Deutsches Institut für Bautechnik DIBt

Approval body for construction products
and types of construction

Bautechnisches Prüfamt

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# European Technical Assessment ETA-09/0226 of 3 June 2021

English translation prepared by DIBt - Original version in German language

**General Part**

| | |
|---|---|
| Technical Assessment Body issuing the European Technical Assessment: | Deutsches Institut für Bautechnik |
| Trade name of the construction product | FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearings |
| Product family to which the construction product belongs | Spherical and Cylindrical bearings with special sliding material made of UHMWPE (ultra high molecular weight polyethylene) SMF |
| Manufacturer | FIP MEC S.r.l.<br>Via Scapacchiò, n. 41<br>35030 SELVAZZANO DENTRO (PD)<br>ITALIEN |
| Manufacturing plant | FIP MEC S.r.l.<br>Via Scapacchiò, n. 41<br>35030 SELVAZZANO DENTRO (PD)<br>ITALIEN |
| This European Technical Assessment contains | 27 pages including 11 annexes (20 pages) which form an integral part of this assessment |
| This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of | EAD 050004-00-0301 |
| This version replaces | ETA-09/0226 issued on 8 May 2018 |

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## Specific Part

### 1 Technical description of the product

The FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearing is a spherical or cylindrical bearing, which permits rotation and displacement movements by a plane and a curved sliding surface between bearing plates of steel (see Figures Annex A). The subject of the ETA is the complete bearing, including, if relevant, the necessary guides or restraints. As an alternative to the Figures in Annex A, the bearing may also be used upside down, i. e. with flat sliding surfaces lying below (meaningful, for example in the case of steel bridges).

The FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearing is designed according to EN 1337-7 and may be combined with sliding elements according to EN 1337-2 as shown in EN 1337-1. A special sliding material made of UHMWPE (Ultra high molecular weight polyethylene) with melting temperature of at least 50 °C higher than the maximum operating temperature described below, suitable for low temperatures outside the scope of EN 1337-2 with improved wear resistance and load-bearing capacity, is used for the sliding surfaces of the bearing.

Sliding surfaces with a diameter of the circumscribing circle of special sliding material sheets made of UHMWPE less than 75 mm or greater than 1500 mm, or with effective bearing temperatures less than -50 °C or greater than +48 °C, are not subject of this ETA.

Bearings with an included angle $2\,\theta > 60°$ for spherical and $2\,\theta > 75°$ respectively for cylindrical bearings are not subject of this ETA.

The combination of materials used are given in Table 1 of this ETA.

Table 1: Combination of materials for permanent applications as sliding surfaces for spherical and cylindrical bearings with special sliding material made of UHMWPE SMF

| Plane surface | | Curved surface | | Guides | |
|---|---|---|---|---|---|
| dimpled SMF | austenitic steel | dimpled SMF | austenitic steel | undimpled SMF 1) | austenitic steel |
| | | | hard chromium | CM1 | |
| | | | | CM2 | |

1) Instead of the undimpled SMF sheets, only where self-alignment between the mating parts of the bearing is possible, composite materials CM1 and CM2 in accordance with either clause 5.3.1 or 5.3.2 of EN 1337-2 can be used.

The mating surfaces are made of either austenitic steel in accordance with clause 5.4 of EN 1337-2, or hard chromium plating in accordance with clause 5.5 of EN 1337-2.

The ferrous materials used for backing plates of the sliding surfaces are in accordance with EN 1337-2, clause 5.6.

Attachment of sliding materials in accordance with clause 7.2 of EN 1337-2.

Instead of PTFE according to EN 1337-2, referred to in EN 1337-7, the specified SMF is used as sliding material.

## 2 Specification of the intended use(s) in accordance with the applicable EAD

The FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearings are intended to be used for the support of bridges or building works in accordance with the scope of EN 1337-1.

The FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearing with special sliding material made of UHMWPE SMF is suitable for all types of structures but especially for non-rigid structures with relatively large and frequent displacements caused by working loads, next for superstructures that in-duce fast sliding displacements in bearings, e.g. in bridges for the high speed railways, as well as for regions with continuously low temperatures.

The FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearing is mainly used in concrete, steel and composite structures.

The verification and assessment methods on which this European Technical Assessment is based lead to an intended working life for the intended use of 50 years, depending on the accumulated total sliding path assessed according to Table 2 of this ETA, and provided that FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearings are subject to appropriate use and maintenance.

The working life of the bearing is reduced to 10 years, if in bearing’s guides the composite materials according to EN 1337-2 are used instead of the special sliding material made of UHMWPE SMF.

It is the responsibility of the manufacturer to ensure that each delivery contains proper information for the use of FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearings including general guidance on the basis of the European Technical Assessment.

The indications given on the working life cannot be interpreted as a guarantee given by the producer or the Technical Assessment Body, but are to be regarded only as a means for choosing the appropriate product in relation to the expected, economically reasonable working life of the works.

## 3 Performance of the product and references to the methods used for its assessment

### 3.1 Performance of the FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearing with special sliding material made of UHMWPE SMF

Table 2:

| Basic requirements for construction works | Essential characteristics | Method of assessment | Performance |
|---|---|---|---|
| **BWR 1** | Load bearing capacity | EAD, Clause 2.2.1 and Annex E of this ETA | 180 [MPa] ($f_k(T_0$=+35°C))<br>135 [MPa] ($f_k(T_0$=+48°C))<br><br>60 [MPa] ($f_k(T_0$=+35°C))<br>45 [MPa] ($f_k(T_0$=+48°C))<br>for permanent loads, effects of temperature, shrinkage and creep of guides |
| | Rotation capability | EAD, Clause 2.2.2 and Annex G of this ETA | +/- 0.003 rad up to limits defined by EAD, clause 2.2.2 (Minimum and maximum rotation angle) |
| | Displacement capacity | EAD, Clause 2.2.3 | 50.000 m |
| | Durability aspects | EAD, Clause 2.2.4 | Durable Protective coating systems of ferrous materials: Durability class "high" in accordance with<br>EN ISO 12944-5, 5.5<br>Corrosivity category C5-I (I = Industrial) for inland locations C5-M (M = Marine) for seaside locations.<br>C4 for locations protected from environmental factors (interior) |
| | Load bearing capacity (of the sliding element) | EAD, Clause 2.2.5 and Annexes E, F of this ETA | Material combinations according to Table 1 of this ETA<br><br>Compressive strength:<br>180 [MPa] ($f_k(T_0$=+35°C))<br>135 [MPa] ($f_k(T_0$=+48°C))<br><br>Curved sliding surfaces:<br>180 [MPa] ($f_k(T_0$=+35°C))<br>135 [MPa] ($f_k(T_0$=+48°C)) |
| | Coefficient of friction (of the sliding element) | EAD, Clause 2.2.6 | Sliding elements combined with dimpled and lubricated special sliding material-sheets: According Annex B of this ETA<br><br>Guides:<br>According Annex B of this ETA |
| | Durability aspects (of the sliding element) | EAD, Clause 2.2.7 | Durable |

