

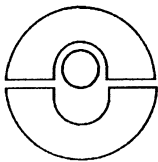
UIC Code

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**Code for the use of rubber bearings  
for rail bridges**



International Union of Railways



**Documents**

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Leaflet to be classified in Volume :

VII - Way and Works

Amendment

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## Introduction

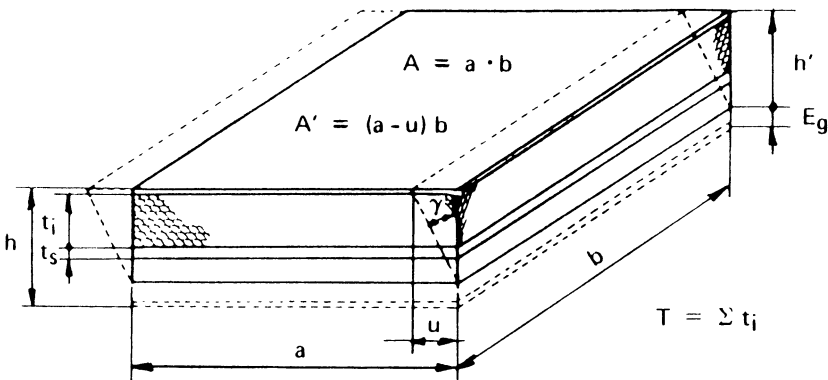
This leaflet is based on studies carried out from 1961 to 1965 by the D 60 Specialists' Committee of the Office for Research and Experiments (ORE) at the request of the UIC 7th Committee. These studies resulted in the drawing up of "Recommendations" (Appendix 2 of the Final ORE report D 60/RF dated October 1965). The many tests carried out for this report allowed formulae to be proposed for the design of the bearings, which were prepared in relation to the test results and are dealt with more specifically in section 3 below.

This leaflet was revised to bring it in line with limit state methods.

Notations and symbols

1 - Material

|                         |       |
|-------------------------|-------|
| "Static" shear modulus  | $G$   |
| "Dynamic" shear modulus | $G_s$ |



2 - Geometrical characteristics

|                                          |       |
|------------------------------------------|-------|
| Number of elementary layers              | $n$   |
| Dimension parallel to the beam           | $a$   |
| Dimension perpendicular to the beam      | $b$   |
| Thickness of an elementary layer         | $t_i$ |
| Total thickness of rubber without casing | $T$   |
| Thickness of casing                      | $E_g$ |
| Total height of bearing                  | $h$   |

(1) generally  $a < b$ .

|                                     |                |
|-------------------------------------|----------------|
| Surface area of bearing             | $A$            |
| Reduced surface area of bearing     | $A' = (a-u) b$ |
| Shape factor of the bearing         | $S$            |
| Shape factor of an elementary layer | $S_i$          |
| Dimensions of plates:               |                |
| Thickness                           | $t_s$          |

### 3 - Forces

|                                     |                 |
|-------------------------------------|-----------------|
| Normal load                         | $P = P_c + P_s$ |
| Normal load, slow application       | $P_c$           |
| Normal load, rapid application      | $P_s$           |
| Tangential force                    | $H = H_c + H_s$ |
| Tangential force, slow application  | $H_c$           |
| Tangential force, rapid application | $H_s$           |
| Coefficient of friction             | $f$             |
| Coefficient of dynamic enhancement  | $\Phi$          |

### 4 - Stresses

|                                                          |               |
|----------------------------------------------------------|---------------|
| Compressive stress                                       | $\sigma_m$    |
| Mean compressive stress due to the action of slow loads  | $\sigma_{mc}$ |
| Mean compressive stress due to the action of rapid loads | $\sigma_{ms}$ |
| Shear stress                                             | $\tau$        |
| Mean shear stress due to a tangential force $H$          | $\tau_H$      |
| Shear stress due to a normal force $P$                   | $\tau_p$      |
| Shear stress due to a rotation                           | $\tau_\alpha$ |

|                                                   |            |
|---------------------------------------------------|------------|
| Yield strength of the steel                       | $\sigma_a$ |
| Partial safety factor of the steel at limit state | $\gamma_s$ |

## 5 - Deformations

Total deformation in compression under the simultaneous action of slow and rapid loads

|                        |       |
|------------------------|-------|
| reinforced bearing     | $e_i$ |
| non-reinforced bearing | $e$   |

