINES

The intention of the present design guidelines is to define bearing types, to present recommendations for their use for different of methods of bridge supporting, as well as to specify conditions and methods of appointing a bearing, of designing the bridge structure in the bearing area, and of taking over, storing, installation, maintenance, and replacement of most frequently used up-to-date bearings.

This design guideline is particularly applicable to reinforced concrete, pre-stressed reinforced concrete and composite bridges of spans up to 150 m.

2. REFERENCE REGULATIONS

This design guideline DG 1.2.6 includes the following codes:
DIN 4141 German codes for bearings
EN 1337:2000 General Design Rules
EN 1337-1:2002
EN 1337-2:2000 Sliding elements
EN 1337-2:2002
EN 1337-3 Elastomeric bearings
EN 1337-4 Roller bearings
EN 1337-5 Pot bearings
EN 1337-6 Rocker bearings
EN 1337-7:2000 Spherical and cylindrical PTFE bearings
EN 1337-7:2002
EN 1337-8 Guided bearings and restrained bearings
EN 1337-9:1997 Protection
EN 1337-9:2002
EN 1337-10 Inspection and maintenance
EN 1337-11:1997 Transport, storage and installation
EN 1337-11:2002

3. EXPLANATION OF TERMS

Bearing is a structural element enabling a transfer of selected forces from the superstructure to the substructure.

Supporting means a structure supporting system in a broader meaning.

Reinforced elastomeric bearing is a product made of rubber, i.e. polychloroprene with at least 60% of an elastomer, reinforced with steel plates.

Pot bearing is a bearing whose main constituent part is a steel pot filled with an elastomer.

Spherical bearing is a bearing composed of steel spherically shaped concave and convex elements that enable the supporting point to rotate by means of their mutual sliding.

Ball-jointed rocker bearing is a bearing enabling rotations around the supporting point.

Tangential rocker bearing is a bearing enabling rotations around the supporting line.

Hinge bearing is a bearing enabling rotations by means of mechanical elements – hinges.

Bearing for horizontal forces is a bearing enabling transfer of horizontal forces.

Reinforcement hinge is a part of concrete structure designed and reinforced in such a way that it can work as a ball-jointed rocker bearing and a tangential rocker bearing, respectively.

Bearing load capacity is the highest value of permissible loading acting on bearing.

Bearing displacement and rotation capacity is a capability of a bearing to enable relative (superstructure vs. substructure) displacement and rotations.

Bearing block is a part of concrete structure onto which a bearing is placed.

4. CHARACTERISTICS OF BEARINGS

Bearings connect different structural elements and transfer only selected forces or moments. The transfer of other forces is completely or partially excluded by enabling certain relative displacements or rotations.

Bridge bearings must:

- take vertical and horizontal reactions of the superstructure and transfer them to piers and abutments;
- enable vertical deformations of superstructure main girders; in the bearing areas, those deformations appear as rotations being a consequence of the slope of elastic bending lines of girders;

- enable superstructure expansion in bridge axis (for wide bridges also in transversal direction) due to a uniform temperature oscillation over the entire cross section.

By an adequate selection of bearings to transfer certain internal forces and moments, the designing engineer can optimize a bridge structure, because the selection of bearings crucially influences the internal forces and the structural deformability thus affecting the price, durability, and serviceability of the particular bridge.

A bearing enables deformability of both superstructure and substructure as required by different types of loading (temperature, shrinkage, creep, deformations due to pre-stressing), however without any harmful loading of the structure. In this function, secondary (constrained) internal forces arise in the bearings. These forces are a consequence of differential deformations of the superstructure and the substructure. Their magnitude is extremely dependent on the bearing type.

With elastically deformable bearings (elastomeric bearings, steel springs with dampers, etc.) it is possible to affect the structural dynamic response, i.e. to isolate dynamically a part of the structure. This is particularly important for construction and service of structures situated in vicinity of dynamically extremely sensitive buildings, or when a certain structure is designed to be seismically isolated thus ensuring an undamaged structure (in elastic condition) during a seismic event.
In certain structural systems such as continuous superstructures being founded in such a way that differential settlements occur due to lasting settlement of the foundation soil, structural deformations can be kept within acceptable limits by means of hydraulic jacks and inserting or taking away steel plates below bearings.

When a bridge is constructed by incremental launching or whenever heavy and large structural elements have to be moved, the up-to-date sliding bearings can be foreseen to enable the horizontal transport.

5. SYSTEMATIZATION OF BEARINGS

In the points where two structural elements are in contact, six internal forces (F_x, F_y, F_z, M_x, M_y, M_z) and six relative displacements (v_x, v_y, v_z, ϑ_x, ϑ_y, ϑ_z) can occur. These are so-called degrees of freedom of a bearing.

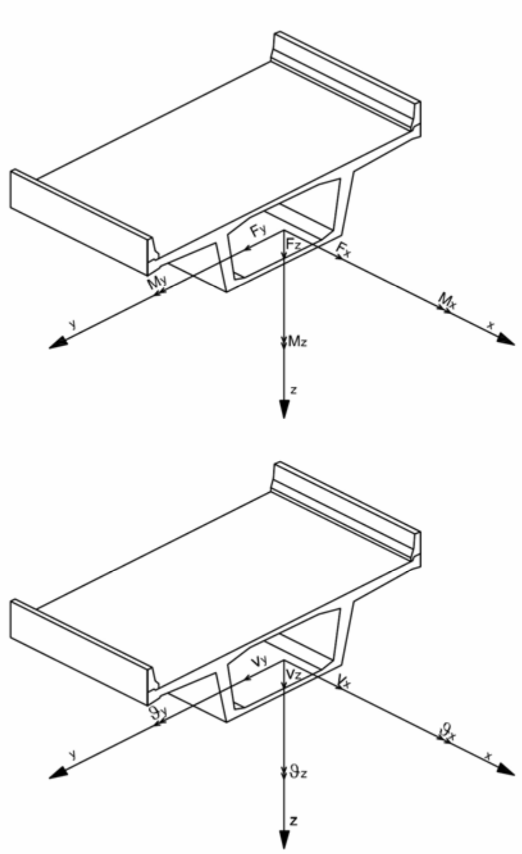


Figure 1: Internal forces and displacements

An individual bearing type enables a transfer of certain forces as well as some displacements. The principle of functioning is the following: the principal internal forces are transferred by a bearing in such a way that the corresponding relative displacements or rotations are prevented, whereas the remaining relative displacements and rotations are made feasible. Hereby, so-called secondary or constrained internal forces arise whose magnitude is limited depending on the bearing type.

Static and kinematical designation of bearings is indicated in the DIN 4141, Part 1 (September 1984), where the bearing types are systematically classified on the basis of the characteristic principal internal forces and degrees of freedom.