## 3.2 Performance of the sliding material material made of UHMWPE SMF

Table 3:

| Basic requirements for construction works | Essential characteristics | Method of assessment | Performance |
|---|---|---|---|
| **BWR 1** | Material properties according to Table C.1, Annex C of this of this ETA | EAD, Clause 2.2.8 | Laid down in the technical documentation deposited with the Technical Assessment Body |
| | Compressive strength of special sliding material | EAD, Clause 2.2.9 | 180 [MPa] ($f_k(T_0$=+35°C))<br>135 [MPa] ($f_k(T_0$=+48°C))<br>Main sliding Surface (permanent and variable loads) |
| | | | 180 [MPa] ($f_k(T_0$=+35°C))<br>135 [MPa] ($f_k(T_0$=+48°C))<br>Guides (variable loads) |
| | | | 60 [MPa] ($f_k(T_0$=+35°C))<br>45 [MPa] ($f_k(T_0$=+48°C))<br>Guides (permanent loads Effects of temperature, shrinkage and creep) |
| | Load-deformation behaviour of special sliding material: Stiffness coefficient, modulus of elasticity | EAD, Clause 2.2.10 | Stiffness coefficient<br>$k$ = ($\sigma$ [MPa] – 45)/78.5<br>Modulus of elasticity<br>$E_{tp}$ = 900 [MPa] |
| | Load-deformation behaviour of special sliding material: Protrusion after loading [mm] | EAD, Clause 2.2.10 | Laid down in the technical documentation deposited with the Technical Assessment Body |
| | Load-deformation behaviour of special sliding material: Ratio tensile strength/yield strength | | |
| | Load-deformation behaviour of special sliding material: Ratio elongation at break/yield deformation | | |
| | Resistance to high temperatures | EAD, Clause 2.2.11 | Resistant |
| | Resistance of the special sliding material against chemical and environmental influences | EAD, Clause 2.2.12 | Resistant |

## 4 Assessment and verification of constancy of performance (hereinafter AVCP) system applied, with reference to its legal base

According to the decision 95/467/EC of the European Commission, amended by the Commission Decision 2001/596/EC and 2002/592/EC, the system(s) of assessment and verification of constancy of performance (see Annex V of Regulation (EU) No 305/2011) is 1.

## 5 Technical details necessary for the implementation of the AVCP system, as provided for in the applicable EAD

Technical details necessary for the implementation of the AVCP system are laid down in in the control plan deposited by the Technical Assessment Body Deutsches Institut für Bautechnik.

The notified production control certification body shall visit the factory twice a year for surveillance of the AVCP.

Issued in Berlin on 3 June 2021 by Deutsches Institut für Bautechnik

LBD Dipl.-Ing. Andreas Kummerow
Head of Department

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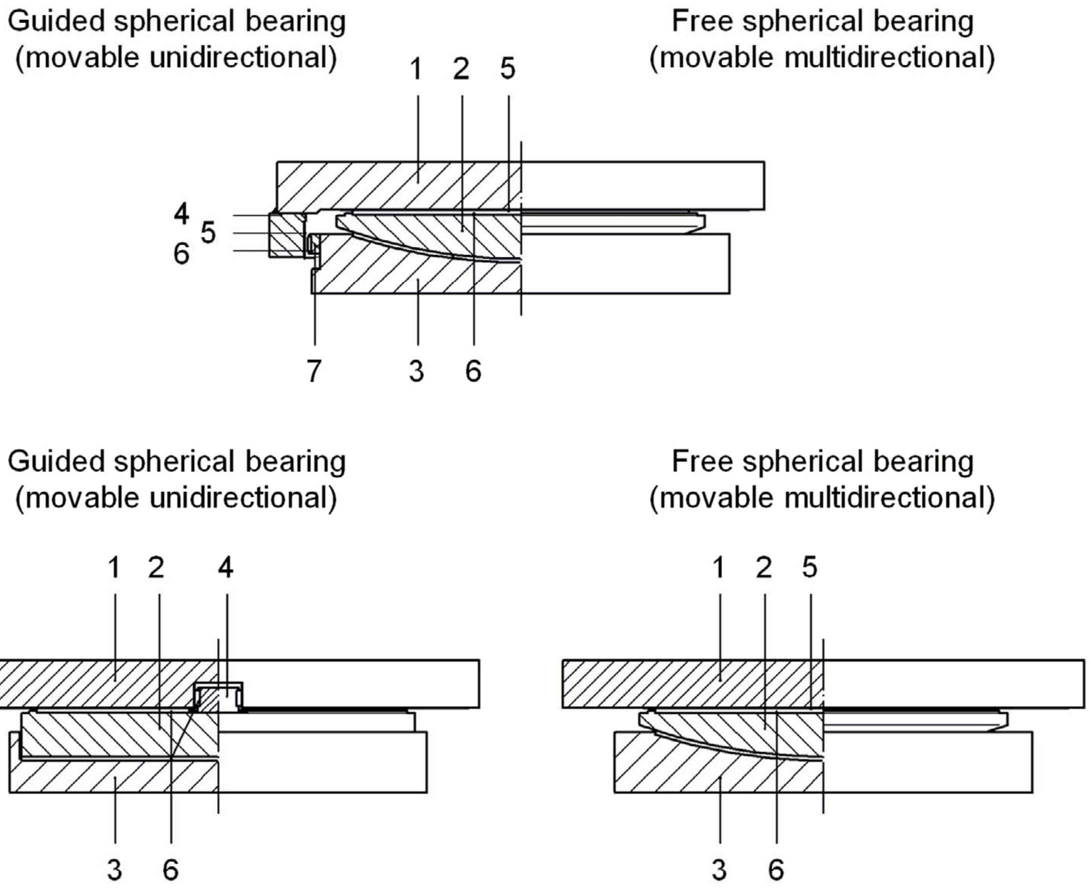
Schult

# Annex A

## Description of the product and its intended use

### FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearing



| | |
|---|---|
| 1 | Sliding plate |
| 2 | Rotational element (convex plate) |
| 3 | Bottom plate (concave backing plate) |
| 4 | Guiding key |
| 5 | Austenitic steel sheet |
| 6 | SMF - sheet or strip |
| 7 | Rocker strip |

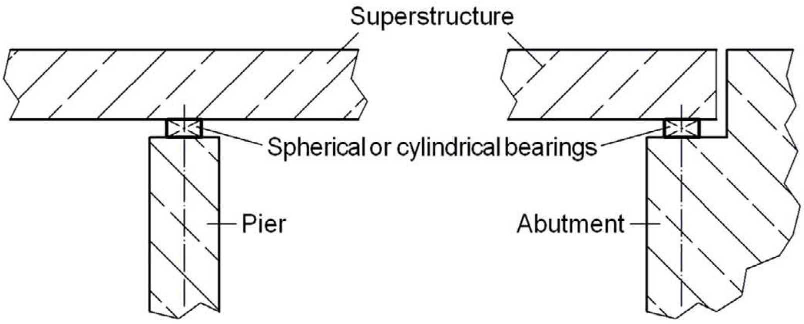
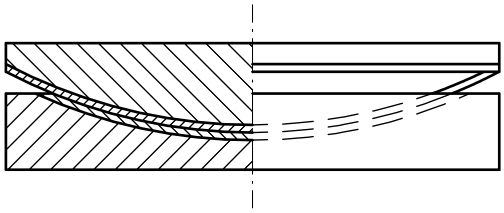


Figure A.1 - Assembly of a guided and free movable FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearing and its intended use (example)

The SFEROPOL and CERNOPOL Spherical and Cylindrical Bearings consist of a backing plate with a convex spherical surface (rotational element) and a backing plate with a concave spherical surface between which a SMF sheet and the mating material form a curved sliding surface (see Figure A.2 and A.4).

