



GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

GUIDELINES FOR DESIGN OF POT-PTFE BEARINGS FOR RAILWAY BRIDGES

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**RESEARCH DESIGNS & STANDARDS ORGANIZATION
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FOREWORD

Indian Railways have been traditionally using rocker-roller bearings in most of the open web girders. All the standard spans designed in past have been with rocker-roller bearings. In the last two decade Pot-PTFE bearings have been found very convenient due to their lighter weight and almost no requirement of maintenance. RDSO has also issued standard drawings of Pot-PTFE bearing for large spans certain limitations are observed in design of Pot-PTFE bearings for lower spans as a minimum stress level is required to be ensured. Construction units in zonal railways are presently preferring Pot-PTFE bearings in non-standard spans for which designs are approved by them. Many of such designs are done by different designers following varying practices. A necessity was therefore being felt to issue standard guidelines on the subject.

Shri R.K. Goel, Director/SB-I, Shri R.N. Shukla, Senior Section Engineer/Design and Shri R.L. Agnihotri, Senior Section Engineer/Design have made a thorough study of existing design provisions of IRC & BS-5400 and compiled all the relevant design provisions in an easy and systematic manner. They have also covered the important aspects of material specification and inspection in the above guideline. Smt. Suman Verma and drawing staff of B&S Directorate has also made important contribution to bring the guidelines in a presentable form.

I hope that these guidelines will be quite useful for the design engineers of various zonal railways and construction units in designing the Pot-PTFE bearings for railway bridges. Suggestions and comments for improvement will be highly appreciated and gratefully acknowledged.

Date : 7th September, 2006

**(Piyush Agarwal)
Executive Director/B&S**

GUIDELINES FOR DESIGN OF POT-PTFE BEARINGS FOR RAILWAY BRIDGES

1.0 INTRODUCTION

The pot bearing consists of circular, non-reinforced natural rubber or elastomer pad, totally enclosed in a steel pot. The load is applied to the elastomer via a piston attached to the upper bearing plate. A seal is used to prevent rubber extruding between piston & pot. As the elastomer is fully confined within a metal cylinder, it provides a load-carrying medium whilst at the same time provides the bearing with a multidirectional rotational capacity. By themselves, pot bearings do not permit translation. In order to permit translational movement in addition to rotation, plain sliding arrangement is provided over the top plate of pot bearing. PTFE (Poly tetra fluoro-ethylene), having very low coefficient of friction with stainless steel is generally used to design this sliding arrangement. The weight of Pot-PTFE bearing is about 50% of the weight of conventional rocker & roller bearing for the same span. Due to its less weight and due to almost no maintenance, it is desired to provide Pot-PTFE bearings instead of conventional rocker-roller bearings. However, due to certain design constraints these bearings cannot be designed for short spans. This guideline describes in brief the design consideration involved and the limitations in the design of such bearings for Steel girder railways bridges.

Depending on the desired degree of freedom Pot Bearings may be of three types as follows:

Fixed type pot bearing: A type of Pot bearing which alongwith vertical load, bears and transmits horizontal force in any direction and allows rotation about any axis in horizontal plane without permitting any movement in horizontal plane as given fig. 2.

Free sliding type POT-cum-PTFE bearing: A type of Pot bearing which bears and transmits vertical load and allows movement in any direction in the horizontal plane and accommodates rotation about any axis in horizontal plane as given fig. 2.

Guided sliding type POT-cum-PTFE bearing: A type of Pot bearing which alongwith vertical load bears and transmit horizontal force in one direction only and allows movement perpendicular to that direction and allows rotation about any axis in horizontal plane as given fig. 3.

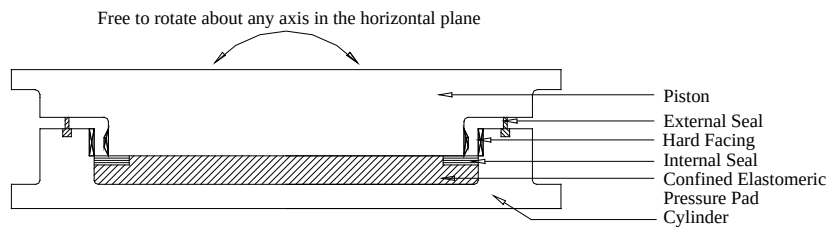


FIG.1 Fixed Type Pot Bearing

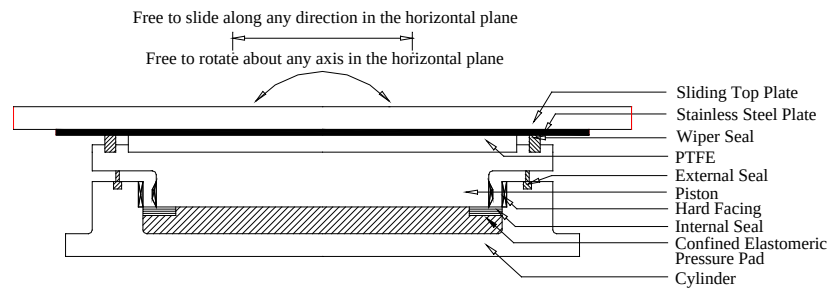
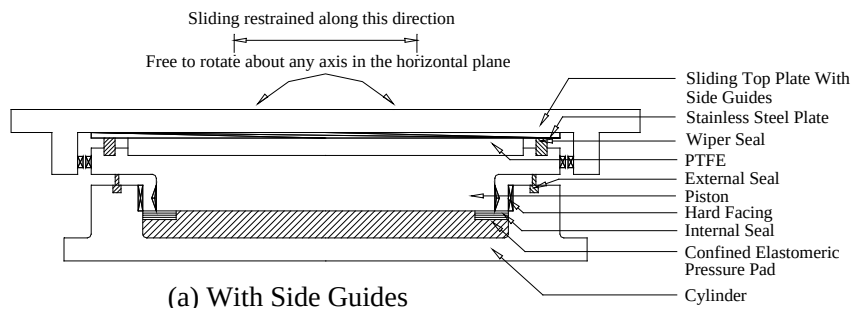


FIG.2 Free sliding type pot-cum-PTFE bearing



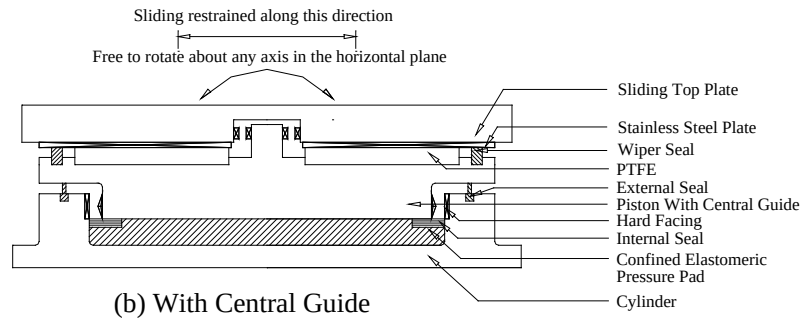


Fig. 3 Guided Sliding Type Pot-Cum-PTFE Bearing

2.0 DESIGN ASPECTS

Pot bearings are fixed against all translation unless they are used with a PTFE sliding assembly with or without restraint in the form of guide along a desired direction to bear and transmit horizontal force. The following actions are there in Pot bearing :

- a) **Compression** – Vertical load is carried through the Piston of the bearing and the elastomeric pad resists the same. Elastomer is incompressible, though deformable. Due to this property, elastomer exerts pressure on the Pot wall like a fluid. Deformation of Pot wall is a concern since this deformation changes the clearances between Pot and Piston. Similarly in the downward direction, the base plate deformation causes the pot wall to rotate in ward.
- b) **Rotation** – Pot bearings are associated with large rotations, which are accommodated by the deformation of elastomeric pad. Large scale rotations can be very damaging to pot bearings due to abrasion and wear of the sealing rings. The elastomeric pad compresses on one side and expands on other, so the elastomer in contact with pot wall tends to leak. To mitigate this problem, silicon grease is generally used.
- c) **Translation** - Lateral load is transferred from the piston to pot by contact between the rim of the piston and the wall of the pot. The contact stresses are generally very high. Such high lateral loads may also contribute to increase wear of the elastomeric pads and may also cause wear and fracture of the sealing rings.