Table 1: Bearing designations

No.	symbol	designation	type and function	displacement: general	displacement: x-direction	displacement: y-direction	displacement: z-direction	principal internal forces / relative displacements								bearing types (examples)	No.
1		V2	deformable bearing	in two axis	elastic	elastic	almost none (low compressibility)	v_z	F_z	v_y	F_y	F_z	ϑ_x	ϑ_y	ϑ_z	elastomeric bearing (EB)	1
2		V1	deformable bearing	in one axis	elastic	none	almost none (low compressibility)	v_z	F_z	F_y		F_z	ϑ_x	ϑ_y	ϑ_z	EB with fixing structure for one axis	2
3		V	deformable bearing	none	none	none	almost none (low compressibility)	F_z		F_y		F_z	ϑ_x	ϑ_y	ϑ_z	EB with fixing structure for two axes	3
4		VG1	deformable sliding bearing	in one axis	sliding and elastic	none	almost none (low compressibility)	v_z		F_y		F_z	ϑ_x	ϑ_y	ϑ_z	EB with sliding part in one axis and fixing structure for the other axis	4
5		VG2	deformable sliding bearing	in two axis	sliding and elastic	sliding and elastic	almost none (low compressibility)	v_z		v_y		F_z	ϑ_x	ϑ_y	ϑ_z	EB with sliding part in two axes	5
6		VGE2	deformable sliding bearing	in two axis	sliding and elastic	elastic	almost none (low compressibility)	v_z		v_y	F_y	F_z	ϑ_x	ϑ_y	ϑ_z	EB with sliding part in one axis	6
7		P	ball-jointed rocker bearing	none	none	none	none	F_x		F_y		F_z	ϑ_x	ϑ_y	ϑ_z	pot bearing, EB with fixing structure for two axes, spherical bearing, steel ball-jointed rocker bearing	7
8		P1	ball-jointed rocker bearing	in one axis	sliding or rolling	none	none	v_x		F_y		F_z	ϑ_x	ϑ_y	ϑ_z	bearings as in 7, free in one axis	8
9		P2	ball-jointed rocker bearing	in two axis	sliding or rolling	sliding or rolling	none	v_x		v_y		F_z	ϑ_x	ϑ_y	ϑ_z	bearings as in 7, free in two axes	9
10		L	tangential rocker bearing	none	none	none	none	F_z		F_y		F_z	M_x	ϑ_y	ϑ_z	concrete hinge bearing, steel tangential rocker bearing	10
11		L1	tangential rocker bearing	in one axis	sliding or rolling	none	none	v_z		F_y		F_z	M_x	ϑ_y	ϑ_z	tangential rocker bearing free in longitudinal direction	11
12		L1q	tangential rocker bearing	in one axis	none	sliding or rolling	none	F_z		v_y		F_z	M_x	ϑ_y	ϑ_z	tangential rocker bearing free in transverse direction	12
13		L2	tangential rocker bearing	in two axis	sliding or rolling	sliding or rolling	none	v_x		v_y		F_z	M_x	ϑ_y	ϑ_z	tangential rocker bearing free in two axes	13
14		H1	bearing for horizontal forces	in one axis	sliding	none	sliding	v_x		F_y		v_z	ϑ_x	ϑ_y	ϑ_z	guided bearing in one axis – takes no vertical forces and moments	14
15		H	bearing for horizontal forces	none	none	none	sliding	F_x		F_y		v_z	ϑ_x	ϑ_y	ϑ_z	fixed bearing - takes no vertical forces and moments	15

It should by taken into consideration that a secondary internal force (constrained internal force) acts in the direction of each degree of freedom. For bearings intended to take predominantly vertical loads it is reasonable to appoint the z-axis in the vertical load direction thus the bearings with tensile forces in the z-direction represent a special case, whereas the loads F_x and F_y as well as the moment M_x have mainly an alternating sign. All the bearing types according to the DIN 4141 classification have the ϑ_z degree of freedom. For all the bearing types it is assumed that they cannot take the moment M_z. Since several bearings are sensitive to rotations ϑ_z, it shall always be verified whether an appointed bearing corresponds to the selected supporting system.

6. SUPPORTING

Supporting influences the bridge durability, functioning and economy. All efforts should be directed to such a bridge design where the superstructure and the substructure are rigidly connected. However, bearings cannot be avoided for more complex bridges. For this purpose, the supporting shall be conceived to correspond to the static system and to pay regard to the characteristics of the foreseen bearings.
An up-to-date supporting is ensured by:
- bearings enabling rotations in all directions,
- bridge scheme enabling the structure also transverse deformations at minimum secondary forces, e.g. in such a way that in one supporting axis only one bearing fixed in transversal direction is applied, whereas the other bearings are free in all directions.

Fundamental conceptions of selecting the supporting with respect to the bridge scheme in plan are described in the DG 1.2.1
On the supports (i.e. piers and abutments) where major settlements are expected or reliable soil mechanical data is not available, such bearings shall be foreseen, which can stand additional displacements or settlements without significant secondary forces, or bearings that can be accommodated to the long-term settlements (e.g. by inserting or taking away of steel plates).

A fixed concrete hinge bearing (reinforcement hinge) is particularly appropriate to connect the superstructure and the substructure where no major displacements are expected (shorter bridges or central parts of longer bridges), and where the pier stiffness could lead to excessive moments in the piers. The reinforcement hinge is usually carried through on the top of a pier; however, it can also be situated underneath or even on both ends of a pier.

Reinforcement hinges are not recommendable in cases where significant settlements of the pier foundations are expected. Even pot bearings are only conditionally applicable in such cases.
To ensure a correct supporting, the following conditions shall be fulfilled:
- an adequately conceived supporting;
- an accurate determination of foreseen maximum moments, forces, displacements, and rotations;
- a correct selection of bearings;
- a regular installation of bearings.

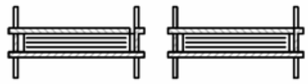
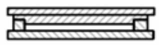
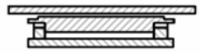
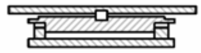
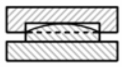
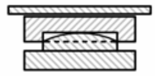
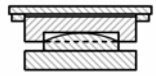
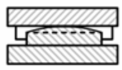
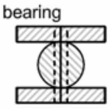
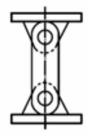
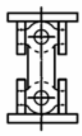
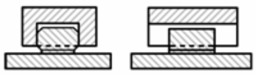
A bridge structure will function in accordance with the designer's idea when all conditions mentioned above are entirely implemented. Clearly, when a bearing is not properly installed, the supporting is not and cannot be appropriate. Therefore, it shall be ensured that the construction site receives an exact plan of the bearing installation including all required information on the bearings, adjustments, and directions and magnitudes of foreseen displacements. Moreover, an adequate supervision is obligatory to ensure a correct installation of bearings.