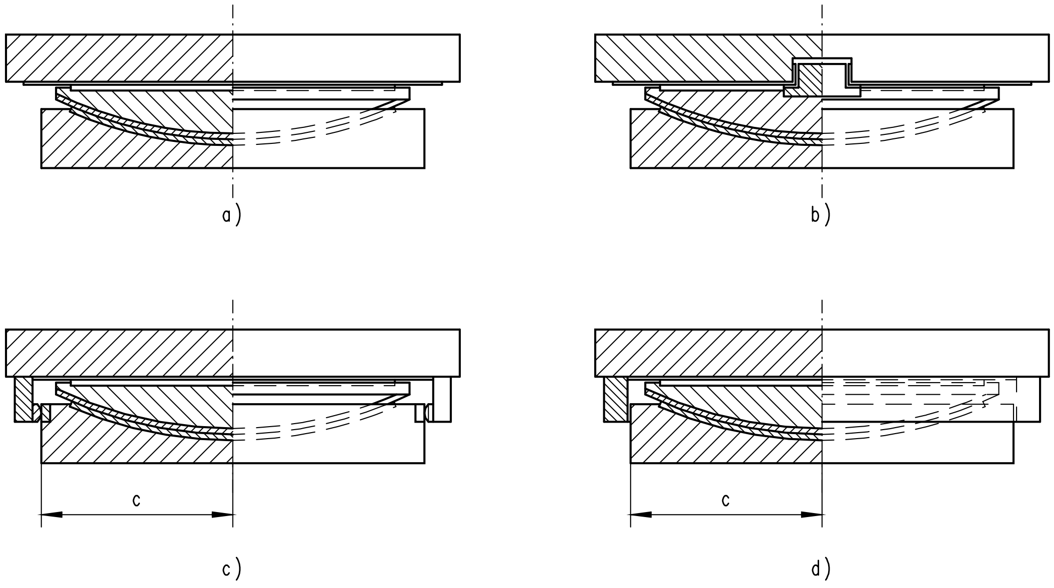
The FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearings are also used in combination with flat sliding elements and guides to form free and guided bearings (see Figure A.3 a) to d) and A.5 a) to c)). The FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearings combined with a flat sliding element can be used together with a restraining ring to form fixed bearings (see Figure A.3 d)).

NOTE: Numbers in brackets in Figures A.2 to A.5 refer to the examples shown in Figure 1 of EN 1337-1.



Fixed by sliding surface (3.2).

Figure A.2 – FIP SFEROPOL and CERNOPOL Spherical Bearings



Key

a) Free for displacements in any direction (3.5)
b) Guided by an internal guide for displacements in one direction (3.4)
c) Guided by external guides in one direction (3.3)
d) Fixed by a restraining ring (3.1)

Figure A.3 – FIP SFEROPOL and CERNOPOL Spherical Bearings combined with flat sliding elements

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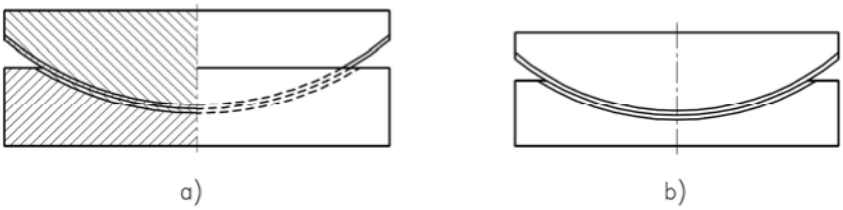
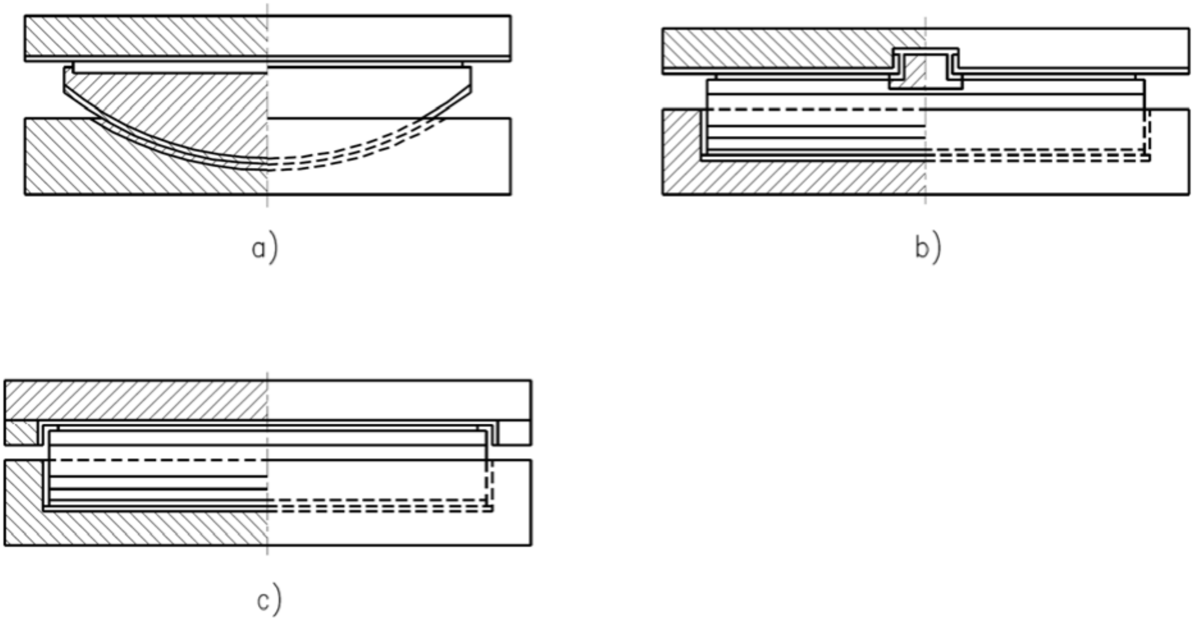


Key

- a) Fixed by end stops and sliding surface (7.1)
- b) Without end stops for displacements in y-direction (7.2)

Figure A.4 – FIP SFEROPOL and CERNOPOL Cylindrical Bearings



Key

- a) Free for displacements in any direction (7.4)
- b) Guided by an internal guide for displacements in x-direction (7.3)
- c) Guided by external guides for displacements in x-direction

Figure A.5 – FIP SFEROPOL and CERNOPOL Cylindrical Bearings combined with flat sliding elements

# Annex B
## Sliding friction coefficient

The following coefficients of friction $\mu_{max}$ shall be used for the design evaluation of the bearing and the structure in which it is incorporated. These values shall not be applied in the presence of high dynamic actions which may occur for instance in seismic zones. The effects of friction shall not be used to relieve the effects of externally applied horizontal loads.

### (a) Coefficient of friction at low temperatures

For sliding elements combined with dimpled and lubricated SMF sheets used in zones where the minimum effective bearing temperature doesn't fall below -35 °C, the coefficient of friction $\mu_{max}$ is determined as a function of the average pressure $\sigma_{SMF}$ [MPa], as follows:

$$0.020 \leq \mu_{max} = \frac{1.6}{15 + \sigma_{SMF}} \leq 0.08$$

For guides, the coefficient of friction shall be considered to be independent of contact pressure. The coefficient of friction $\mu_{max} = 0.10$ shall be used.

### (b) Coefficient of friction at very low temperatures

For sliding elements combined with dimpled and lubricated SMF sheets used in zones where the minimum effective bearing temperature does fall below -35 °C (down to -50 °C), the coefficient of friction $\mu_{max}$ is determined as a function of the average pressure $\sigma_{SMF}$ [MPa], as follows:

$$0.027 \leq \mu_{max} = \frac{2.8}{30 + \sigma_{SMF}} \leq 0.08$$

For guides, the coefficient of friction shall be considered to be independent of contact pressure. The coefficient of friction $\mu_{max} = 0.12$ shall be used.

### (c) Coefficient of friction at moderate low temperatures

For sliding elements combined with dimpled and lubricated SMF sheets used in zones where the minimum effective bearing temperature doesn't fall below -5 °C, the coefficient of friction $\mu_{max}$ is determined as a function of the average pressure $\sigma_{SMF}$ [MPa], as follows:

$$0.015 \leq \mu_{max} = \frac{1.2}{15 + \sigma_{SMF}} \leq 0.06$$

For guides the coefficient of friction shall be considered to be independent of contact pressure. The coefficient of friction $\mu_{max} = 0.07$ shall be used.