3.0 DESIGN PROVISIONS

3.1 Design of Diameter and Thickness of Elastomeric Pad:

3.1.1 Average stress in confined elastomeric pressure pad of Pot bearing shall not exceed 35 MPa and extreme fibre pressure shall not exceed 40 MPa.

3.1.2 The minimum thickness of the confined elastomeric pressure pad shall not be less than $\frac{1}{15}$ th of its diameter or 16mm, whichever is higher and the diameter shall not be less than 180mm.

3.1.3 Minimum average stress in confined elastomeric pressure pad of Pot bearing, under any critical combination of loads and forces that can coexist, shall in no case be less than 5 MPa.

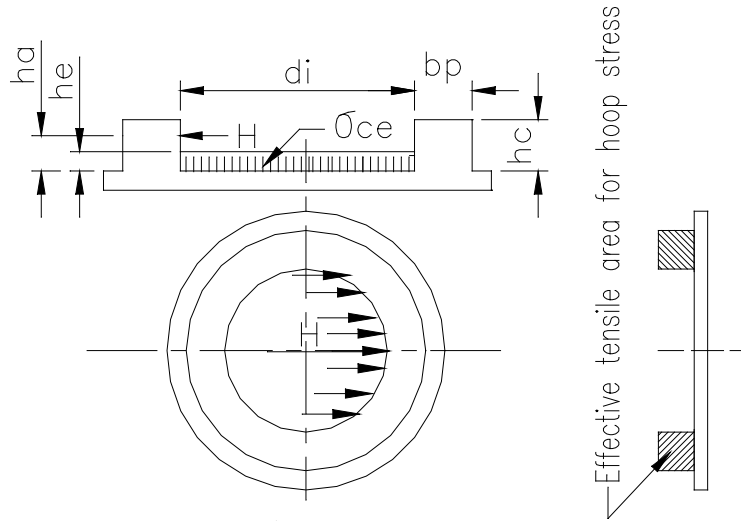


Fig. 4 : Design Principle of Cylinder Wall

3.1.4 The dimension of the confined elastomeric pressure pad shall be such that at design rotation the deflection at the perimeter shall not exceed 15 percent of the pad thickness below the internal seal.

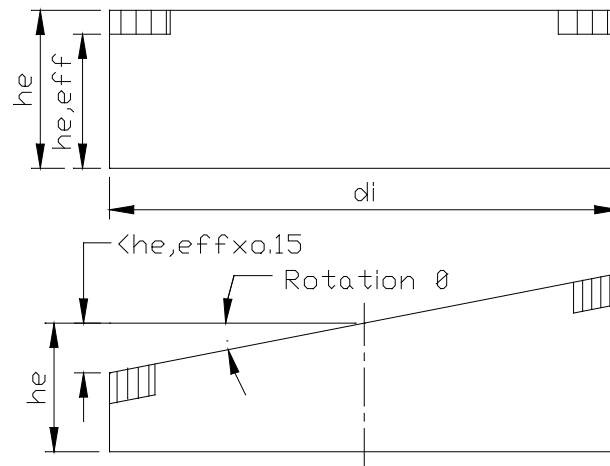


Fig. 5 : Allowable Strain in Elastomeric Pressure Pad

3.2 Design of Pot Wall:

3.2.1 The design of Pot wall is done with respect to the hoop tensile stresses in the cross section of the cylinder wall. Hoop tensile stress in the cross section of cylinder wall due to :

- i. Fluid pressure, $\sigma_{at1} = (d_i \times h_e \times \sigma_{ce}) / (2 \times b_p \times h_c)$
- ii. Horizontal force, $\sigma_{at2} = H / (2 \times b_p \times h_c)$,

Where,

- d_i = diameter of confined elastomeric pressure pad in mm
 h_e = thickness of confined elastomeric pressure pad in mm,
 σ_{ce} = Fluid pressure in confined elastomeric pressure pad due to vertical load in MPa.
 b_p = thickness of cylinder wall in mm
 h_c = height of cylinder wall in mm

Total hoop tensile stress ($\sigma_{ats,cal}$) due to fluid pressure and horizontal force i.e. ($\sigma_{at1} + \sigma_{at2}$), shall not exceed the value of permissible stress in axial tension as specified.

3.2.2 The pot wall is sized on the basis of hoop stress caused by internal pressures arising from vertical load. It must also carry horizontal load, transferred through the piston rim. The stresses caused by horizontal loads are, though complicated but they need to be accounted for. Suitable methods of analysis such as finite element analysis may be used to compute the stresses caused by the horizontal loads. In the absence of any such analysis, the wall thickness may be taken as double the value based on hoop stress due to vertical load alone.

3.2.3 The minimum theoretical clearance between the top edge of cylinder and the bottom edge of piston at design rotation shall not be less than 5mm as given in Fig. 6.

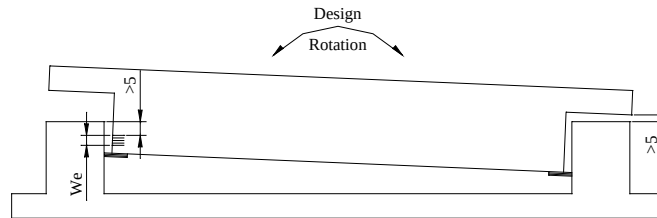


Fig. 6 : Interconnection and Clearance of Components

3.3 Piston and Cylinder Mating Interface (Surface hardness seals)

3.3.1 The mating surface of piston and cylinder of pot bearings shall be metallurgically hardened. The surface hardness shall not be less than 300 BHN.

3.3.2 The contact surface of the piston may be flat according to para 3.3.3 provided the width of the piston contact surface, W , is less than 15mm and if the width of the contact surface, W , is greater than 15mm then the contact surface shall be curved as per Para 3.3.4.

3.3.3 Effective contact width, W_e of the flat contact surface shall be calculated using the following formulae:

$$W_e = (1.3 \times H) / \sigma_p \times d_p$$

Where H = design horizontal force in N.

σ_p = permissible bearing stress of the steel material of the piston or the cylinder, whichever is lower in MPa as per Para 3.8.