7. UP-TO-DATE BRIDGE BEARINGS

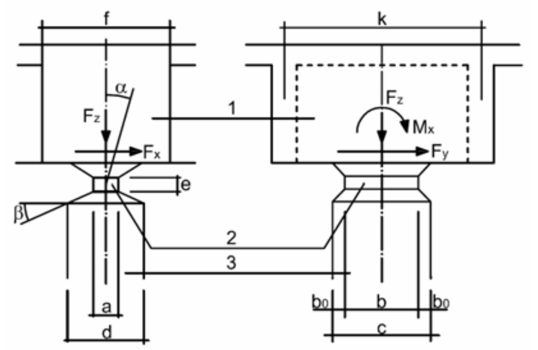
Up-to-date bridge bearings can be classified in the basic groups indicated in table 2.

Theoretically, forces can be transferred via contact points, lines or surfaces. In the first two cases, steel elements permitting high Hertz's stresses are required to transfer the forces, whereas in the third case, elastomers can be used.
Rotation of a bearing is made possible by rolling of a plate on a sphere (in all directions) or a cylinder (in one direction), by sliding between spherically shaped convex or concave steel elements of a bearing, or by the deformation of an elastomeric body.
Displacements of a bearing are enabled by the elastic deformation of an elastomeric body (small displacements) or by the interacting sliding of two bearing elements. In the second case, the contact surfaces are PTFE and stainless steel as a rule.
Beside the bearings shown in table 2, fixed concrete hinge bearing (reinforcement hinges) are frequently used. This bearing type is described in detail in item 7.1.

Table 2: Basic groups of bearings

Bearings	Standard type	Combinations	
Elastomeric bearings	Reinforced elastomeric bearing  Anchored elastomeric bearing 	Elastomeric bearing with restrained displacements 	
Pot bearings	Pot bearing 	Sliding pot bearing 	Sliding pot bearing in one axis 
Spherical bearings	Free spherical bearing 	Fixed spherical bearing 	Free bearing in one axis 
Ball-jointed bearings	Ball-jointed fixed bearing 	Sliding bearing 	Sliding bearing in one axis 
Tangential bearings	Tangential bearing 	Roller bearing 	
Hinge bearings			Cardan joint 
Bearings for horizontal forces		Guided bearing 	

7.1 Fixed concrete hinge bearing (reinforcement hinge)



Structure: 1 Cross girder
2 Narrowing area
3 Distributing area (support)

Materials:

Concrete grade MB 40, galvanized deformed steel reinforcement RA 400/500-2

Hinge dimensions:

$$A_{G,\max} = a \cdot b = \frac{F_{z,D}}{2\alpha_{dej}\sqrt{\beta_{w28}}}$$

$$A_{G,\min} = \frac{F_{z,\max}}{0.85\beta_{w28}\left[1+\lambda\left(1-2.35\eta\frac{\alpha_{dej}}{\sqrt{\beta_{w28}}}\right)\right]}$$

$$\eta = \frac{F_{z,\max}}{F_{z,D}},$$

$$\lambda = 1.2 - 4\frac{a}{d} \le 0.8,$$

$$\alpha_{dej} = \frac{\alpha_0}{2} + \alpha_1$$

α_0 rotation due to pre-stressing, shrinkage and creep
α_1 rotation due to temperature, traffic load, etc.
$F_{z,max}$ maximum normal force
$F_{z,D}$ normal force at dead load
A_G cross section of reinforcement hinge
β_{w28} cube compressive strength after 28 days

Additional conditions:

$a \le 0.3d$, $a \le 0.4b$,
$b_0 \ge 0.7a$, however ≤ 4 cm
b ... optional

Construction depth:

$e \le 0.2a$, however ≤ 4 cm
$tg\beta \approx 1/8$

Range of vertical load bearing capacity:

$F_{z,D} \le F_z \le F_{z,max}$

Load at failure:

$$F_{z,Br} = \sqrt[3]{\frac{d}{a}}\,0.75\beta_{w28}ab + \sigma_{02}A_s$$

A_s cross section of reinforcement in the hinge

Range of horizontal load bearing capacity:

$F_h \le 1/8\ F_z$ no special measures required
$F_h \le 1/4\ F_z$ to be reinforced with straight rebars according to structural principles
$F_h > 1/4\ F_z$ should be avoided whenever possible (this ratio can be improved by pre-stressing of the hinge)

Range of taking transverse moments:

$M_x \le 1/6\ b\ F_z$ no special measures required
$M_x > 1/6\ b\ F_z$ special stress verification and special structural measures required

Angle of rotation:

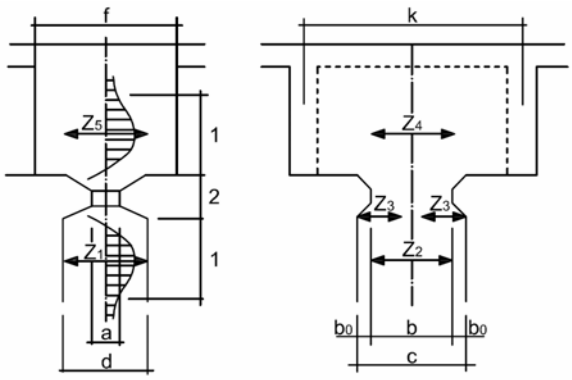
$$\alpha_{dop} = \frac{F_z}{2A_G\sqrt{\beta_{w28}}}, \qquad F_{z,D} \le F_z \le F_{z,\max}$$

Retroacting moment:

$$M_{y,R} = \frac{F_z a}{2}\left(1-\frac{2}{9}\sqrt{\frac{F_z}{\alpha A_G\sqrt{\beta_{w28}}}}\right)$$

When hinges are not cracked or contain centrically built-in rebars, $M_{y,R}$ can become significantly greater!

Reinforcing of the hinge:



1 ... anchoring ~ 30 ϕ
2 ... galvanized rebars

Splitting forces:

$Z_1 = 0.3\ F_{z,max}$
$Z_2 = 0.3\ (1-b/c)\ F_{z,max}$
$Z_3 = 0.03\ a/b\ F_{z,max}$
$Z_4 = 0.3\ (1-b/k)\ F_{z,max}$

Changeability: not changeable!

Sphere of application:

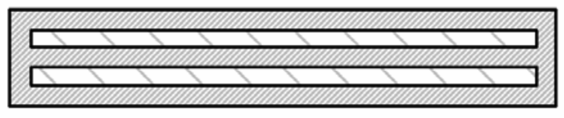
For all bridges allowing a use of tangential bearings, however only in such cases when no subsequent height accommodation (e.g. due to settlements) is required.