For composite materials see 6.7 of EN 1337-2.

# Annex C
## Material properties

### C.1 Special sliding material made of SMF

Table C.1: Material properties of special sliding material SMF

| Property | Testing Standard |
|---|---|
| Young modulus | EN ISO 527-1 and -3 |
| Yield strength | |
| Tensile strength | |
| Elongation at break | |
| Ball hardness | EN ISO 2039-1 |
| Mass density | EN ISO 1183 |
| Melting temperature and enthalpy | EN ISO 11357-5 |

# Annex D
## Manufacturing plants

**Plant :**

FIP MEC S.r.l.
Via Scapacchio
35030 Selvazzano D. (PD)
ITALIEN

# Annex E
## Load bearing capacity (compressive strength)

NOTE: Higher pressure may cause loss of the sliding function and this may be lead to structural failure or states close to structural failure. This state is considered as ultimate limit state.

### E.1 Design verification for sliding surface

When dimensioning sliding surfaces, all the internal forces and moments due to actions and frictional resistance shall be considered. The design values of the action to be taken into account shall be determined in accordance with the basic design criteria given in EN 1337-1.

Deformation of sliding materials shall not be used to accommodate rotations except as permitted in E.2.

The following conditions shall be verified under a fundamental combination of actions:

$$N_{Sd} \leq \frac{f_k}{\gamma_m} \cdot A_r = \frac{f_k}{\gamma_m} \cdot \lambda \cdot A$$

where

| | |
|---|---|
| $N_{Sd}$ | is the design axial force at ultimate limit state |
| $f_k$ | is the characteristic value of compressive strength acc. Table E.1 |
| $\gamma_m$ | partial safety factor for materials in accordance with EN 1990 |
| A | is the contact area of the flat sliding surface or the projection of curved surfaces |
| $\lambda$ | is a coefficient given in Annex I of this ETA |
| $A_r$ | is the reduced contact area of the sliding surface whose centroid is the point through which $N_{Sd}$ acts with the total eccentricity $e_t$, which is caused by both mechanical and geometrical effects. $A_r$ shall be calculated on the basis of the theory of plasticity assuming a rectangular stress block (see Annex I of this ETA). For guides eccentricity can be neglected. |

NOTE: The $\gamma_m$ value should be given in NDP (national determined parameter). In absence of NDP the recommended value is $\gamma_m = 1.4$.

For SMF sheets with smallest dimension "L" or "a" ≥ 100 mm, contact areas A and $A_r$ shall be taken as the gross area without deduction for the area of the dimples. For sheets with "L" or "a" < 100 mm the area of the dimples shall be deducted from the gross area.

The indication of products performance is based on the assessment under the conditions as given in clause 2.2.1 of the EAD 050004-00-0301.

The characteristic compressive strengths of SMF are given in Table E.1 and are valid for effective bearing temperatures up to 35 °C. For bearings exposed to a maximum effective bearing temperature in excess of 35 °C and up to 48 °C the characteristic compressive strength shall be estimated by linear interpolation of the values given in the table E.1.

Table E.1: Characteristic compressive strength of SMF

| Effective bearing temperature [°C] | ≤ 35 °C | 48 °C |
|---|---|---|
| Sliding surface | Characteristic compressive strength $f_k$ | |
| Main sliding surface<br>Dead loads and variable loads | 180 MPa | 135 MPa |
| Guides<br>Variable loads | | |
| Guides<br>Dead loads<br>Effects of temperature, shrinkage and creep | 60 MPa | 45 MPa |

For guides with composite material see 6.3 and 6.6 of EN 1337-2:2000.

For the purpose of compressive stress evaluation the curved sliding surface shall be replaced by its projection on a plane surface as shown in Figure E.1.

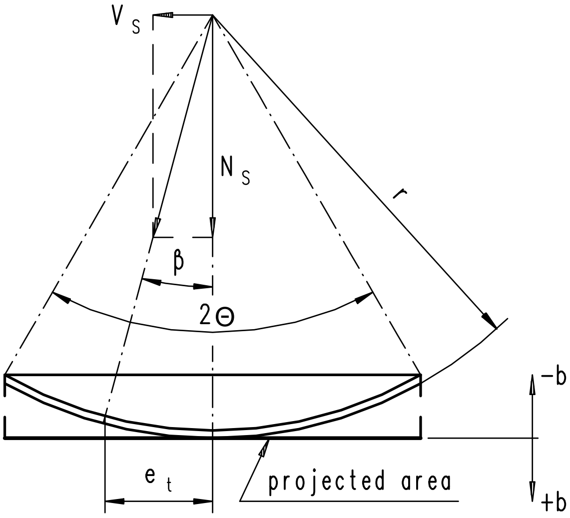


Figure E.1 -Evaluation scheme for the curved sliding surface (example)

Internal forces and moments acting on the curved sliding surface due to frictional resistance, externally applied horizontal loads and the rotated condition of the bearing shall be taken into account when determining the resulting total eccentricity $e_t$ of the axial force $N_S$.

Secondary effects due to the action of the restraints shall be also be considered.

NOTE: In Annex J of this ETA, formulae are given for the evaluation of the eccentricities in the most common cases.

Separation of the sliding surfaces may lead to wear due to contamination and increased deformation due to lack of confinement of the SMF sheet. As this could endanger long term fitness for use, the achievement of the edge pressure $\sigma_{SMF} = 0$ is considered as serviceability limit state.

With the exception of guides, it shall be verified that $\sigma_{SMF} \geq 0$ under the characteristic combination of actions. In doing so the sliding material shall be assumed to be linear elastic and the backing plates shall be deemed to be rigid. The condition $\sigma_{SMF} \geq 0$ is satisfied when the total eccentricity $e_t$ falls within the kernel of the projected area.

For circular sheets this condition is satisfied when:

$$e_t \leq \frac{L}{8}$$

where

L diameter see Annex H of this ETA

## E.2 Guides

Guides may be used for resisting horizontal forces $V_d$ due to variable and permanent actions. Depending on the bearing construction, the guides may be arranged externally or centrally. The sliding materials shall be fixed on keys and keyways in the backing plates.

Clearance c between sliding components in unused condition shall meet the following condition:

$$c \leq 1.0\ \text{mm} + \frac{L\ [\text{mm}]}{1000}$$

A typical example of the attachment of guides is shown in Figure A.1 of Annex A of this ETA. In the design of the connection at ultimate limit state in accordance with EN 1993-1-1, the effects of horizontal force $V_d$, its induced moment and the friction forces shall be considered.

Where, under the design rotation about transverse axis, the differential deformation of the SMF sheet across its smallest dimension "a" would exceed 0.2 mm, a rotation element shall be included in the backing plate (see Figure 1 and 3.3 of EN 1337-1). This condition shall be verified under the characteristic combination of actions.

## E.3 Restraining rings

The indication of products performance is based on the assessment under the following conditions:

The free FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearing may be fixed by a steel restraining ring. The design rules for pot and piston of pot bearings given in clause 6 of EN 1337-5 shall be followed.

## E.4 Austenitic steel sheets

The minimum thickness of austenitic steel sheet shall be in accordance with Table E.2.

The indication of products performance is based on the assessment under the following conditions:

- The austenitic steel sheet shall be fully in contact with the backing plate over the area which will be in contact with the SMF sheet.
- When attaching the austenitic steel sheet by screwing, counterpunched screwing and riveting, corrosion resistant fasteners compatible with the austenitic steel sheet shall be used for securing its edges. They shall be provided at all corners and along the edges outside the area of contact with the SMF sheet with the maximum spacing listed in Table E.3.