Total deformation in compression under the action of a slow load

|                        |          |
|------------------------|----------|
| reinforced bearing     | $e_{ic}$ |
| non-reinforced bearing | $e_c$    |

Shear strain (distortion)  $\tan \gamma$

Shear strain due to simultaneous application of slow and rapid forces  $\tan \gamma_{c,s}$

Tangential shear strain  $u = u_c + u_s$

Tangential shear strain due to the application of slow tangential forces  $u_c$

Tangential shear strain due to the application of rapid tangential forces  $u_s$

Rotation  $\alpha = \alpha_c + \alpha_s$

Rotation due to the application of slow loads  $\alpha_c$

Installation tolerances  $\alpha_0$

Rotation due to the application of rapid loads  $\alpha_s$

Breaking strength of the rubber  $\lambda$

## **1 - Purpose of the leaflet**

The purpose of the leaflet is to define the scope of use of rubber bearings, the types to be used, the design of the bearings, their installation and also the precautions to be taken with regard to inspection, maintenance and replacement.

The only bearings to which the code is intended to apply the two kinds described below, to the exclusion of any other different forms and arrangements, which will have to be made the subject of special provisions (see also Leaflet 772-1).

### **1.1 - Non-reinforced bearings**

Non-reinforced bearings consist of one rubber layer only in the form of a rectangular parallelepiped, usually elongated.

### **1.2 - Reinforced bearings**

Reinforced bearings consist of a certain number of rubber layers, usually rectangular, separated by sheet steel plates, also rectangular, with or without perforations, which during manufacture are strongly bonded (1) to the rubber layers to reduce deformation. The sides of the steel plates may be visible or encased in rubber during manufacture. The same applies to the external faces of the end plates. When the bearing is completely enclosed, it has the appearance of a uniform block.

In the case of skew bridges bearings with a circular form can be adopted. Their calculation will be governed by the regulations below.

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(1) This bond is usually obtained by applying adhesive during vulcanisation.

## **2 - Properties and use**

### **2.1 - Properties**

These bearings can withstand heavy normal loads, while permitting considerable tangential movement and rotation.

### **2.2 - Use**

They are used as movable or fixed bearings. In the first case the deformation of rubber absorbs both the rotation and tangential movement of the supported structure within the limits specified below. In the second case it is necessary to install special equipment preventing any possibility of tangential movement (in either one or both directions) without however hindering rotation and compressibility of the bearing.

Correct functioning, however, requires a sufficient load to prevent creep and a sufficiently high deformation under normal loading to ensure that the rotation of the supported structure does not bring about total unloading of a section of the bearing surface. However, this deformation must not be too high in order to prevent secondary forces being created in the supported structure.

Use of rubber bearings is a priori not advisable, if they are required to undergo simultaneously light loading and considerable longitudinal movement. This would apply, for example, to bearings intended for metal rail bridges with a short span or in certain cases of end spans of continuous girder bridges.

### **2.2.1 - Non-reinforced bearings**

Due to their deformation they are used for distributed loads of moderate intensity (usually in the form of a strip).

### **2.2.2 - Reinforced bearings**

They are used for heavy concentrated loads.

## **2.3 - Effect of deformation of bearings on the supported structure**

The deformation of rubber bearings has little effect on the eccentricity of normal loads, even when rotation occurs.

In certain cases, however, it is advisable to check the satisfactory transmission of the horizontal forces induced by the presence of bearings on the remainder of the structure, especially when these forces lead to the creation of a couple in the bearing zone.

These bearings do not distribute the vertical loads uniformly over the contact surface: pressure at the edge is always less than the pressure at the centre, which can reach 1.5 to 2 times the average pressure; the reinforcement of the bedstone and the bearing plate-reinforcement system of the structure carried should take this into account.

The superstructure can, as a general rule, be calculated disregarding the forces caused by the vertical differential deformations of bearings.

## **2.4 - Effect of the deformation of bearings on the supporting structure**

### **2.4.1 - Vertical loading**

Strictly speaking, the calculation of supporting structures (abutments, piers, piling ...) does not require the eccentricity of loading due to the deformation of the bearings to be taken into account.

### **2.4.2 - Horizontal loading**

Unlike metal bearings, the horizontal reactions of rubber bearings are proportional to movement.

Consequently:

- the tangential movement imposed produces considerable horizontal forces,
- any horizontal forces applied are translated into movement (distortion) at bearing level (except when prevented: fixed bearings for example).