3.3.4 Curved contact surface shall be designed using the following formulae:

$$\sqrt{\{(H \times ES) / (18 \times R \times d_d)\}} \leq \sigma_u,$$

$$W_e + \Phi \times d_p \leq w, \text{ and}$$

$$W_e = 3.04 \sqrt{\{(H \times R) / ES \times d_p\}}$$

Where,

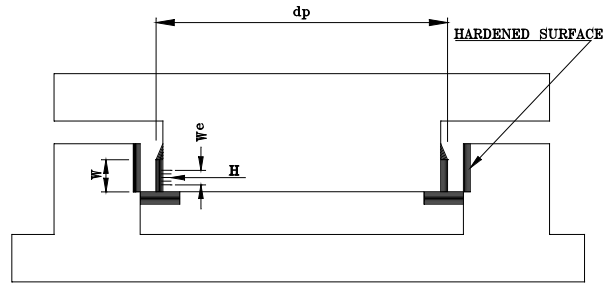
σ_u = ultimate tensile strength of material of the piston or the cylinder, whichever is lower in MPa.

Es = Static modulus of elasticity of steel in MPa

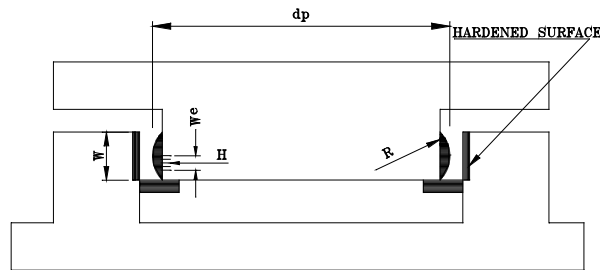
R = Radius of curvature of the curved contact surface in mm

ϕ = Design rotations in Radian

W_e = effective contact width of contact surface in mm



a) FLAT CONTACT INTERFACE



b) CURVED CONTACT INTERFACE

Fig. 7 : Detail of Piston – Cylinder mating Interface

3.4 Seals

3.4.1 Internal Seal

For brass sealing ring type internal seal, 2mm thick and 20mm wide split rings made of metallic brass shall be provided in layers with staggered split positions to prevent extension of confined elastomer, under load between piston and cylinder of Pot bearing. Minimum two layers of rings shall be provided for elastomeric pressure pad of diameter upto 480mm and minimum three layers of rings shall be provided for elastomeric pressure pad of diameters more than 480mm.

3.4.2 External Seal or Dust Seal

This sealing arrangement is provided for preventing ingress of moisture and debris through the gap between the piston and cylinder for pot bearings.

3.4.3 Wiper Seal

This sealing arrangement is provided for retaining the lubrications and preventing contamination of sliding surfaces.

3.5 Sliding Bearing

A big advantage the PTFE sliding bearings have over bearings of the roller type is that eccentricity of loading on the substructure can be obviated. Older types of sliding bearings with metal-to-metal contact may require individual assessment of their eccentricity. It can be seen from Fig. 8 that movement of roller bearing inevitably gives rise to an eccentricity of load from the mean position of half the movement. On the other hand, if the sliding plate is built into the moving structure and the rotational element is built into the substructure, the loading remains axial in spite of movement. Load eccentricities on PTFE bearing surface should not exceed one-eighth of the diameter for circular areas or one-sixth of the side for rectangular areas to ensure that surfaces are not separated and the PTFE squeezed out of the unstressed periphery nor dirt admitted to the interface.

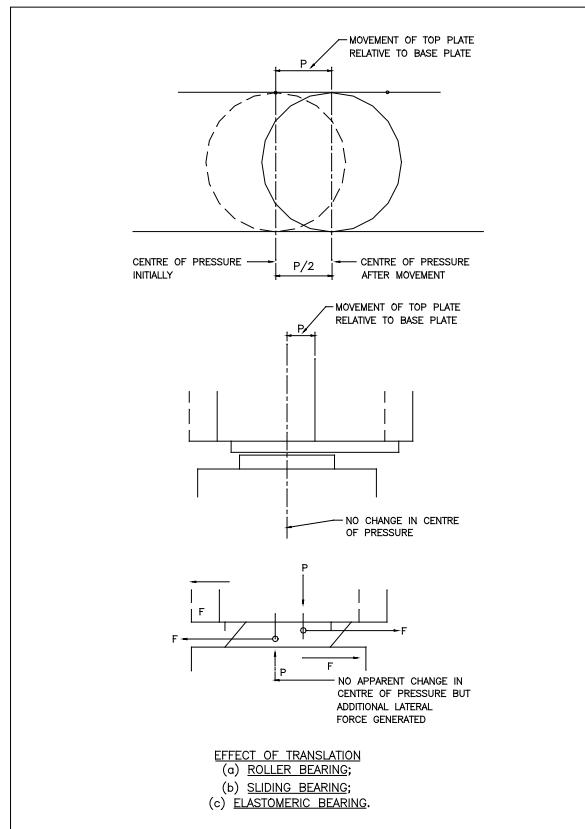


Fig. 8 : Effect of Translation of roller bearing, sliding bearing and elastomeric bearing

3.6 Design of PTFE Guided Sliding Assembly

- 3.6.1 PTFE shall be located into recess of a sufficiently rigid metal backing plate by confinement and shall either be dimpled large sheet(s) or an array of solid (i.e., without dimples) rectangular modules of size 80mm x 50mm. The dimpled large sheets shall be circular or rectangular in shape and may be subdivided into a maximum of four parts. For dimpled sheets with smallest dimension (diameter or

smaller side) exceeding 100mm, contact area shall be taken as the gross area without deduction for the area of the dimples. In arrayed PTFE layout the distance between the individual modules shall not be more than 10mm. The shoulders of the recess should be sharp and square to restrict the flow of PTFE. The thickness of the PTFE and its protrusion from the recess should be related to its maximum plan dimension in accordance with Table 1.

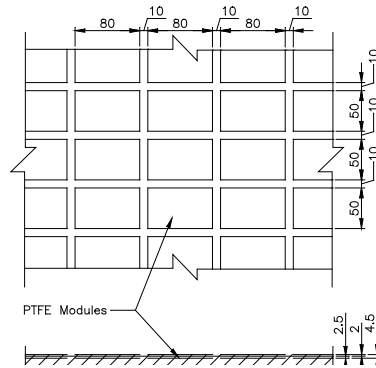


Fig. 9: Typical Arrangement of Modular PTFE

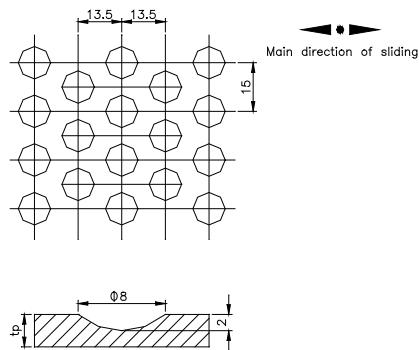


Fig. 10 : Pattern of Dimples in Recessed PTFE Sheet

Table 1. Dimension of Confined PTFE

Maximum dimension of PTFE (diameter or diagonal) (mm)	Minimum thickness (mm)	Maximum protrusion above recess (mm)
≤ 600	4.5	2.0
$> 600, \leq 1200$	5.0	2.5
$> 1200, \leq 1500$	6.0	3.0

3.6.2 Average pressure on confined PTFE shall not exceed 40 MPa and extreme fibre pressure shall not exceed 45 MPa.

3.6.3 The characteristic maximum coefficient of friction for steel sliding on uniformly lubricated PTFE shall be as per Table 2. Liner interpolation may be used for intermediate values. In absence of test data the coefficient of friction of unlubricated PTFE