Table E.2: Thickness and methods of attachment of austenitic steel sheets.

| Type of surface | Method of attachment | Thickness t [mm] |
|---|---|---|
| flat | full surface bonding | 1.5 |
| | continuous fillet weld | ≥ 1.5 |
| | counterpunched screwing | ≥ 1.5 |
| | screwing, riveting | ≥ 2.5 |
| curved | full surface bonding | ≥ 2.5 |
| | continuous fillet weld | ≥ 2.5 |
| | recessed in concave surfaces | ≥ 2.5 |
| cylindrical | full surface bonding | ≥ 1.5 |
| | continuous fillet weld | ≥ 1.5 |
| | recessed in concave surfaces | ≥ 2.5 |

Table E.3: Maximum fastener spacing for attachment of austenitic steel sheets by screwing, counterpunched screwing and riveting.

| Austenitic steel sheet thickness [mm] | Maximum fasteners spacing [mm] |
|---|---|
| 1.5 | 150 |
| 2.0 | 300 |
| 2.5 | 450 |
| 3.0 | 600 |

# Annex F
## Load - deformation behaviour

The indication of products performance is based on the assessment under the following conditions:

- The SMF and the mating sliding materials shall be supported by metallic plates (backing plates) with plane or curved surfaces.
- The geometrical conditions are given in Annex K of this ETA.

The design of the backing plates shall take into account the following:

- strength evaluation at ultimate limit state when internal forces and moments from lateral actions are to be considered in addition to the effects from deformation as per hereafter,
- any cross section reduction (for example due to keyway and the attachment bolts),
- deformations as per hereafter,
- the required stiffness for transport and installation as per hereafter,
- distribution of forces to the adjacent structural members as per hereafter.

NOTE: If the deformations (see Figure F.1) exceed the values given below, unacceptably small clearance between the adjacent backing plates and higher wear will occur. As this could endanger the long term fitness for use of the sliding element, this condition is considered serviceability limit state.

The deformation $\Delta w$ (see Figure F.1) shall meet the following condition:

$$\Delta w \le h\,(0.45 - 1.708\,k\sqrt{h/L}) \text{ mit } 0 \le 1.708\,k \le 1.0 \qquad \text{and} \qquad k = \frac{\sigma_{SMF}[\text{MPa}]-45}{78.5}$$

where is

| | |
|---|---|
| L, h | see Annex H of this ETA |
| $\sigma_{SMF}$ | average pressure in the sliding surface under the characteristic combination of action |
| k | stiffness coefficient depends on sliding material |

The stress in the backing plate induced by the respective deformation shall not exceed the yield stress in order to avoid permanent deformations. The theoretical model for evaluation of the above requirements (deformation $\Delta w$ and yield strength) shall include the effects of all the bearing components which have a significant influence on these deformations including the adjacent structural members and their short and long-term properties.

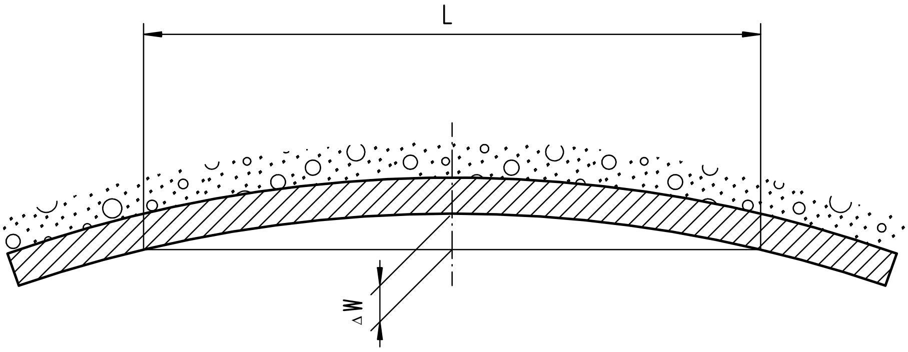


Figure F.1 - Deformations of backing plates.

For steel and concrete, the design values of material properties in accordance with EN 1993-1-1 and EN 1992-1-1 respectively apply.

In this model the following assumptions shall be made:

a) central load
b) notional design modulus of elasticity of SMF = 900 MPa
c) the total thickness $t_{SMF}$ of SMF sheet

d) notional design Poisson' s ratio of SMF = 0.44

e) in the case of adjacent structural members of solid construction: linear reduction of the elastic modulus of concrete or mortar from the edge to the centre of the backing plate from 100 % to 80 %.

A suitable method for calculating deformation $\Delta w$ for common materials is given by K.5 in Annex K of this ETA.

When using the method given in Annex K of this ETA yield stress evaluation of the backing plate is not required if:

- the condition for the deformation $\Delta w$ is met;
- the concrete strength class is at least C25/30 in accordance with EN 206-1;
- and the steel grade is at least S355 in accordance with EN 10025.

The above also applies when using lower concrete strength classes and/or steel grades, provided the deformation limit values calculated as above are reduced by a factor of:

| | |
|---|---|
| 0.90 | when using concrete strength class C20/25 |
| 0.67 | when using steel S 235 |
| 0.60 | when using both concrete C20/25 with steel S235. |

NOTE: The above is not the only criterion to be considered in determining the relative deformation $\Delta w$. Particular attention shall be paid to loadings during construction (e. g. when large backing plates are not propped during concrete casting).

The calculation of the relative deformation of the backing plate with convex surface shall be omitted.

Square or rectangular plates shall be idealised to circular plates of diameter

$$d_b = 1.13\, a_b$$

where $a_b$ is the side of the square plate or the minor side of the rectangular plate.
The thickness of the backing plate shall be:

$$t_b \geq 0.04 \cdot \sqrt{a_b^2 + b_b^2}$$

or 10 mm, whichever is greater, where:

$a_b$ is the minor side of backing plate and

$b_b$ is the major side of backing plate.

# Annex G
## Rotation capability

The indication of products performance regarding the sliding surfaces is based on the assessment under conditions given in this ETA:

Especially the fundamental combination of the following conditions is concerned:

- the metallic surfacing mating with the SMF material shall completely cover the SMF sheet,
- there is no contact between the upper and the lower part of the bearing or any other metallic component (see EN 1337-1, Annex A).

Concerning the above conditions the increase of rotations, specified in clause 5.4 of EN 1337-1, shall be taken into account.

For rotations about a transverse axis of guides see E.2 in Annex E of this ETA.

For guides with composite material see 6.3 of EN 1337-2.

# Annex H

## Geometrical characteristics of SMF sheets

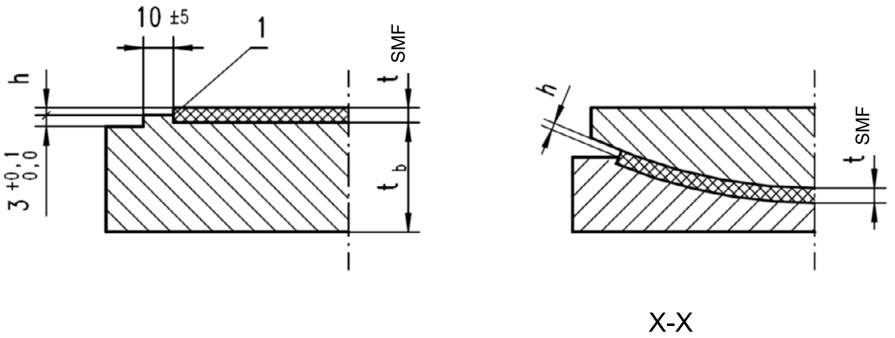
### H.1 Details of recess and relief for sliding elements with SMF

The performance characteristics of FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearings given in this ETA are valid only for the following geometrical conditions.

### H.1.1 Recessed SMF sheets

The SMF sheets shall be recessed into a backing plate as shown in Figure H.1.