It is advisable that these factors are taken into account in the design of bearings, piers and abutments, including foundations. As regards the overall structure this should take into account their presence by a distribution of the horizontal forces at the top of the supporting structure (bearing + abutment or pier + foundation) in relation to their relative stiffnesses.

As regards the calculation of the bearings and foundations it is advisable to consider the increase of rigidity of the bearing with ageing, on the one hand, and its functioning at low temperature, on the other hand. Where these affect safety, it is recommended to increase the stiffness of the bearing by 50 % (G modulus) to make allowance for these two points.

## **3 - Definition of materials**

### **3.1 - Rubber**

#### **3.1.1 - Type**

The rubber may be of a natural or synthetic type. It must satisfy the regulations and any standards in force in each country.

#### **3.1.2 - Special properties**

In particular, the rubber must have adequate resistance to the action of oils, weather, atmospheric ozone and extreme temperatures to which the bearing is subjected.

Natural rubbers are usually able to withstand variations in temperature, particularly low and very low temperatures ( $- 30\text{ }^{\circ}\text{C}$ ,  $- 40\text{ }^{\circ}\text{C}$ ).

The composition of synthetic rubbers must be designed in accordance with their use. The behaviour of the rubber at low temperatures needs to be checked both on the rubber itself as well as on the type of bearing envisaged.

The behaviour of the rubbers at high temperatures ( $+ 50\text{ }^{\circ}\text{C}$ ) calls for no special remarks. In the case of structures situated in certain areas, resistance to certain biological agents (insects, fungi, etc.) may be the subject of special specifications.

#### **3.1.3 - Mechanical properties**

The rubber is characterised in mechanical terms by its shear modulus measured in accordance with the conditions laid down in Appendix 1 below.

Modulus G and Shore hardness A of the rubber, often used for acceptance tests, usually increase correspondingly.

The following comparison (at a temperature of 20 °C) is given as a guide.

|                  |     |     |     |       |
|------------------|-----|-----|-----|-------|
| Shore hardness A | 50  | 60  | 70  |       |
| Modulus G        | 0.5 | 0.8 | 1.1 | (MPa) |

In the case of bearings for railway bridges the Shore hardness A is generally  $60 \pm 5$  (1).

### 3.2 - Steels for plates

#### 3.2.1 - Mechanical properties

The steel used for the plates must have:

- a yield strength of not less than 240 MPa,
- a tensile strength of not less than 420 MPa.

#### 3.2.2 - Thickness of the plates

The steel plates used as reinforcements must be at least one millimetre thick.

#### 3.2.3 - Machining of plates

The edges of the plates and any holes provided in them shall be carefully machined to prevent any notch effect.

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(1) It may be accepted that the readings given by the Shore durometer A are approximately the same as the readings in international rubber hardness degrees (I R H D) to which certain standards refer.

### **3.3 - Adhesives**

Any adhesives used to bond together the steel plates and rubber pads or, where applicable, two steel plates during vulcanisation must have at least the same shear strength as the rubber used. They must also be fully resistant to the action of oils, weather, atmospheric ozone, biological agents and extreme temperatures to which the bearing may be subjected.

### **3.4 - Other materials**

The use of materials with characteristics different from those specified above must be subject to prior agreement by the railway concerned.

## **4 - Dimensioning - Validation of calculations**

### **4.1 - General**

Validation and dimensioning of rubber bearings is carried out using the limit state method.

In principle, this requires consideration of the two limit states defined in UIC Leaflet 776-1 (Loads to be considered in the design of railway bridges):

- serviceability state: state where the performance of the bearing under service conditions is only just ensured,
- ultimate state: state where any further increase of stresses would lead to the fracture, or irreversible deformation, of the bearing.

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To carry out the calculations the nominal loads and partial safety factors of UIC Leaflet 776-1 are used.

The vertical loads of the UIC load diagram should be increased in accordance with the dynamic shear coefficient of the element supported.

Furthermore, tests have shown that rapidly applied normal loads should be catered for by an enhancing coefficient to make allowance for their hostile effect as far as the shear stresses are concerned (under normal and rotational forces).

Checking and validation should be carried out generally with load case II as described in UIC Leaflet 776-1.

In certain special cases load scheme V could be envisaged. The partial safety coefficients must then be fixed in relation to the construction stages and to the forces liable to develop. However, these coefficients must not fall below those of load schemes I and II combined.