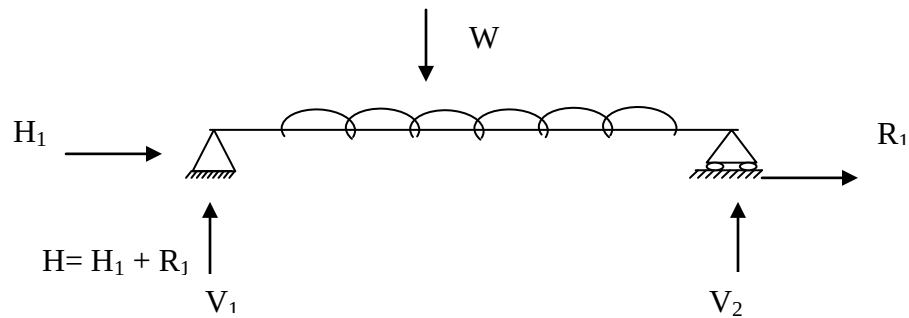
on stainless steel should be taken as twice the value on lubricated PTFE. For design purposes, induced horizontal force caused by the resistance to translational movement due to friction at the PTFE-stainless steel interface shall be determined considering the PTFE as unlubricated.

Table 2- Coefficient of Friction for Stainless Steel Sliding on PTFE

Average pressure on confined PTFE (MPa)	Maximum coefficient of friction	
	on properly lubricated PTFE	on un-lubricated PTFE
5	0.08	0.16
10	0.06	0.12
20	0.04	0.08
≥ 30	0.03	0.06

3.7 Design Horizontal Force:

- 3.7.1 For design of Pot bearings or part thereof the design horizontal force to be considered shall be the resultant of the coexisting active horizontal force, determined from global analysis, and induced horizontal forces, generated due to friction at sliding interface (if any), but shall in no case be less than 10 percent and greater than 25 percent of the design vertical load.



H_1 = Horizontal force determined from global analysis

R_1 = Induced horizontal force due to friction ($\mu \cdot V_2$)

Fig. 11 : Induced Horizontal force due to frictional resistance

- 3.7.2 Induced moment resulting from resistance to rotation due to the effect of tilting stiffness of elastomeric pressure pad shall be determined as follows:

$$M_{e,d} = di^3 \times (k_1 \cdot \theta_p + k_2 \cdot \theta_v),$$

Where,

d_i = diameter of elastomeric pressure pad in mm
 h_e = thickness of confined elastomeric pressure pad in mm
 k_1 & k_2 = shall be as per Table 3. Intermediate values may be obtained by liner interpolation.
 θ_p = calculated value of resultant rotation angle due to permanent

actions and long term effects, in radian

θ_v = calculated value of resultant rotation angle due to variable actions, in radian, and
 $M_{e,d}$ = induced moment in N-mm.

Table 3. Values of Constants k_1 and k_2

d_i/h_e	k_1	k_2
1.5	2.2	101
12.5	1.8	58.8
10	1.5	30.5
7.5	1.1	13.2

Induced moment resulting from resistance to rotation due to friction at the piston-cylinder contact surface due to coexisting horizontal force shall be determined as follows:

$$M_{R,d} = 0.2 \times C \times H,$$

Where,

C = the perpendicular distance from the point of action of horizontal force on cylinder wall to the axis of rotation in mm, Fig. 12.
 H = design horizontal force in N
 $M_{R,d}$ = induced moment in N-mm

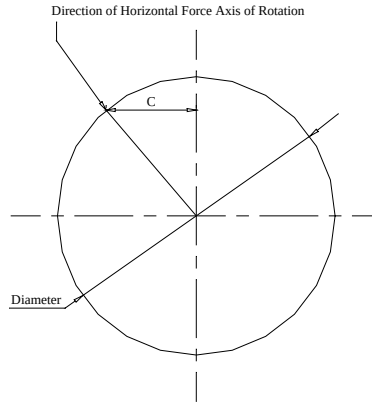


Fig. 12 : Moment Arm for Rotation Resistance Due to Friction

For Pot bearings total induced moment will be $M_{T,d} = M_{e,d} + M_{R,d}$.

Design values of rotational and translational movement shall be determined by multiplying the respective calculated values by a factor of 1.3.

The line of action resultant horizontal force shall be considered at the middle of the contact width of the piston and cylinder.

3.8 Permissible stresses in steel

- 3.8.1 Permissible stress in axial tension σ_{at} shall not exceed $0.6 f_y$, where f_y = minimum yield stress of steel in MPa.
- 3.8.2 Maximum bending stress in tension (σ_{bt}) or in compression (σ_{bc}) in extreme fibre shall not exceed $0.66 f_y$.
- 3.8.3 Maximum shear stress (τ_{vm}) shall not exceed $0.45 f_y$.
- 3.8.4 Maximum bearing stress (σ_p) shall not exceed $0.75 f_y$.
- 3.8.5 Irrespective of any increase in the permissible stress specified the equivalent stress (σ_e) due to coexisting bending (tension or compression) and shear stress obtained from the following formula and shall not exceed $0.9 f_y$.

$$\sigma_{e, cal} = \sqrt{(3 \times \tau_{vm, cal}^2 + \sigma_{bt, cal}^2)} \text{ or } \sigma_{e, cal} = \sqrt{(3 \times \tau_{vm, cal}^2 + \sigma_{bc, cal}^2)}$$

Where,

- $\tau_{vm, cal}$ = Calculated value of shear stress in MPa,
- $\sigma_{bt, cal}$ = Calculated value of bending stress in tension in MPa
- $\sigma_{bc, cal}$ = Calculated value of bending stress in compression in MPa

$\sigma_{e, cal} =$ Calculated value of combined stress in MPa

- 3.8.6 When the effect of wind or earthquake is taken into account the above permissible stresses shall not be increased.
- 3.8.7 The above permissible values are also applicable for stresses on steel structure, adjacent to the bearing.

3.9 Design of Metallic Guides

3.9.1 Guides are used to restrict bearing movement in one direction. In many cases restraint of temperature deformations in the bridge super structure leads to forces in the guides which are difficult to predict, so the guides are required to be designed for min 10% of the vertical load.

3.9.2 Sliding surface for guides of Pot-cum-PTFE bearings and PTFE sliding assemblies shall be made of stainless steel sliding on either confirmed PTFE or composite material or stainless steel. The coefficient of friction at the sliding interface of guides shall be considered as follows:

PTFE to stainless steel	– Value of coefficient of friction for unlubricated PTFE as given in Table above
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Composite material to stainless steel	– 0.05
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Stainless steel to stainless steel	– 0.2
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- 3.9.3 The cantilever vertical projections of metallic guide bearing shall be checked against permissible specified values for bending, shear and combined stresses due to the effect of design horizontal force.
- 3.9.4 Guides shall always be monolithic to the component to which it is connected. The thickness of the component to which the guide is connected shall in no case be less than the thickness of the guide, measured along the direction of horizontal force, acting on the guide.
- 3.9.5 For stainless steel sliding on stainless steel bearing stress at sliding interface of guides shall not exceed 150 MPa. When the effect of wind or earthquake is taken into account the above permissible stresses may be increased by 33.33 percent.
- 3.9.6 For stainless steel sliding on composite material, pressure on composite material shall not exceed 70 MPa.
- 3.9.7 For stainless steel sliding on confined PTFE pressure on PTFE shall not exceed the allowable average pressure as given in Para 3.6.2.
- 3.9.8 For central guides, the thickness of the recessed portion of the sliding plate recessed to accommodate guide shall not be less than 0.3 times the thickness of the sliding plate or 0.3 times the width of recess or 12mm which ever is higher.