7.2 Reinforced elastomeric bearings

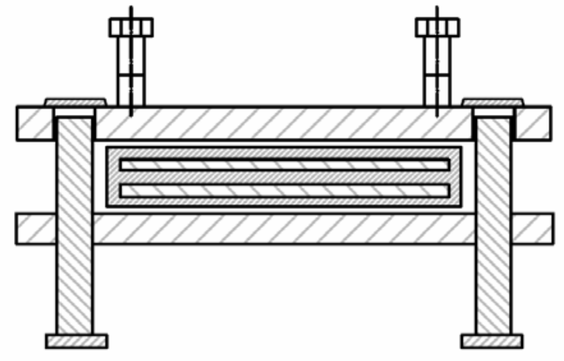
7.2.1 Bearing types

7.2.1.1 Bearings without sliding function:

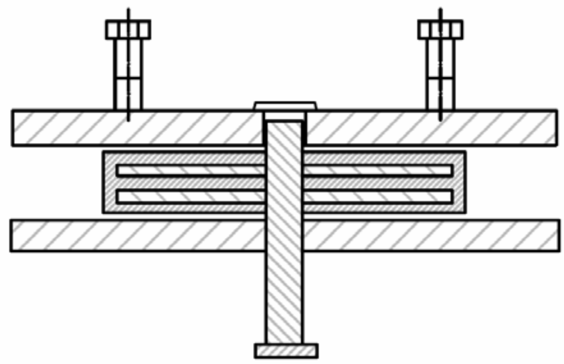
- elastically free in all directions,



- elastically free in one direction,

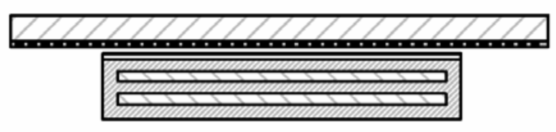


- fixed bearing.

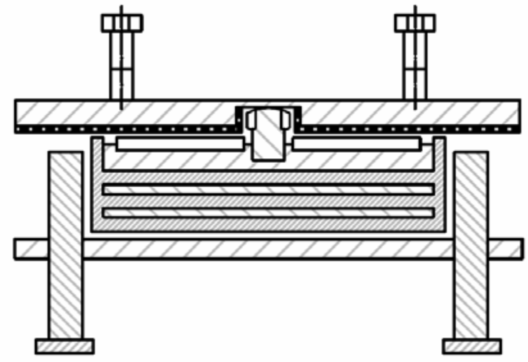


7.2.1.2 Bearings with sliding function

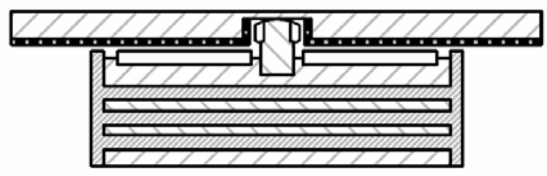
- elastic in all directions and sliding free bearing (VG2),



- transversally fixed, longitudinally elastic and sliding free bearing (VG1),



- transversally elastic free, longitudinally elastic and sliding free bearing (VGE2).



7.2.2 Composition of bearings

Up-to-date reinforced elastomeric bearings are made of:

- an external elastomeric layer serving as corrosion protection of steel plates;
- internal elastomeric layers enabling the function of a bearing;
- steel vulcanized-in steel plates preventing transverse extensions and enabling significant loading of these bearings.

The bearings with a sliding function contain sliding plates with specially executed sliding surfaces (stainless steel surface in contact with PTFE).

7.2.3 Bearing characteristics

An elastomeric bearing can also take horizontal forces that, however, must not act permanently. During the transfer of these horizontal forces, displacements occur being necessary for creation of the retroacting force. Since this force is transferred by friction, a minimum pressure set up by the vertical load shall be ensured.

The retroacting horizontal force:

$$H = A \cdot G \cdot \frac{v}{h}, \qquad \frac{v}{h} = \tan\gamma$$

v horizontal displacement at force H,
h total depth (thickness) of elastomeric layers,
G shear module of the elastomer
A area of the bearing in plan

Dimensions in plan:

- rectangular bearings: from 100x100 mm to 900x900 mm,
- circular bearings: from ϕ 200 to ϕ 900 mm.

Construction depth: from 14 to 332 mm.

Load bearing capacity (vertical): from 100 to 12,150 kN

Angle of rotation: from 1 %0 to 36 %0 .

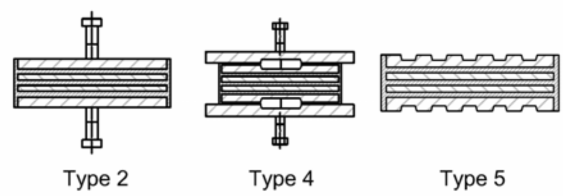
Permissible pressures on bearings:

Bearing dimensions in plan mm	Permissible pressure MPa
up to 150x200, up to ϕ 200	10.0
up to 250x400, up to ϕ 350	12.5
greater	15.0

Minimum required pressures on bearings:

Bearing dimensions in plan mm	Minimum pressure MPa
up to 350x400, up to ϕ 350	3.0
greater	5.0

In case of insufficient minimum pressures, i.e. when the friction is unsatisfactory, one of the anchored elastomeric bearing types shall be foreseen.



Types of anchored elastomeric bearings

The individual blocks of elastomeric bearings must not be combined to obtain greater load bearing or displacement capacity.

Special characteristics:

- small construction depths,
- simple installation,
- uniform distribution of pressure on concrete,
- compression occurs due to vertical load (vertical yielding),
- secondary retroacting forces are activated due to horizontal displacements,
- temperature range of application: from –30°C to +70°C,
- should not be combined with steel or pot bearings on the same pier or abutment.

Changeability:

Due to short service life of elastomers, the changeability of reinforced elastomeric bearings shall be ensured.

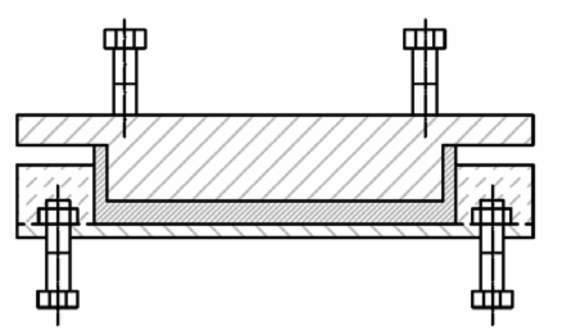
Sphere of application:

Without sliding function these bearings can be used for all bridges of shorter or middle spans, particularly for broad and inclined bridges, as well as for the central parts of longer bridges. With the sliding function, bearings of this type can be applied where the elastically free bearings should be combined with the sliding ones.

