STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES

SECTION - IX
BEARINGS

(SPHERICAL AND CYLINDRICAL)
PART - IV

INDIAN ROADS CONGRESS
2014

STANDARD SPECIFICATIONS
AND
CODE OF PRACTICE
FOR
ROAD BRIDGES

SECTION - IX
BEARINGS

(SPHERICAL AND CYLINDRICAL)
PART - IV

Published by:

INDIAN ROADS CONGRESS

Kama Koti Marg,
Sector-6, R.K. Puram,
New Delhi-110 022

August, 2014

Price : ₹ 600/-
(Plus Packing & Postage)

First Published : August, 2014

Printed by India Offset Press, Delhi-110064

1000 Copies

Contents

PERSONNEL OF THE BRIDGES SPECIFICATIONS AND STANDARDS COMMITTEE
(As on 6th January, 2014)

1.	Kandasamy, C. (Convenor)	Director General (RD) & Spl. Secy. to Govt. of India, Ministry of Road Transport and Highways, Transport Bhavan, New Delhi
2.	Patankar, V.L. (Co-Convenor)	Addl. Director General, Ministry of Road Transport and Highways Transport Bhavan, New Delhi
3.	Pathak, A.P. (Member-Secretary)	Chief Engineer (B) S&R, (Ministry of Road Transport & Highways, Transport Bhavan, New Delhi

Members

4.	Agrawal, K.N.	DG(W), CPWD (Retd.) Ghaziabad
5.	Alimchandani, C.R.	Chairman & Managing Director, STUP Consultants (P) Ltd., Mumbai
6.	Arora, H.C.	Chief Engineer (Retd.) MORTH, New Delhi
7.	Bagish, Dr. B.P.	C-2/2013, Vasant Kunj, Opp. D.P.S. New Delhi
8.	Bandyopadhyay, Dr. N.	Director, Stup Consultants (P) Ltd. New Delhi
9.	Bandyopadhyay, Dr. T.K.	Joint Director General (Retd.) INSDAG, Kolkata
10.	Banerjee, A.K.	Chief Engineer (Retd.) MoRT&H, New Delhi
11.	Banerjee, T.B.	Chief Engineer (Retd.) MoRT&H, New Delhi
12.	Basa, Ashok	Director (Tech.) B. Engineers & Builders Ltd., Bhubaneswar
13.	Bhasin, P.C.	ADG (B), (Retd.), MoRT&H, New Delhi
14.	Bhowmick, Alok	Managing Director, Bridge & Structural Engg. Consultants (P) Ltd., Noida
15.	Bongirwar, P.L.	Advisor, L&T, Mumbai
16.	Dhodapkar, A.N.	Chief Engineer (Retd.) MoRT&H, New Delhi
17.	Ghoshal, A.	Director and Vice President, STUP Consultants (P) Ltd. Kolkata
18.	Joglekar, S.G.	Vice President, STUP Consultants (P) Ltd. , Mumbai
19.	Kand,, C.V.	Chief Engineer (Retd.), MP, PWD Bhopal
20.	Koshi, Ninan	DG(RD) & Addl. Secy., (Retd) MOST, New Delhi
21.	Kumar, Ashok	Chief Enginee (Retd.), MoRT&H, New Delhi
22.	Kumar, Prafulla	DG (RD) & AS, MoRT&H (Retd.) New Delhi
23.	Kumar, Vijay	E-in-Chief (Retd.) UP, PWD,
24.	Manjure, P.Y.	Director, Freyssinet Prestressed Concrete Co. Mumbai
25.	Mukherjee, M.K.	Chief Engineer (Retd.) MoRT&H, New Delhi
26.	Nagpal, A.K.	Prof. IIT, New Delhi
27.	Narain, A.D.	DG (RD) & AS, MoRT&H (Retd.) New Delhi
28.	Ninan, R.S.	Chief Engineer (Retd.) MoRT&H New Delhi
29.	Pandey, R.K.	Chief Engineer (Planning), MoRT&H, New Delhi

30.	Parameswaran, Dr. (Mrs.) Lakshmy	Chief Scientist (BAS), CRRI, New Delhi
31.	Raizada, Pratap S.	Vice President (Corporate Affairs). Gammon India Ltd. Mumbai
32.	Rao, Dr. M.V.B.	A-181, Sarita Vihar, New Delh
33.	Roy, Dr. B.C.	Senior Executive Director, M/s. Consulting Engg. Services India (Pvt.) Ltd. Gurgaon
34.	Saha, Dr. G.P.	Executive Director Construma Consultancy (P) Ltd. Mumbai
35.	Sharan, G.	DG (RD) & Spl. Secy (Retd.) MoRT&H, New Dellhi
36.	Sharma, R.S.	Chief Engineer (Retd.) MoRT&H, New Delhi
37.	Sinha, N.K.	DG(RD) & SS, (Retd.) MoRT&H New Delhi
38.	Subbarao, Dr. Harshavardhan	Chairman & Managing Director, Construma Consultancy (P) Ltd. Mumbai
39.	Tandon, Mahesh Prof.	Managing Director, Tandon Consultants (P) Ltd.,New Delhi
40.	Thandavan, K.B.	Chief Engineer (Retd.) MoRT&H, New Delhi
41.	Velayutham, V.	DG (RD) & SS (Retd.) MoRT&H, New Delhi
42.	Viswanathan, T.	7046, Sector B, Pocket 10 , Vasant Kunj ,New Delhi
43.	The Executive Director (B&S)	RDSO, Lucknow
44.	The Director and Head,	(Civil Engg.), Bureau of Indian Standards, New Delhi