- 3.9.9 For central guides the vertical clearance between the guide and the recessed sliding plate shall not be less than 0.2 percent of the length of recess or 2mm whichever is higher.

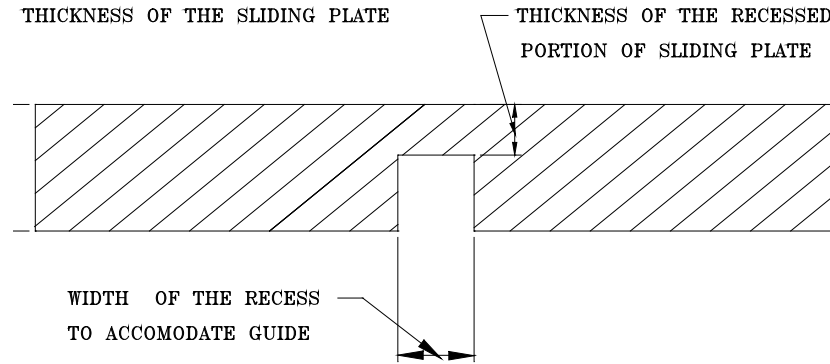


Fig13: Recess in Sliding Plate for Central Guide

3.10 Distribution of Vertical Load

3.10.1 In absence of 3D FEM analysis, load distribution through the bearing component(s) and to the adjacent structure shall be calculated considering effective contact area after one vertical to two horizontal (1V: 2H) distribution of confined elastomer stress as shown in Fig. 14. Flexural stresses due to active and induced moments shall be calculated considering the section modulus of the effective contact area as shown in Fig. 14. Average contact stress, flexural stress and the combined effect shall not exceed the limiting values as specified. For dispersion through sliding components it should be ensured that the dispersed area is contained within the particular component, even when maximum design displacement occurs.

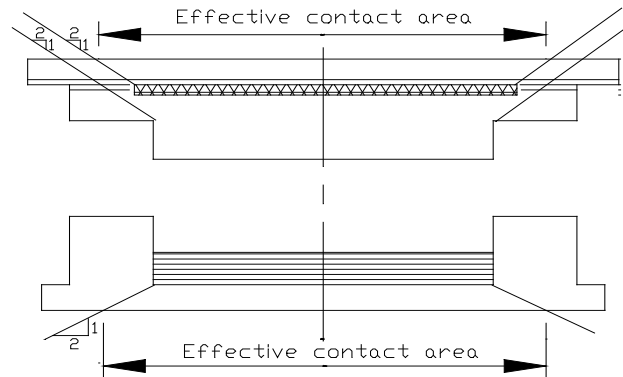


Fig. 14 : Load Dispersion Through Bearing components

3.11 Shear Stress & Bending Stresses

3.11.1 Shear stress at cylinder wall and base interface calculated considering 1mm radial slice of the cylinder due to:

- (i) Fluid pressure, $\tau_{vm1} = (h_e \times \sigma_{ce})/b_p$
- (ii) Horizontal force, $\tau_{vm2} = 1.5 \times H/(d_i \times b_p)$

Where, Parabolic distribution factor is considered as 1.5.

3.11.2 Total shear stress ($\tau_{vm, cal}$) due to fluid pressure and horizontal force, i.e. $\tau_{vm1} + \tau_{vm2}$, shall not exceed the value of permissible stress in shear as specified.

3.11.3 Bending stress at cylinder and base interface calculated considering 1mm radial slice of the cylinder due to:

- (i) Fluid pressure, $\sigma_{bt1} = (6 \times \sigma_{ce} \times h_e^2)/(2 \times b_p^2)$
- (ii) Horizontal force, $\sigma_{bt2} = 1.5 \times 6 \times H \times h_a/(d_i \times b_p^2)$

Where,

h_a = height of line of application of design horizontal force from cylinder wall above base interface in mm,

H = design horizontal force in N.

h_e = thickness of confined elastomeric pressure pad in mm

σ_{ce} = fluid pressure in confined elastomeric pressure pad due to vertical load in MPa

b_p = thickness of cylinder wall in mm

d_i = diameter of confined elastomeric pressure pad in mm.

Parabolic distribution factor is considered as 1.5.

3.11.4 Bending stress ($\sigma_{bt, cal}$) due to fluid pressure and horizontal force, i.e. $\sigma_{bt} + \sigma_{bt2}$, shall not exceed the value of permissible bending stress as specified.

3.11.5 Equivalent stress (σ_e, cal) due to combined bending and shear shall be checked with respect to the specified permissible stress values.

3.11.6 Cantilever projection of guide shall be checked for shear, bending and combined stresses against permissible values specified.

3.12 Average Permissible Direct Bearing Pressure on Pier/abutment

3.12.1 Average permissible direct bearing pressure σ_{cc} on the adjacent concrete structure shall be calculated using the following equation:

$$\sigma_{cc} = \sigma_{co} \sqrt{A_1/A_2}$$

σ_{co} = permissible direct compressive stress in concrete = $0.25 f_{ck}$, where f_{ck} is the characteristic compressive strength of concrete.

A_1 = dispersed concentric area, which is geometrically similar to the loaded area A_2 and also the largest area that can be contained in a plane of A_1 (maximum width of dispersion beyond the loaded area face shall be limited to twice the height).

A_2 = loaded area and,

$$\sqrt{A_1/A_2} \leq 2$$

The projection of the adjacent structure beyond the loaded area shall not be less than 150mm. Adequate reinforcement for spalling and bursting tension shall be provided.

3.12.2 In case of coexisting direct and flexural compressive stresses on the adjacent concrete structure, the following criteria should be satisfied:

$$\sigma_{cc, cal}/\sigma_{cc} + \sigma_{c, cal}/\sigma_c \leq 1$$

Where,

$\sigma_{cc, cal}$ = calculated direct compressive stress,
 $\sigma_{c, cal}$ = calculated compressive flexural stress.

3.12.3 When the effect of wind or earthquake is taken into account, the above permissible stresses may be increased by 25 percent.

3.13 Permissible Limits for Bolt and Screws

3.13.1 For bolts and screws of property class 4.6 (Ref. IS:1367) permissible stress in axial tension σ_{tf} shall not exceed 120 MPa.

3.13.2 For bolts and screws of property class 4.6 (Ref. IS:1367) permissible stress in shear τ_{vf} shall not exceed 80 MPa.

3.13.3 For bolts and screws of property class 4.6 (Ref. IS:1367) permissible stress in axial tension σ_{pf} shall not exceed 250 MPa.

3.13.4 The permissible stresses in bolts and screws of property class higher than 4.6 shall be those given above multiplied by the ratio of its yield stress or 0.2 percent proof stress or 0.7 times its tensile strength, whichever is lesser to 235 MPa.