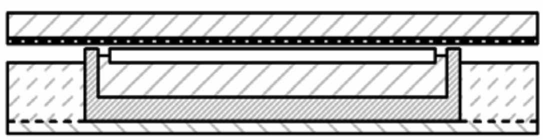
7.3 Pot bearings

7.3.1 Types of pot bearings

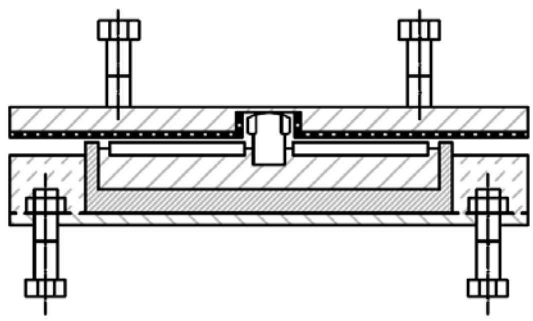
- fixed bearing (P);



- sliding free in all directions (P2);



- transversally fixed, longitudinally sliding free bearing (P1).



7.3.2 Composition of bearings

- steel pot,
- elastomeric cushion,
- pot cover.

7.3.3 Characteristics of bearings

Dimensions in plan: from ϕ 290 mm to ϕ 1,910 mm
Construction depth: from 65 mm to 210 mm

Load bearing capacity:
- vertical: 1,000 kN – 50,000 kN
- horizontal: 100 kN – 2,500 kN

Angle of rotation: up to 10 %0 in all directions.

8. APPOINTMENT OF BEARINGS

8.1 Parameters for selection of bearings

In addition to the bearing type appointed at the selection of supporting, the following structural and general parameters shall be taken into consideration for the selection of the most appropriate bearings.

8.1.1 Static parameters:

- vertical forces acting on a bearing – maximum, permanent, minimum;
- horizontal forces in both longitudinal and transverse direction;
- required displacements and the number of possible displacements;
- required rotations and the number of possible rotations;
- displacements and rotations;
- safety against position change;
- magnitudes of secondary (constrained) forces that the structure can stand.

8.1.2 Structural parameters:

- material for bridge superstructure;
- superstructure construction method;
- spatial conditions at abutments, piers, and superstructure;
- accommodation of pier and abutment settlements.

8.1.3 General parameters:

- installation of bearings;
- maintenance of bearings;
- replacement of bearings;
- economy;
- appearance.

8.2 Bearing load capacity

The bearing load capacity in both vertical and longitudinal direction (longitudinally and transversally) is determined on the basis of the maximum forces acting on the particular bearing.

8.3 Bearing rotation and displacement capacity

The required rotation and displacement capacity of a certain bearing is calculated from the actions mentioned below. For the permanent loads, i.e. dead load and pre-stressing, plastic deformations (creep) shall be taken into consideration.

Actions to determine the required rotation capacity:

- deformations of the superstructure due to the dead load, pre-stressing, traffic load, settlements, temperature differences, and differential shrinkage;
- rotations of the pier head due to its displacement.

Actions to determine the required displacement capacity in both longitudinal and transverse direction:

- deformations of the superstructure due to the pre-stressing, uniform temperature oscillation (over the entire cross section), uniform shrinkage, displacements of abutments, and rotation of the girder;
- displacement of the pier head at “elastic supporting” due to braking forces, wind forces, and friction forces.

8.4 Bearing dimensioning

Up-to-date bearings are products of the up-to-date industry. They should be designed by an adequate expert, and their dimensioning shall be carried through in accordance with the data submitted by the structural designer. Those data are indicated in 8.5. Only reinforcement hinges shall be designed and dimensioned by the bridge designer himself. The procedure of dimensioning the reinforcement hinges is indicated in 7.1.

The bridge designer shall provide for the transfer of forces from the bearing into both substructure and superstructure (cross girder). He is particularly obliged to foresee an adequate reinforcement to take the splitting forces.

8.5 Bearing design data

Bridge contractors shall select the bearings and their suppliers on the basis of the following data (figure 2, table 3):

- scheme of bearing arrangement in plan: position, designation, orientation (which is of extreme importance for curved and wide bridges), as well as magnitude and direction of pre-adjustment shall be specified for each bearing;
- vertical forces: permanent, maximum and minimum forces;
- horizontal forces: maximum forces in both longitudinal and transverse direction;
- displacements: maximum displacements in longitudinal or both longitudinal and transversal direction (for all bearings free in one or all directions);
- rotations: maximum rotations in both longitudinal and transverse direction;
- pre-adjustments (for sliding bearings) at presumed temperature upon installation, and required modifications of adjustment at temperature upon installation that differs from the presumed one.

8.6 Bearing design

The selected bearing supplier is obliged to work out a bearing design comprising the following items:

- arrangement drawing of bearings with exact designations appointing each individual bearing;
- drawings of individual bearings;
- instructions for installation, maintenance, and replacement of bearings.

The bearing design shall be submitted to the bridge designer for approval.

8.7 Data to be obtained by the contractor prior to bearing installation

Before the bearing installation, the contractor is obliged to obtain the following data and documents ensuring that the bearing has been selected in accordance with the design documents, as well as that its conformity has been proven by an appropriate certificate and that the bearing is in a perfect condition:

- approval of the bearing design by the bridge designer;
- certificate of suitability for all the bearings to be installed on a bridge;
- record of the bearing taking over.