Dimensions in millimetres



Key

1 Sharp edge

Figure H.1 - Details of SMF recess and relief

NOTE: A fixed value for the depth of the relief is given to facilitate the measurement of the SMF protrusion "h" after installation. For section x-x, see figure H.2 resp. H.3.

The thickness $t_{SMF}$ and protrusion h of the SMF sheet in the unloaded condition with corrosion protection shall meet the conditions given in Table H.1

Table H.1: Thickness $t_{SMF}$ and protrusion h of the SMF sheet

| Design values | Flat and curved sliding surfaces | Guides |
|---|---|---|
| Thickness $t_{PE}$ in mm | $2.65 \cdot h \leq t_{SMF} \leq 10.0$; with h in mm | $8.0 \leq t_{SMF} \leq 10.0$ |
| Protrusion h in mm | $h = 2.50 + \frac{L}{3000}$<br>L diameter of the projected area of the SMF sheet in mm | $h = 3.0 \pm 0.2$ |

The tolerance on the protrusion h is ± 0.2 mm for L 1200 mm and ± 0.3 mm for L 1200 mm. The protrusion h shall be verified at marked measuring points, where the corrosion protection coating shall not exceed 300 µm. There shall be at least two measuring points, suitably located. The admissible tolerance on thickness $t_{SMF}$ of single SMF sheets or associated multiple sheets is $^{+0,3}_{-0,0}$ mm for sheets with a diameter L 1200 mm and $^{+0,4}_{-0,0}$ mm for larger sheets.

### H.1.2 Flat SMF sheets

Flat SMF sheets for the main sliding surface shall be circular and may be sub-divided into a maximum of four identical parts. Further sub-divisions are beyond the scope of this ETA. The smallest dimension "a" shall not be less than 50 mm. The distance between individual SMF sheets shall not be greater than twice the thickness of the backing plate, of the SMF or the mating material, whichever is least. Figure H.2 shows some examples of sub-division of flat SMF sheets.

Dimensions in millimetres

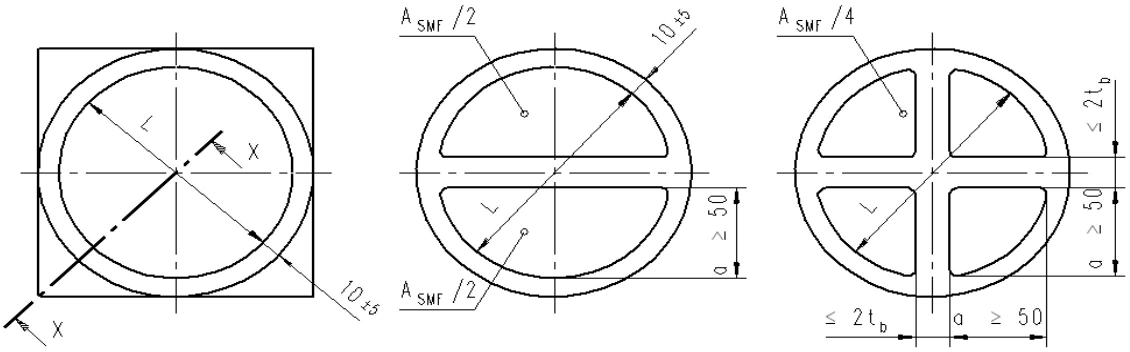


Figure H.2 - Examples of recessed flat SMF configurations

### H.1.3 Curved SMF sheets

Curved SMF sheets shall be circular and may be subdivided into a disc and an annulus. The disc, if subdivided, shall not be less than 1000 mm in diameter and the width of the annulus shall not be less than 50 mm. The annulus may be divided into equal segments. Both the disc and the annulus may be retained in recesses. The separating ring of the backing plate shall not be more than 10 mm wide. Figure H.3 shows the configurations of curved SMF sheets for spherical sliding surfaces.

Dimensions in millimetres

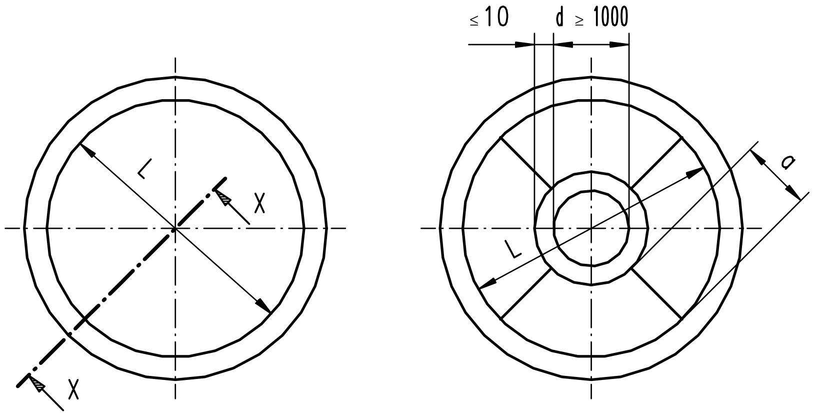


Figure H.3 - Subdivision of recessed SMF sheets for spherical sliding surfaces

### H.1.4 SMF sheets for guides

Dimension "a" shall not be less than 15 mm and the modified shape factor

$$S = \frac{A_{SMF}}{u \cdot h} \cdot \frac{t_{SMF} - h}{h}$$

shall be greater than 4 (see figure H.4). $A_{SMF}$ is the compressed (undeformed) surface and u the perimeter of the SMF sheet.

Dimensions in millimetres

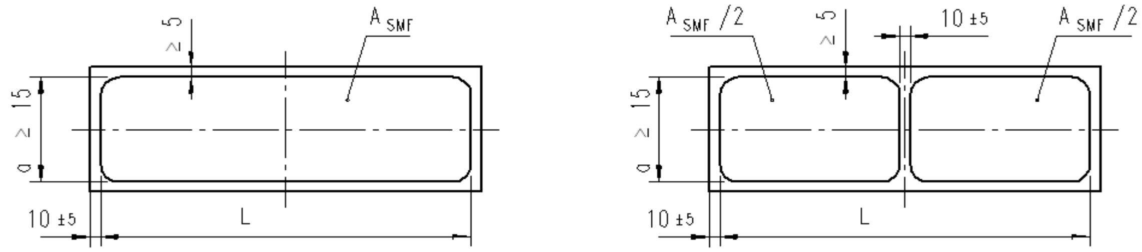
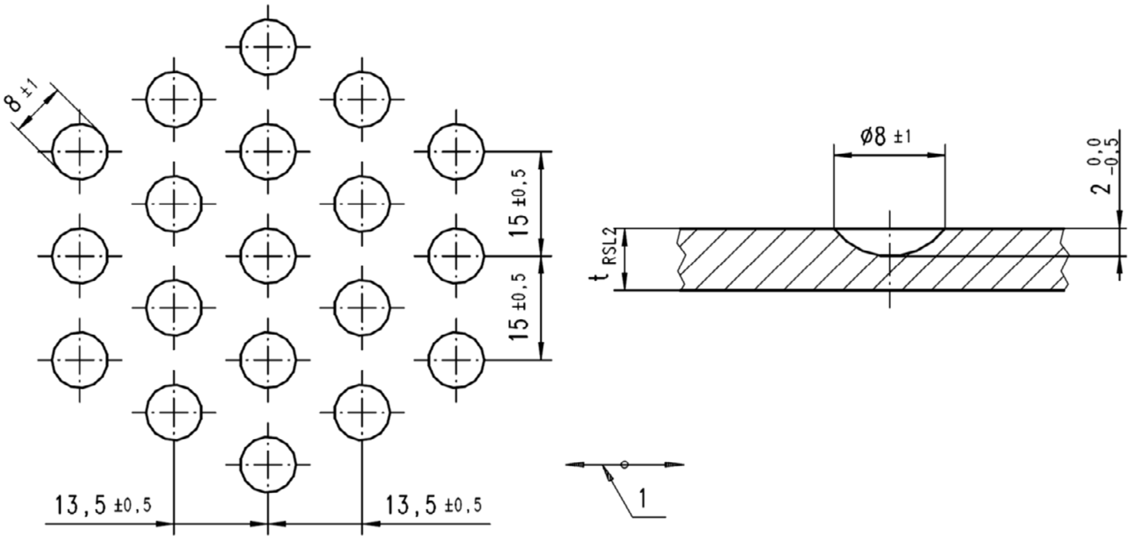


Figure H.4 - Examples of recessed SMF sheets for guides

## H.2 Dimple pattern for sliding elements with SMF

For pressures due to characteristic permanent actions $G_k$ exceeding 5 MPa a uniform pattern of dimples shall be provided to retain the lubricant. The shape and arrangement of the dimples in the unloaded and unused condition and the alignment with the main direction of sliding is shown in figure H.5.