3.13.5 For bolts and screws subject to both shear and axial tension, the following expression shall be satisfied:

$$\tau_{vf, cal}/\tau_{al} + \sigma_{tf, cal}/\sigma_{al} \leq 1.4$$

Where,

$\tau_{vf, cal}$ = calculated value of shear stress

$\sigma_{tf, cal}$ = calculated value of tensile stress

3.13.6 When the effect of wind or earthquake is taken into account, the above permissible stresses shall not be increased.

4.0 MANUFACTURING TOLERANCES

4.1 The overall dimensions of any assembled bearing or component thereof shall not exceed the values given in table 3.

Table 4 – Overall Dimensional Tolerances

1.	Plan dimension of assembled bearing	: -0mm to +5mm or 0.5 per cent of plan dimension, whichever is higher
2.	Overall height of assembled bearing	: -0mm to +3mm or 1 per cent of overall height, whichever is higher 1 in 200
3.	Parallel-ness of top surface of assembled bearing w.r.t. the bottom surface as datum	: 1 in 200
4.	Height of confined elastomeric pressure pad	: -0 per cent to +5 percent
5.	Thickness of any machined steel component	: -0mm to + 1mm
6.	Overall dimensions of any unmachined cast steel component	: Class 2 of IS:4897
7.	Stainless steel sliding surface	:
	a) Flatness	: 0.0004L, where L = length in direction of movement
	b) Surface finish	: $R_a \leq 0.25 \mu m$ as per IS: 3073

- 4.2 The tolerance of flatness of PTFE shall be 0.2mm where the diameter or diagonal is less than 800mm and 0.025 per cent of the diameter or diagonal where this dimension is greater than or equal to 800 mm. On PTFE surfaces made up of more than one piece of PTFE, the above conditions shall apply to the diameter or diagonal dimension of the inscribing circle or rectangle around the PTFE. The tolerance of center-to-center distance of dimples, depth of dimples and diameter of dimples for dimpled PTFE shall be $\pm 0.5\text{mm}$, $\pm 0.5\text{mm}$ and $\pm 1.0\text{mm}$ respectively.
- 4.3 The dimensional tolerances of confined PTFE shall be as given in Table 4. The gap between the edge of the PTFE sheet and the edge of the recess in which it is confined shall not anywhere exceed 0.5mm or 0.1 per cent of the corresponding plan dimensions of the PTFE sheet, in the direction measured, whichever is greater but in no case shall exceed 1mm. The profile tolerance on the specified projection of PTFE above its confining recess shall be as given in Table 5.

Table 5 - Dimension Tolerance of Confined PTFE and Profile Tolerance of its Projection

Maximum dimension of PTFE (diameter of diagonal) (mm)	Tolerance of Plan dimension (mm)	Tolerance on thickness (mm)	Tolerance on specified projection above recess (mm)
≤ 600	± 1.0	-0 to +0.5	-0 to +0.6
$> 600, \leq 1200$	± 1.5	-0 to +0.6	-0 to +0.6
$> 1200, \leq 1500$	± 2.0	-0 to +0.7	-0 to +0.8

- 4.3.1 Tolerance of fit between different components of bearings shall be as follows:
- 4.3.1.1 For Pot bearings the tolerance of fit between the piston and cylinder shall be +0.75mm to +1.25mm.
- 4.3.1.2 For Pot bearings the tolerance of fit between the confined elastomeric pressure pad and cylinder shall not exceed 0.5 per cent of the diameter of the pad or 1mm, whichever is higher.
- 4.3.1.3 For Pin bearings the tolerance of fit between the pin and cylinder shall be +1.5mm to +2mm. Manufacturing tolerances of the contact surfaces of pin and cylinder shall be as per h 11 and H11 of IS:919 respectively.
- 4.3.1.4 The tolerance of fit between guide(s) and adjacent component shall be +2mm to +4mm.

5.0 FINISHING

- 5.1 All non working surfaces as well as the surfaces to be in contact with structure shall be suitably prepared by sand/shot blasting to Sa 2^{1/2} quality as per IS:9954.
- 5.2 All non working surfaces shall be given suitable protective coating either by painting as per Clause 927.3.3 or by zinc spraying. The total dry film thickness of protective coating shall not be less than 160 µm.
- 5.3 Painted protective coating shall comprise of two coats of epoxy primer enriched with metallic zinc, one intermediate coat of high build epoxy paint reinforced with MIO (Micaceous Iron Oxide) and one coat of high performance epoxy finish paint as per paint manufacturer's specification.
- 5.4 Bearing components to be embedded in concrete structure or surfaces of any component to be in contact with concrete structure shall be given coat of epoxy primer or any other suitable coating before dispatch, to prevent coating shall not affect the bond between the bearing component and the concrete.
- 5.5 Silicon grease shall be applied at the PTFE-Stainless steel interface of Pot bearings.
- 5.6 Suitable lubricant shall be used to lubricate the pressure pad. The lubricant shall be such that it shall not affect the material of the pressure pad.

6.0 TESTING OF BEARING

The actual stress in the elastomer in Pot bearing due to design load effects is limited by the effectiveness of the seal preventing it from extruding between the piston and the pot wall. Since the details of pot bearings vary considering and stress analysis is complex, the design is invariably verified by testing. A sample test proforma is attached as Annexure-III.

7.0 PLACEMENT AND FIXING OF BEARING

7.1 Placement of Expansion End

For placement of expansion end of the bearing at a particular ambient temperature, other than the mean temperature, necessary correction has to be applied. The drawings of Pot-PTFE bearings, generally specify the values of the movement of the point of intersection (of bottom chord and end raker) with reference to center line of base slab under combined effect of temperature and loading. At the mean temperature, the center line of the bearing and the point of intersection shall match under full live load with impact. Therefore, under the dead load alone, the point of intersection of girder shall be towards the span with respect to the centerline of the bearing. Mean temperature is to be taken as $T_{min} + (T_{max} - T_{min})/2$, where T_{min} & T_{max} are the specified values of the minimum and maximum temperatures for the location.

7.2 Fixing of Bearings

- 7.2.1 To cater for vibration and accidental impact, some anchorage should be provided. Anchorage should be accurately set into recesses cast into the structure using templates and the remaining voids in the recesses should be filled with material capable of withstanding the loads involved.
- 7.2.2 Bearings that are to be installed on temporary supports should be firmly fixed to the substructure by anchorage or other means to prevent disturbance during subsequent operations. Finally, voids beneath the bearings should be completely filled with bedding material using the appropriate method.
- 7.2.3 Bearings may be fixed directly to metal bedding plates that may be cast in or bedded on top of the supporting structure to the correct level and location.
- 7.2.4 If the structure is of steel, the bearings may be bolted directly to it. Proper care shall be taken to ensure that there are no mismatch in the bolt holes of the structure and the bearing.
- 7.2.5 Threaded fasteners shall be tightened uniformly to avoid overstressing of any part of the bearing.

8.0 COMMON PROBLEMS WITH POT-CUM-PTFE BEARINGS

The concept of pot bearing is based on effectively confining the elastomer within a metallic piston-cylinder arrangement so that the elastomer remains in a state of uniform strain and no tension is produced while subjected to very large compressive stress. Unlike traditional laminated elastomeric bearing, such a perfectly confined elastomer, while subjected to large compressive stress, behaves

like a viscous fluid and therefore is capable to cater for high degree of multi directional rotational movement. Extremely tight tolerance of manufacturing is required to be maintained together with properly detailed effective sealing system to confine the elastomer effectively. If the steel piston is manufactured with high tolerance relative to the base pot, a condition of steel-to-steel contact develops which inhibits the rotational capacity of the bearing device. When the piston is manufactured with a low tolerance relative to the base pot, the sealing ring has difficulty in containing the elastomer, which acts like a fluid under pressure.