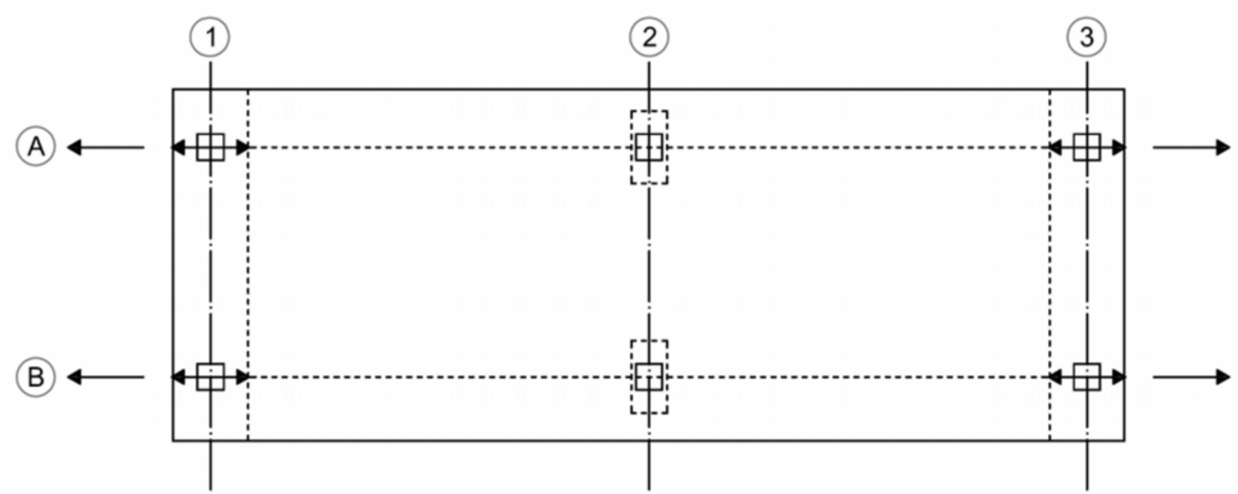


Figure 2: Scheme of bearing arrangement in plan

Table 3: Bearing data

Pozicija	Bearing type	Vertical force F_z (kN)			Horizontal forces (kN)		Maximum rotation (%o)		Total displacement (cm)	Pre-adjustments (cm)	
		permanent	max.	min.	longitudinal F_x	transverse F_y	longitudinal u_y	transverse u_x	v_x	installation at T=+10ºC	modification for ΔT=±10ºC
A1	VGE2	700	1000	500	-	50	5	3	15.0	7.1	+/- 0.9
B1	VGE2	700	1000	500	-	50	5	3	15.0	7.1	+/- 0.9
A2	V2	1400	2100	1200	45	65	3	3	6.0	-	-
B2	V2	1400	2100	1200	45	65	3	3	6.0	-	-
A3	VGE2	700	1000	500	-	50	5	3	15.0	7.1	+/- 0.9
B3	VGE2	700	1000	500	-	50	5	3	15.0	7.1	+/- 0.9

9. CONDITIONS FOR STRUCTURAL DESIGN IN THE BEARING AND HINGE AREAS

For a proper functioning of bearings certain structural conditions shall be fulfilled by the load bearing bridge structure (figures 3, 4, 5) ensuring a correct position of bearings, the foreseen displacements and rotations, as well as inspection, maintenance, and replacement of the bearings.

There are two types of structural conditions: general conditions and special conditions. The general conditions shall be fulfilled irrespective of the bearing type and will be handled in this chapter. The special conditions depend on the bearing type and are presented within descriptions of the individual bearings.

Generally, a bearing is placed onto the bearing block located either below (figure 3) or both above and below. The bearing block enables a correct placing of the bearing as well as a perfect transfer of forces. The concrete grade shall be at least MB 30 or equal to that of the bridge structure. Bearing blocks can be executed either with or without construction joints. The required dimensions are indicated in figure 3. Special attention shall be paid to an adequate reinforcing of the bearing block in the area where reaction forces enter the block: reinforcement to cover splitting, and reinforcement in the cross girder to cover bending. Bearings should not be in a direct contact with the bearing block. It is recommended to place the bearings on a steel bearing plate connected with the bearing block via levelling mortar. These bearing plates shall be installed absolutely horizontally, and the levelling mortar shall entirely fill the void between the bearing block and the bearing plate. All required dimensions are indicated in figure 3.

In case of monolithic concrete structures where concrete is cast directly onto bearings, as well as of bridge rehabilitations where the available space is insufficient, the use of steel bearing plates in combination with elastomeric bearings is not necessary.

Since the bearing service life is shorter than the bridge one, conditions for bearing replacement shall be ensured. The bridge designer shall foresee sufficient place for placing hydraulic jacks as well as a place for an easy replacement of a bearing. The required dimensions are indicated in figure 4. Common and simple hydraulic jacks shall be foreseen. Locations where jacks will be placed must enable a transfer of forces acting onto the bearing. Therefore, sufficient dimensions of such locations shall be ensured by the bridge design.

The structure has to be of such a shape that the bearings are protected from atmospheric and other harmful actions as much as possible. Special attention shall be paid to the prevention of wetting the bearing, especially with salt water.

If feasible, the bearings shall be protected from birds by means of wire meshes or Plexiglas to prevent dirt and to enable inspection of bearings.