Dimensions in millimetres



Key

1 main direction of sliding

Figure H.5 - Pattern of dimples in recessed SMF sheets

# Annex I

## Reduced area for circular sliding elements

The values of the coefficient λ have been calculated by means of a mathematical model made with the following assumptions:

1) only compressive stresses are transmitted;
2) the stresses in the compressed area are constant and equal to the design value $f_d$ of compressive resistance of SMF sheets (i. e. the stress block theory is adopted);
3) stresses are always normal to the contact surface: a conservative hypothesis justified by the low coefficient of friction of SMF in contact with polished metal surfaces;
4) the adjacent backing plates are perfectly rigid.

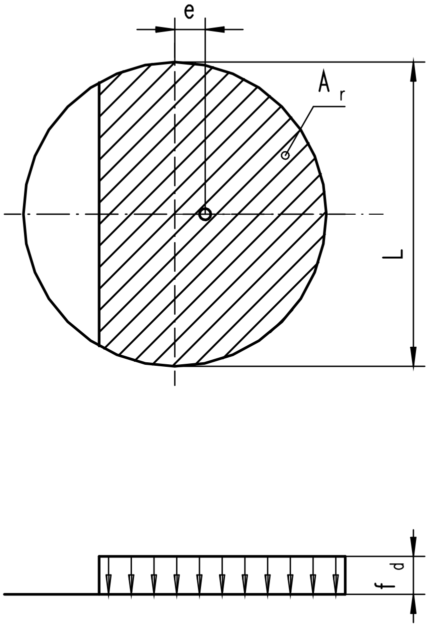


Figure I.1 - Reduced contact area $A_r$ for circular sliding surfaces.

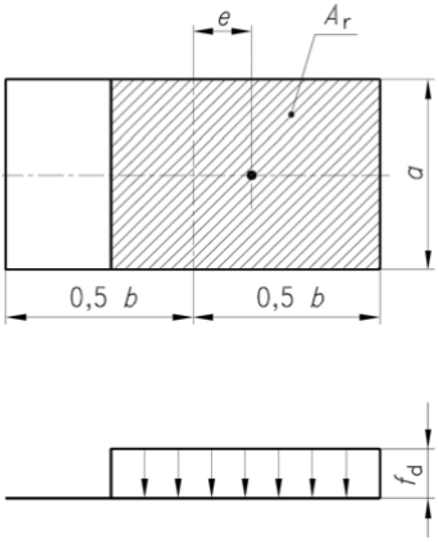


Figure I.2 - Reduced contact area $A_r$ for rectangular sliding surfaces.

$$A_r = \lambda \cdot A$$

where is

$\lambda$ Coefficient given in Table H.1.

A Contact area for flat sliding surfaces or projection area of the curved sliding surface $A = \pi L^2/4$

As an alternative to the exact values given in Table H.1, the following approximate formula can be used for flat sliding surfaces:

$$\lambda = 1 - 0.75\, \pi\, e / L$$

Table I.1: Coefficient $\lambda = A_r / A$

| e / L | | sliding surface | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | flat | spherical | | | | cylindrical | | | |
| | | Θ | | | | | | | |
| | | 30° | 25° | 20° | 10° | 30° | 25° | 20° | 10° |
| 0.0000 | | | | | | | | | |
| 0.0500 | 0.990 | 0.991 | 0.991 | 0.990 | 0.990 | | | | |
| 0.0100 | 0.979 | 0.982 | 0.981 | 0.980 | 0.979 | 0.984 | 0.983 | 0.981 | 0.980 |
| 0.0200 | 0.957 | 0.962 | 0.961 | 0.960 | 0.958 | 0.968 | 0.965 | 0.962 | 0.961 |
| 0.0300 | 0.934 | 0.942 | 0.940 | 0.938 | 0.936 | 0.951 | 0.947 | 0.943 | 0.941 |
| 0.0400 | 0.912 | 0.922 | 0.919 | 0.916 | 0.913 | 0.934 | 0.929 | 0.924 | 0.921 |
| 0.0500 | 0.888 | 0.901 | 0.898 | 0.894 | 0.890 | 0.917 | 0.911 | 0.905 | 0.901 |
| 0.0600 | 0.865 | 0.880 | 0.876 | 0.872 | 0.867 | 0.900 | 0.893 | 0.886 | 0.881 |
| 0.0700 | 0.841 | 0.858 | 0.853 | 0.849 | 0.844 | 0.882 | 0.874 | 0.866 | 0.862 |
| 0.0800 | 0.818 | 0.836 | 0.831 | 0.826 | 0.820 | 0.864 | 0.855 | 0.847 | 0.842 |
| 0.0900 | 0.793 | 0.814 | 0.808 | 0.803 | 0.796 | 0.846 | 0.837 | 0.827 | 0.822 |
| 0.1000 | 0.769 | 0.792 | 0.786 | 0.780 | 0.773 | 0.828 | 0.818 | 0.808 | 0.802 |
| 0.1100 | 0.745 | 0.770 | 0.763 | 0.757 | 0.749 | 0.809 | 0.799 | 0.788 | 0.782 |
| 0.1200 | 0.722 | 0.747 | 0.740 | 0.733 | 0.724 | 0.790 | 0.779 | 0.768 | 0.762 |
| 0.1255 | 0.709 | 0.736 | 0.729 | 0.722 | 0.712 | 0.780 | 0.769 | 0.758 | 0.752 |
| 0.1300 | 0.697 | 0.725 | 0.717 | 0.710 | 0.700 | 0.771 | 0.760 | 0.749 | 0.742 |
| 0.1400 | 0.673 | 0.702 | 0.693 | 0.686 | 0.676 | 0.752 | 0.740 | 0.729 | 0.722 |
| 0.1500 | 0.649 | 0.680 | 0.670 | 0.663 | 0.653 | 0.733 | 0.721 | 0.709 | 0.702 |
| 0.1600 | 0.625 | 0.657 | 0.647 | 0.639 | 0.628 | 0.713 | 0.701 | 0.689 | 0.682 |
| 0.1700 | 0.601 | 0.635 | 0.624 | 0.616 | 0.604 | 0.693 | 0.681 | 0.669 | 0.662 |
| 0.1800 | 0.577 | 0.612 | 0.601 | 0.592 | 0.581 | 0.673 | 0.661 | 0.649 | 0.642 |
| 0.1900 | 0.552 | 0.590 | 0.578 | 0.569 | 0.557 | 0.653 | 0.641 | 0.629 | 0.622 |
| 0.2000 | 0.529 | 0.567 | 0.556 | 0.546 | 0.533 | 0.633 | 0.621 | 0.609 | 0.602 |
| 0.2100 | 0.506 | 0.545 | 0.533 | 0.523 | 0.510 | 0.612 | 0.600 | 0.589 | 0.582 |
| 0.2155 | 0.500 | 0.541 | 0.529 | 0.518 | | 0.602 | 0.590 | 0.579 | 0.572 |
| 0.2200 | 0.482 | 0.523 | 0.511 | 0.500 | | 0.592 | 0.580 | 0.569 | 0.562 |
| 0.2300 | 0.458 | 0.501 | | | | 0.571 | 0.559 | 0.548 | 0.542 |
| 0.2400 | 0.435 | | | | | 0.550 | 0.539 | 0.528 | 0.522 |
| 0.2500 | 0.412 | | | | | 0.529 | 0.518 | 0.508 | 0.502 |
| NOTE: Intermediate values may be obtained by linear interpolation | | | | | | | | | |

# Annex J
## Method for calculation the eccentricities in FIP SFEROPOL and CERNOPOL Spherical and Cylindrical Bearing

### J.1 General

Frictional forces, forces from applied horizontal loads and the rotated condition of the bearing produce eccentricity of the axial force $N_S$, which is used in the verification of SMF sheets, the adjacent structural members and the anchoring devices. This annex gives methods for calculating the significant eccentricities. Depending on the design features of a particular bearing, additional eccentricities may exist. When several eccentricities occur in a cross-section under consideration, they need to be added.