### 4.2 - Validation to be provided

Dimensioning requires the checking of a number of conditions.

The order given below makes it possible to limit trial and error and obtain the various dimensions quickly.

The following checks should be made:

#### 4.2.1 - Plan dimensions

- compressive stresses
- non-slip conditions of the bearings in relation to the supported structure and to the bearing structure.

In the case of fixed bearings where special arrangements are made for preventing any movement, by transmitting forces directly, this check need not be made.

#### 4.2.2 - Thickness dimensioning

- limitation of distortion
- no uplift of the most lightly loaded edge of the bearing
- no buckling of the bearing
- limitation of the rubber shear stress.

#### 4.2.3 - Plates

- strength of the plates

#### 4.2.4 - Limit states to be considered

The following limit states must be examined:

|                    | Reinforced bearing                 |                | Non-reinforced bearing |                |
|--------------------|------------------------------------|----------------|------------------------|----------------|
|                    | Serviceability state               | Ultimate state | Serviceability state   | Ultimate state |
| Average pressure   | X                                  |                | X                      |                |
| Non-slip           | X                                  |                | X                      |                |
| Distortion         | X                                  |                | X                      |                |
| No uplift          |                                    | X              |                        | X              |
| No buckling        | Independent: geometrical condition |                |                        |                |
| Shear              | X                                  |                | Not applicable         |                |
| Strength of plates |                                    | X              |                        |                |

### 4.3 - Guidance on validation

#### 4.3.1 - Notations and symbols

The meaning of the various notations and symbols is described at the beginning of the leaflet.

Important remark:

It is necessary to distinguish between semi-permanent loads and those subject to rapid changes, the latter having a much more severe effect on rubber because of their repetitive nature.

Semi-permanent loads are, for example, dead loads, loading due to temperature changes, shrinkage or creep; the corresponding values will be identified by the index **c**. Rapidly varying loads (live loads) will be identified by the index **s**.

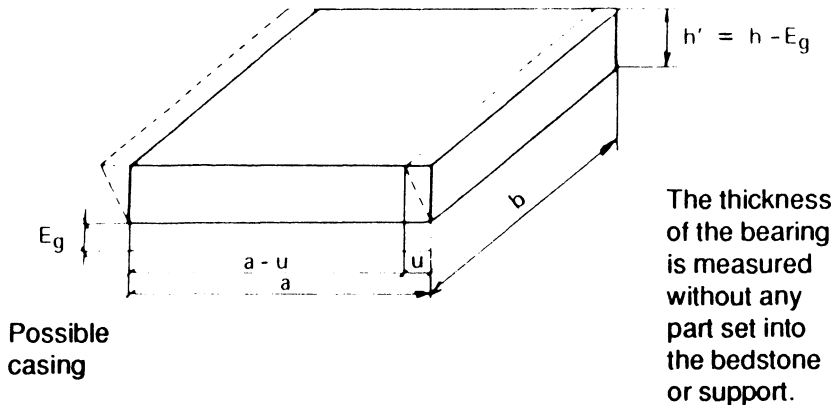
#### 4.3.2 - General calculation principles

##### 4.3.2.1 - Geometrical considerations

The dimensions **a** and **b**, respectively parallel and perpendicular to the beam, are related to those of the beams and the bedstones. Generally, **b** in particular, must be near the plan width of the beam and **a** must be less than **b**.

In addition, the area **A = ab** must be such that the mean pressure remains within the two limits corresponding respectively to the maximum permissible pressure both on the bearing and on the bedstone, and a minimum pressure corresponding to the no-slip condition.

Generally, it is advantageous to use a rubber with a fairly high shear modulus  $G$  to obtain the lowest possible values of  $A$  and  $a$ .



#### 4.3.2.2 - Compression:

The mean pressure is defined by:

$$\sigma_m = \frac{P}{A'} \text{ or } \sigma_m = \frac{P}{A} \quad \text{depending on the checks made to find the most adverse value}$$

with  $A' = (a - u) b$  and  $A = a \cdot b$ ,

$u$  is the tangential shear strain.

For this calculation  $u$  can be given a provisional value equal to  $a/5$ , if the value of  $u$  is unknown.

Depending on their dimensions rubber bearings can become deformed by elastic instability, which imposes a limit on the mean compressive stress.

The critical stress is determined by  $\sigma_{crit} = k \frac{a}{T} G S_i$ .