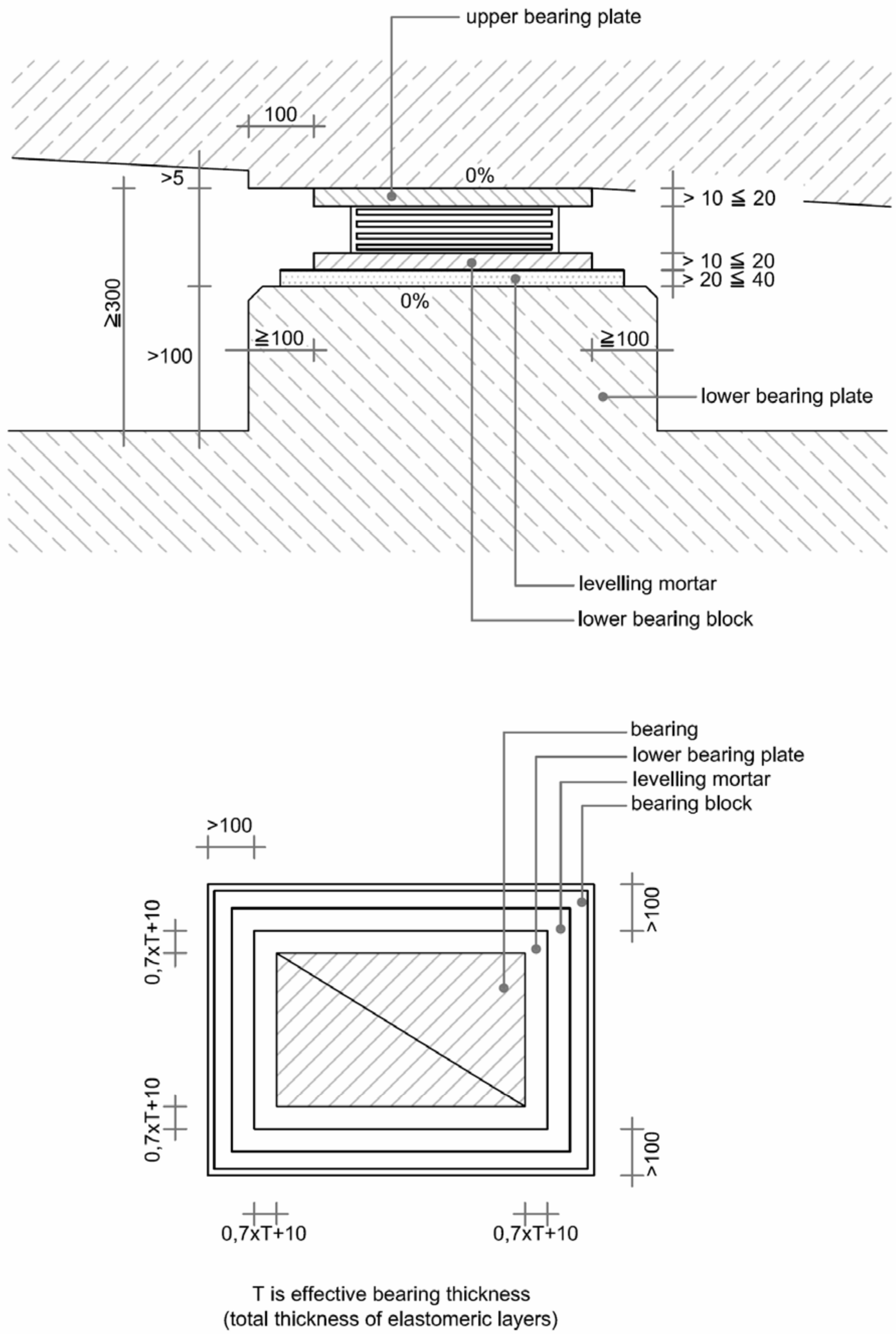
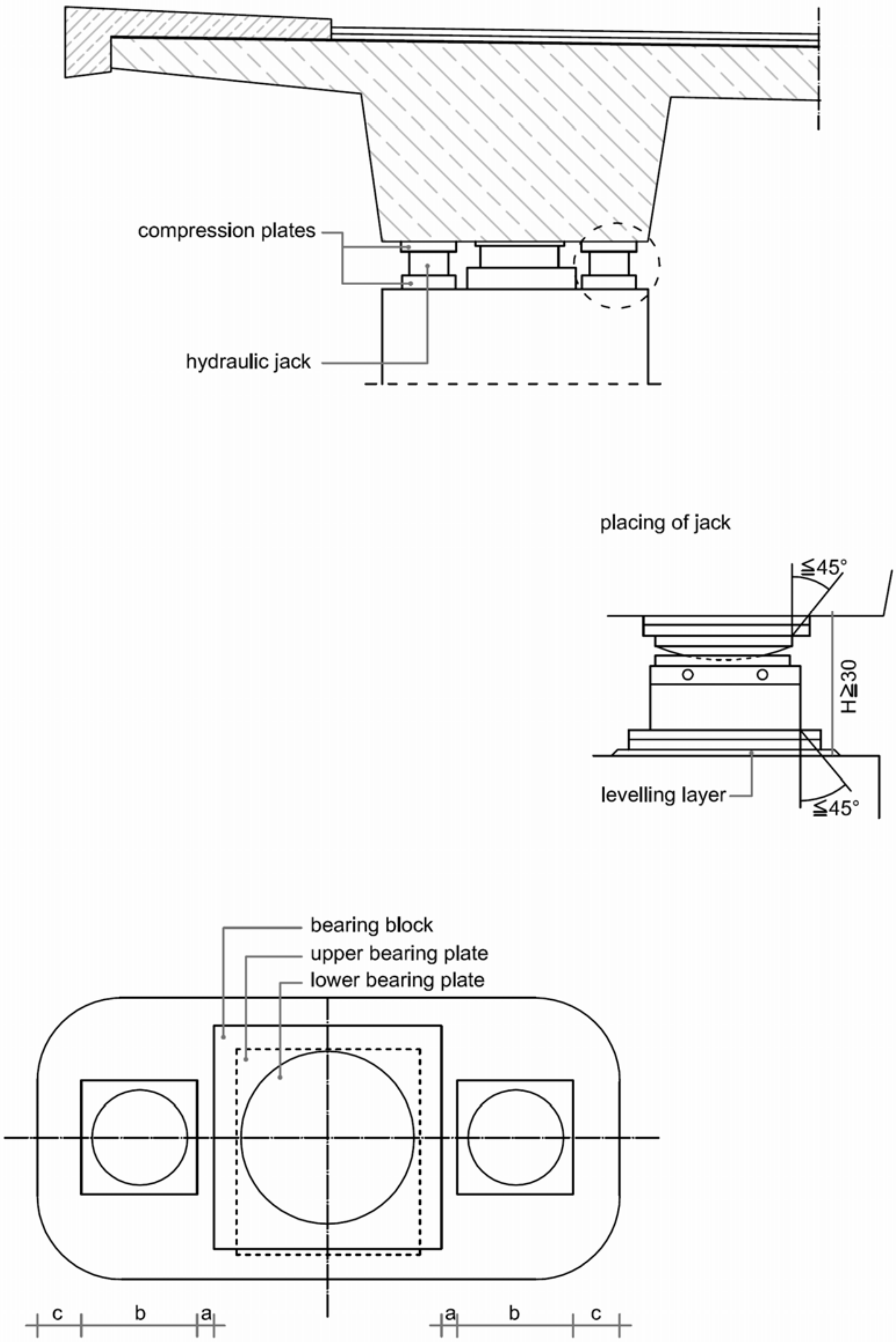


Figure 3: Structural design in bearing area and required dimensions of bearing block and bearing plates (in mm)

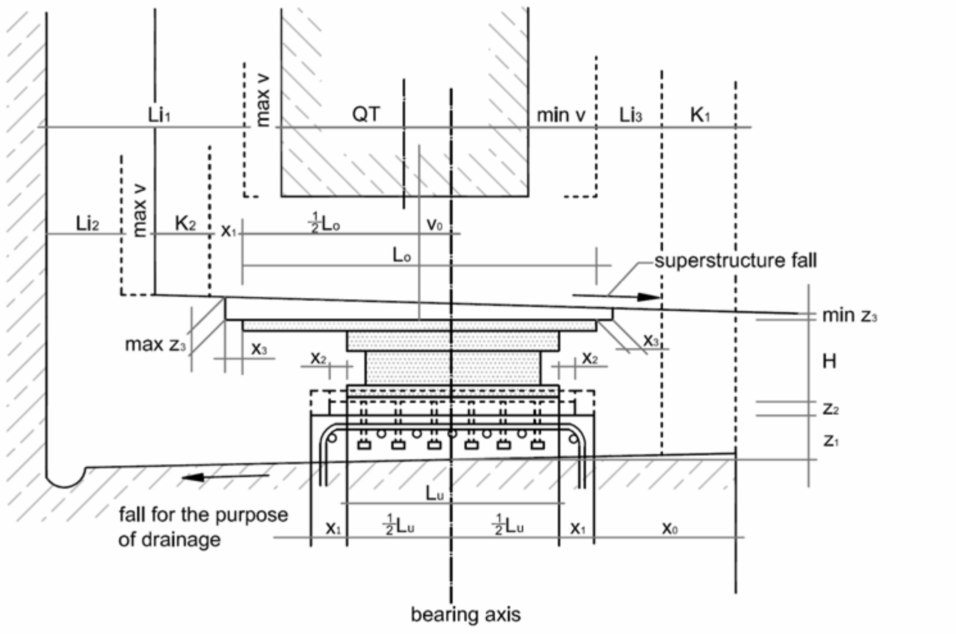


a - distance between bearing block or bearing plate and compression plate ≧ 5cm

b - compression plate width

c - distance between compression plate and concrete structure edge (above or below) ≧ 12cm