### J.2 Friction resistance

### J.2.1 Curved sliding surfaces

In the presence of rotational movements an internal moment occurs due to the frictional resistance. Regardless of whether the bearing has one or two surfaces, the associated eccentricity $e_1$ is:

$$e_1 = \mu_{max} \cdot r$$

The coefficient of friction $\mu_{max}$ is given in Annex B of this ETA.

### J.2.2 Sliding surfaces with external guides and restraining rings

For the spherical and cylindrical bearings of the type shown by Figures A.3 c) and d) and A.5 c) in Annex A of this ETA rotational movements produce an eccentricity which affects only the adjacent structural members (i.e. plinth, beam etc.) and the anchoring devices, where:

$$e_2 = \frac{V_s}{N_s} \cdot \mu_{max} \cdot c$$

For bearings with sliding elements in guides as per Table 1 of this ETA, the coefficient of friction $\mu_{max}$ is given in Annex B of this ETA. For restraining rings with steel to steel contact $\mu_{max}$ should be assumed to be 0.2.

### J.3 Rotation

In all the types of bearings with two sliding surfaces a rotation angle $\alpha$ produces an eccentricity $e_3$ of the vertical load on the curved surface equal to:

$$e_3 = \alpha \cdot (r + b)$$

where b represents the distance between the cross-section under consideration and the sliding surface. At any rate, this eccentricity acts nonetheless in the opposite direction to that given under Annex E of this ETA. The occurrence of $e_3$ depends on whether the curved SMF sheet is either attached to the convex or concave backing plate and whether the value $\alpha$ is greater or lesser than $\mu$ as well as on whether the bearing clearance is performing its function effectively in the case of guided bearings. In the type of bearings equipped with only one sliding surface $e_3$ occurs only in the curved SMF sheet and, furthermore, only when said sheet is attached to the convex backing plate.

### J.4 Lateral forces

Lateral forces result from horizontal actions and the friction resistance of the other bearings in the structure. In bearings where lateral forces are transmitted by external guides or restraining rings, the eccentricity in the curved sliding surface is equal to zero. In bearings of the fixed type with only one sliding surface or with internal guides the horizontal load $V_s$ produces an eccentricity given by:

$$e_4 = \frac{V_s}{N_s} \cdot (r + b)$$

In all cases where the lines of application of lateral action and reaction are not coincident the resulting couple causes an eccentricity that shall be additionally taken into account.

# Annex K
## Backing plates

### K.1 General

Dimensional limitations of backing plates with concave surfaces are shown in Figure K.1.

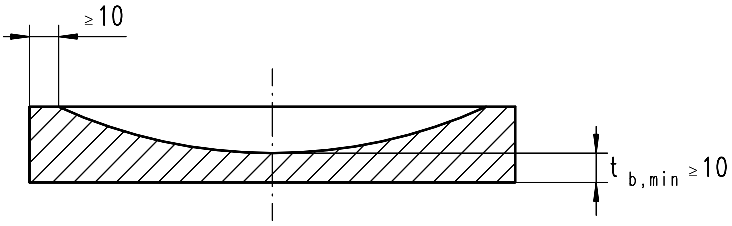


Figure K.1 – Dimensional limitations of a backing plate with a concave surface

### K.2 SMF confinement

The shoulders of the recess shall be sharp and square to restrict the flow of SMF (see Figure H.1 in Annex H of this ETA). The radius at the root of the recess shall not exceed 1 mm. The depth of the confining recess shall be related to the dimensions of the SMF sheet in accordance with Annex H of this ETA. In principle the SMF sheet shall fit the recess without clearance. Intermittent gaps between the edge of the SMF sheet and the recess shall not exceed the values given in Table K.1 at room temperature.

Table K.1: Fit of confined SMF sheets.

| Dimension L [mm] | Gap [mm] |
|---|---|
| $75 \leq L \leq 600$ | 0.6 |
| $600 < L \leq 1200$ | 0.9 |
| $1200 < L \leq 1500$ | 1.2 |

where is

L see Annex H of this ETA

### K.3 Flatness

Surfaces of backing plates in contact with sliding materials or anchor and shimming plates shall be treated in such a way that the maximum deviation $\Delta z$ from theoretical plane surface shall not exceed $0.0003 \cdot d$ or 0.2 mm, whichever is greater.

### K.4 Fit of sliding surfaces

The maximum deviation $\Delta z$ from theoretical plane or curved surface within the area of the mating SMF sheet shall not exceed $0.0003 \cdot L$ or 0.2 mm, whichever is greater.

## K.5 Method for calculating the deformation of backing plates attached to concrete

For circular steel plates attached to concrete structural members of concrete strength class C20/25 according to EN 206-1 or greater and mortar layers of equivalent strength, the maximum relative deformation Δw over the diameter L is given by the equation below:

$$\Delta w = \frac{0.55}{L} \cdot k_c \cdot \alpha_c \cdot k_b \cdot \alpha_b$$

with

$$k_c = 1.1 + (1.7 - 0.85 \cdot d_b / L) \cdot (2 - d_b / L_0) \quad \text{if} \quad L_0 \leq d_b \leq 2 \cdot L_0$$

$$k_c = 1.1 \quad \text{if} \quad d_b > 2 \cdot L_0$$

$$\alpha_c = \frac{N_{Qd}}{E_{cd}} + \frac{N_{Gd}}{E_{crd}}$$

$$k_b = 0.30 + 0.55 \cdot d_b / L$$

$$\alpha_b = \left(\frac{L}{L + 2 \cdot t_b}\right)^2 \cdot \left(\frac{3 \cdot L_0}{d_b}\right)^{0.4}$$

where is

| | |
|---|---|
| $d_b$ | diameter of the backing plate |
| $t_b$ | thickness of the backing plate; for backing plates with a concave surface the calculation may be based on the equivalent constant thickness $t'_b = t_{b,min} + 0.6\,(t_{b,max} - t_{b,min})$ |
| L | diameter of SMF sheet |
| $L_0$ | reference diameter = 300 mm |
| $N_{Qd}$ | design axial force due to variable actions |
| $N_{Gd}$ | design axial force due to permanent actions |
| $E_{cd}$ | design secant modulus of elasticity of concrete |
| $E_{crd}$ | design reduced modulus of elasticity of concrete, for the determination of creep when acted upon by permanent design actions $N_{Gd}$ ( $E_{crd} \cong 1/3\, E_{cd}$ ) |

The above approximate procedure may also be applied to square plates and rectangular plates if they are idealised to circular plates of diameter

$d_b = 1.13\, a_b$

where $a_b$ is the side of the square plate or the minor side of the rectangular plate.