There have been a number of problems with pot bearings, due to inadequate design, incorrect selection of raw material and improper production technique. Leakage of the elastomer has been noted, even with bearings, considered well manufactured. Abrasion or wear of the elastomeric pad has also been noted in some cases. A number of reasons have been postulated for these problems including inadequate clearances or tolerances between the piston and cylinder, excessive rotation, number of rotational cycles or lateral loads, abrasion of the sealing ring, deformation of the Pot due to excess lateral load or gravity load, inadequate surface finish of the portion of piston/cylinder in contact with elastomer pad etc.

The other problems include inability of the steel pot to withstand the transverse loadings, combined with the pressure developed from the elastomer. Another is the fact that satisfactory rotational distribution is not achieved until a load of atleast 25% of the bearing capacity, is applied. The rotational resistance of the confined elastomer pad, though not negligible, is often ignored due to lack of understanding of behaviour of the pad and in some cases due to absence of data. Another problem has been experienced with the pot concept in cold climates. This deals with the rotational element being typically manufactured from synthetic rubber (chloroprene rubber) as in India. During extreme cold temperatures, coupled with high-design pressures, the rotational element has been known to crystallize, which in turn eliminates the rotational capacity of the device. Many cases of such types of failures have forced the design authorities to revert back to traditional steel bearings.

All these defects/deficiencies in the confined elastomeric pad element in a pot bearing cannot be detected after installation and transfer of full load, unless the bearings are removed and elastomeric pressure pad is taken out for inspection of the elastomeric element, metallic cylinder and piston. For the same reason, the behaviour of the elastomeric rotational element cannot be checked visually during proof load and movement testing at manufacturer's works. Therefore, a lot of care has to be exercised at the manufacturing and inspection stage.

9.0 MAINTENANCE

- 9.1 The Pot-cum-PTFE bearings are designed and manufactured so as to make it almost maintenance free. However, the surrounding area of the bearings shall always be kept clean and dry to avoid damage to the bearings.
- 9.2 Suitable easy access to the bearing shall be provided for inspection and maintenance. Provision shall be made for jacking up the superstructure so as to allow repair/replacement of the bearings.
- 9.3 Inspection of bearing at site is required from time to time to ascertain the performance of the bearings. Periodic nominal maintenance of bearing shall be carried out in order to ensure better performance and longer life. The bearings are required to be inspected at an interval of one year for the first five years and at an interval of two years thereafter. However, the bearings shall also be examined carefully after unusual occurrences, like movement of abnormal heavy traffic, earthquakes, cyclones and batterings from debris in high floods.
- 9.4 The inspection shall be preceded by careful cleaning of the bearings and its surrounding space, depending on the actual conditions around the bearings, e.g., deposit of salt, debris, dust or other foreign material.

10.0 ELEMENTS OF INSPECTION

- 10.1 The following are recommended inspection elements and actions which are considered necessary to monitor and unkeep the bearing:
- (i) **Measurement of movement** - During inspection at site, measurements are required to be taken and documented to compute its movement and rotation values in relation to their design values to ascertain whether the performance of the bearings are satisfactory. To ascertain maximum movement, measurement should be taken once during peak winter (early morning) and once during peak summer (after noon) and corresponding atmospheric temperature should be recorded. The recorded value of movement shall be compared with the design values.
 - (ii) **Measurement of dimensions** - Overall dimensions of the bearings are required to be measured and compared with the actual dimensions to ascertain any excessive stress or strain on the bearing.
 - (iii) **Evidence of lock in condition**- If any moveable or rotating part of a bearing is found to be in locked-in/jammed condition, necessary rectification measures shall be taken immediately.
 - (iv) **Evidence of corrosion** - If corrosion of any part of exterior exposed steel surface of the bearing is detected the following

measures may be taken. In addition, the root cause of defect should be searched and proper actions should be taken to avoid recurrence of the problem.

- Detect affect part
- Wire brush the affected portion to clean of it's rust.
- Apply protective coating as per manfuacturer's specifications.

- (v) **Condition of the adjacent bridge structure** - The adjacent structure of the bearings are also required to be inspected for any damage and necessary actions to repair the same, should be taken immediately.

11.0 RESULTS AND ACTIONS

The results of every inspection to be recorded in the inspection report and shall be classified in each case into the following types of action:

- i) No action
- ii) Further measures/long-term monitoring or design analysis needed (e.g., considering extreme temperatures/exposures, variation of loads, etc.).
- iii) Minor repair works e.g. cleaning, repainting etc.
- iv) Repair or replacement of entire bearing or parts of the bearing.

In case of defects where the cause of necessary actions cannot be determined by the inspecting person or the responsible bridge engineer, the bearing manufacturer should be consulted.

12.0 REFERENCES

- [1] IRC-83 (Part III), Standard Specifications and Code of Practice for Road Bridges, Section:IX, Bearings, Part-III:Pot, Pot cum PTFE, Pin and Metallic Guide Bearings.
- [2] BS-3784 Grade 'A', Specifications for Poly tetrafluroethylene (PTFE) Sheet
- [3] BS-5400:Section 9.1, Design of Pot-PTFE Bearings.
- [4] LEE, DAVID J., Bridge Bearings and Expansion Joints, E & FN Spon London, UK.

- [5] IRS Steel Bridge Code, Research Design and Standard Organization, Ministry of Railways, Govt. of India, Lucknow (U.P.)
- [6] RDSO Design Documents for design of Pot-PTFE bearings for different spans and loadings.
- [7] Preprint Third World Congress on Joint Sealing and Bearing System for concrete Structures, American Concrete Institute, Toronto, Ontario, Canada.

MATERIAL SPECIFICATIONS

- (i) Mild Steel : IS: 2062 grade-B
- (ii) Stainless Steel : IS: 6911
- (iii) Cast steel : IS:1030 grade 280-520W.
- (iv) Elastomer pad :
 - a) IRC:83 (Part-II) Standard specifications and code of practice for Road Bridges- Elastomeric Bearings.
 - b) IRC-83 (Part-III) Properties of confined elastomer.
- (v) PTFE :
 - a) BS:3784 grade 'A'. Specification for poly tetrafluroethylene (PTFE) sheet.
 - b) IRC:83 (Part-III) for permissible pressure on confined PTFE.
 - c) BS:5350: Standard method of test for adhesives, Part-C9, Floating Roller Peel Test.
- (vi) Wiper seal & dust seal : RDSO/M&C/RP-194/94.