Figure 4: Conditions for placing hydraulic jacks upon bearing replacement



L_o	- length of upper bearing plate
L_u	- length of lower bearing plate
H	- height of bearing upon installation
QT	- width of cross girder
K_1	- thickness of abutment wall in front of cross girder
K_2	- non-bearing structural concrete (i.e. protection of stressing heads)
v_0	- pre-adjustment of bearing
min v	- in addition to v_0 expected minimum
max v	- and maximum displacement
Li_1 to Li_3	- required dimensions to ensure feasibility of inspection and maintenance as well as safety with regard to functioning
$x_{0,1,2,3}$	- required horizontal distances of bearing block, bearing plates, and levelling mortar
$z_{1,2,3}$	- required heights of bearing blocks and levelling mortar

Figure 5: Schematic presentation of interdependence of structure and bearings

10. TAKING OVER, STORAGE, INSTALLATION, MAINTENANCE, AND REPLACEMENT OF BEARINGS

An adequate supporting can be achieved by installing undamaged and properly fabricated bearings, by their maintenance and, if required, by their replacement as well.

In case that no special instructions by the bearing supplier, contractor, supervising engineer or carrier are available, the provisions of this design standard shall be taken into consideration.

Transportation, provisional storage, and installation of bearings shall be carried through only by specially appointed and qualified labour.

The bearing installation drawing, all certificates, licences, eventual special instructions, and the record of bearing shall be permanently available on the construction site.

10.1 Taking over of bearings

Upon taking over of the bearings, the following shall be checked:
- eventual visible damages, in particular of corrosion protection;
- cleanliness of bearings;
- conformity with the bearing design;
- bearing designations;
- bearing dimensions;
- magnitude and direction of pre-adjustment;
- possibility of subsequent modification of pre-adjustment.

10.2 Storage of bearings

After being transported to the construction site, the bearings shall be carefully unloaded and kept in an appointed store protected from atmospheric actions and impacts by the construction site in order to remain clean and undamaged.

10.3 Installation of bearings

Special attention shall be paid to the bearing installation to prevent damage to the bearings and structure as well as to ensure a proper functioning.

Bearings shall be installed in accordance with exact instructions being a constituent part of the bearing design, or with special instructions.

Prior to application of filling mortar below the bearing, the following shall be checked:

- identity of the installed bearing with the designed one;
- height levels;
- bearing orientation (X-axis or Y-axis);
- horizontality of the bearing;
- magnitude and direction of the pre-adjustment;
- consideration of supplier’s eventual special instructions for bearing installation;
- filling mortar (composition, properties, method of its filling below the bearing).

When a bearing has to be exceptionally inclined towards the horizontal, this shall be extra denoted in the design (in the bearing installation drawing as well) and checked prior to concreting.

The bearings shall be secured by means of special accessories in such a way that they remain in their designed position during installation. Wooden wedges must not be used.

Before establishing the bearing function, installation accessories shall be removed.

Welding and flame cutting can be carried through only if permitted by the bearing supplier in order to prevent excessive temperature loading.

The inclination of the bearing plane can deviate from the designed inclination by no more than 5 %0, unless specified otherwise.

After installation the bearings shall be rechecked to establish whether any changes in the bearing position or any damage to the bearings have occurred.

A record of bearing shall be kept prior to its installation and afterwards. The record shall be signed by the bridge contractor, by the representative of the bearing supplier, and by the supervising engineer. An example of the record form is presented in 10.6.

10.4 Maintenance of bearings

For an adequate bearing maintenance, regular inspections, periodical examinations, and maintenance in its strictest meaning, i.e. cleaning, renewal of corrosion protection, lubricating and eliminating of structural defects affecting the bearing (e.g. wetting) shall be carried through.

The bearing maintenance shall be worked out in the bearing design and approved by the institution that has issued a certificate on the bearing suitability.

10.5 Replacement of bearings

The bearing design shall comprehend certain conditions to ensure a correct bearing function. When these conditions fail to be fulfilled due to damages or wearing out which is established upon regular inspection and verified by a control investigation, the bearing shall be replaced.

When a bearing is replaced due to wearing out, the entire structure shall be taken into consideration, since an unfavourable redistribution of reaction forces can occur because of the stiffness change.

The worn out bearings shall be replaced simultaneously on the entire bridge. In case that this might not be necessary, all the bearings on the same transverse bearing axis shall be replaced.

When a bridge is reconstructed, eventual modifications of the static system shall be considered, and the bearings shall be redesigned, if necessary.

10.6 Record of bearing

A record of taking over, installation, and condition at the beginning of the service of a bearing shall be kept. An example of the record form is presented on the next page.

Table 4: Record of bearing

Road:	Section:	km:	
Bridge (designation, location):			
Method of installation:			
No. of bearing drawing			
No. of supplier / order:			
No. of certificate:	Validity of certificate:		
Client:	Receiver:	Supervisor:	
No.	**Stage**	**Description**	**Entry**
1	Prior to installation	Location of installation (No. of support / position)	
2		Bearing type	
3		Vertical force F_z in kN	
4		Horizontal force F_x/F_y in kN	
5		Calculated displacement (from fixed point) in mm $\pm e_x/\pm e_y$	
6		Previous adjustment in mm $\pm e_x/\pm e_y$	
7		No. of drawing / No. of sheet	
8		Delivery date	
9		Properly unloaded, supported and covered	
10		Designation on bearing	
11		Displacement gauge on bearing (yes/no)	
12		Cleanliness and corrosion protection	
13		Fixing structure	
14		Cleanliness of contact surface	
15		Thickness of joint (mortar) in mm above/below	
16		Mortar composition / quality test	
17		Method of mortar application	
18	Installation	Date / hour	
19		Temperature of structure in °C	
20		Direction and magnitude of previous adjustment in mm/m	
21		Deviation from horizontal in mm/m longitudinally/transversally	
22		Cleanliness and corrosion protection	
23	Service	Date / hour	
24		Temperature of structure in °C	
25		Blocking loosened / removed	
26		Cleanliness and corrosion protection	
27		Deviation from horizontal in mm/m longitudinally/transversally	
28		Zero-measurement displacement/slip/opening in mm	
29		Notes / warnings	

Contractor:............... Bearing manufacturer: ....Supervisor:..........................

Place: ....Date: ....