ANNEXURE-II

Data for design of sliding and fixed Pot PTFE bearing for 76.2m MBG loading

1	Clear span	76.2	m
2	Effective span	78.8	m
3	D.L of girder including Track, gangway etc	322.3	t
4	L.L shear	707.1	t
5	CDA	172.84	t
6	Vertical load due to wind/Bearing	22.88	t
7	Lateral load due to wind/Bearing	22.78	t
8	Lateral load due to seismic effect for zone-v	30.43	t
9	Longitudinal force/Bearing	61.14	t
10	Max. horizontal movement -	62	mm
11	Deflection at center	116	mm
12	Vertical load due to seismic effect for zone-v	44.5	
13	Total vertical load/bearing with wind	323.44	t
14	Total vertical load/bearing with seismic effect for zone v	345.06	t
15	Rotation Theeta	0.0029442 radian	< 0.25
		0.1686876	degree

ANNEXURE-III

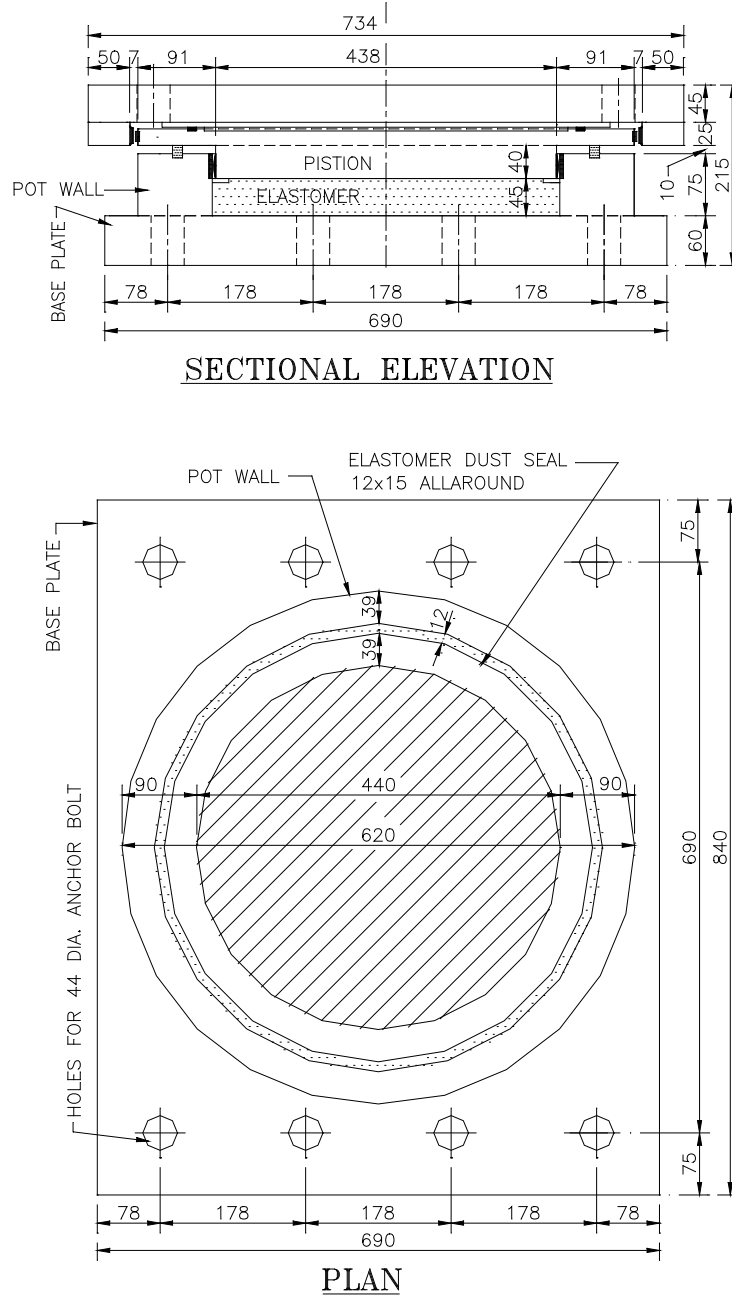


Fig. 15 : Typical Sectional Elevation and Plan of Sliding Bearing for 76.2m span MBG loading

CHECK LIST OF INSPECTION FOR FABRICATION OF POT PTFE BEARING

1.0 Raw Material

- | | | |
|----|----------------------------|---|
| 1. | M.S. Steel | As per IS 2062 Gr. B or C as mentioned in Drawing |
| 2. | Cast Steel | As per IS 1030 Gr. 280-520 W or As per IRC 83 (iii) as mentioned in drawing or contract agreement |
| 3. | PTFE | As per drawing or IRC 83 (iii) BS 3483 Gr. A |
| 4. | Elastomer | As per IRC 83 (Part II) |
| 5. | Stainless Steel Plate | IS-6911 |
| 6. | Internal seal (brass ring) | As per IS 410 |
| 7. | Wiper seal and dust seal | As per drawing and RDSO's Specification M&C/RP-194/94 |

2.0 Dimensional Test

2.1 Fixed Bearing (Pot Bearing)

Sl. No.	Item	Dimension (mm)		Whether within tolerance
		Nominal	Measured	
1.	Pot cylinder and elastomer			
	a)	Inner dia of the Pot		
	b)	Outer dia/size of the pot		
	c)	Center to center distance of holes in the lugs of pot		
	d)	Width of lugs (measure and record width of all lugs)		
	e)	Thickness of the pot wall		
	f)	Thickness of the base of pot		

- g) Thickness of lugs
- h) Thickness of the pot wall
- i) Inner height of the pot
- j) Thickness of elastomer

2. Piston/top plate

- a) Thickness of the top plate in piston
- b) Thickness of the top plate above pot wall
- c) Dia of the top plates
- d) Center to center distance of holes in the lugs of top plate
- e) Thickness of lugs

3. Sealing ring

- a) Thickness
- b) Width
- c) Inner diameter

4. High tensile bolts and washers

- a) Dia of bolt sleeve with HT anchor
- b) Dia of bolt hole in bolt sleeve
- c) Dia of HT anchor
- d) Length of bolt sleeve
- e) Length of bolt sleeve with anchor

5. Overall height of bearing in assembled condition

2.2 Free Bearings (Pot cum PTFE bearings)

Sl. No.	Item	Dimension (mm)		Whether within tolerance
		Nominal	Measured	
1.	Pot cylinder and elastomer			
	a) Inner dia of the Pot			
	b) Outer dia/size of the pot			
	c) Center to center distance of holes in the lugs of pot			
	d) Width of lugs (measure and record width of all lugs)			
	e) Thickness of the pot wall			
	f) Thickness of the base of pot			
	g) Thickness of lugs			
	h) Thickness of the pot wall			
	i) Inner height of the pot			
	j) Thickness of elastomer			
2.	Saddle Plate & PTFE			
	a) Size of the saddle plate			
	b) Size of PTFE sheet in plan			
	c) Thickness of PTFE sheet			
	d) Depth of dimples			
	e) Dia dimples			
	f) Spacing of dimples			
	g) Depth of groove in saddle plate for housing			
	h) Thickness of saddle plate			

- i) Thickness of the collar of saddle plate

3. Top Plate, Stainless Steel & Ear Plate

- a) Plan size of underside of top plate
- b) Thickness of top plate
- c) Plan size of steel plate
- d) Size of the lugs of top plate

4. Sealing ring

- a) Thickness and no.
- b) Width
- c) Inner diameter

5. High tensile bolts and washers

- a) Dia of bolt sleeve with HT anchor
- b) Dia of bolt hole in bolt sleeve
- c) Dia of HT anchor
- d) Length of bolt sleeve
- e) Length of bolt sleeve with anchor

6. Overall height of bearing in assembled condition