Corresponding Members

1.	Raina, Dr. V.K.	Consultant (W.B.)
2.	Singh, R.B.	Director, Projects Consulting India (P) Ltd. New Delhi

Ex-Officio Members

1.	President, IRC & Director General (Road Development) & Special Secretary	(Kandasamy, C.), Ministry of Road Transport and Highways, New Delhi
2.	Secretary General	(Prasad, Vishnu Shankar), Indian Roads Congress, New Delhi

STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES SECTION - IX BEARINGS PART - IV (SPHERICAL AND CYLINDRICAL)

INTRODUCTION

The Bearings, Joints and Appurtenances Committee (B-6) of the Indian Roads Congress was constituted in 2011 with the following personnel:

Sharan, G.	Convenor
Pandey, R.K.	Co-Convenor
Gaharwar, Dr. S.S.	Member-Secretary

Members

Banerjee, A.K.	Kumar, Ashok
Bagish, Dr. B.P.	Majumdar, S
Datta, R.K.	Mitra, Dr. A.J.
Deshpande, V.P.	Ninan, R.S.
Gupta, Vinay	Patankar, V.L.
Ghosh, Prof. Achyut	Pandey, A.K.
Gupta, D.K.	Prakash, Suraj
Gupta, Ujjwal	Rao, Dr. M.V.B.
Jambekar, A.R.	Rathore, Jitendra
Khaira, V.S.	Sharma, D.D.
Kurian, Jose	Singh, B.N.

(Rep. of RDSO, Lucknow)

Invitee

Gupta, A.K.	Manjure, P.Y.
Ghosh, S.	Panja, A

Ex-officio Members

President, IRC & Director General (Road Development) & Special Secretary	(Kandasamy, C.), Ministry of Road Transport and Highways, New Delhi
Secretary General	(Prasad, Vishnu Shankar), Indian Roads Congress, New Delhi

Shri Jitendra Rathore prepared the initial draft with the active support of Shri S. Mazumdar. The initial draft was discussed in the meetings of the B-6 Committee. The final draft of IRC:83-2014 (Part IV), "Standard Specifications and Code of Practice for Road Bridges", Section IX Bearings (Spherical and Cylindrical), was discussed and approved by the Bearings, Joints and Appurtenances Committee (B-6) held on 30th November, 2013 for placing it in the Bridges Specifications and Standards Committee (BSS). The Bridges Specifications and Standards Committee (BSS) approved this document in its meeting held on 6th January, 2014. The Executive Committee in its meeting held on 9th January, 2014 approved this document. Finally, the document was considered by IRC Council in their 201st meeting held on 19th January, 2014 at Guwahati (Assam), and approved the document for publishing.

1 SCOPE

This Code deals with the requirements for the materials, design, manufacture, testing, installation and maintenance of Spherical and Cylindrical Bearings for Bridges. The provisions of this code are meant to serve as a guide to both design and construction engineers, but mere compliance with the provisions stipulated herein will not relieve the manufacturer in any way of their responsibility for the performance and soundness of the product in the structure.

The provisions of this code shall apply for operating temperature between - 15°C and + 50° Service life of Spherical Bearings depends on the condition of rotation and translation movements posed by the Structure on Bearings. The provisions made in this code are based on an assumed working life of the Spherical Bearing upto 30 years with PTFE and of 50 years with UHMWPE.

Bearings which are subjected to Tensile Loads are beyond the scope of this code as requiring special arrangement/configuration. Established codes and Specifications worldwide may please be referred for such Bearings. However this specification may be considered as a guide for general purpose in such cases.

Spherical and Cylindrical Bearings with an included angle (2θ) greater than 60° and 75° respectively are beyond the scope of this code. In no case the radius of curvature shall be less than the projected diameter of the Spherical curved sliding surface.

Sliding surfaces with a diameter of the circumscribing circle less than 75 mm or greater than 1500 mm are beyond the scope of this code. For cases of bearing application requiring larger diameter of the sliding surface, established codes, Specifications and approval documents worldwide may please be referred. The recommendations of such document for all aspects incl. design, material, manufacturing and tolerances and testing and acceptance shall then be applicable in addition to this specification which may well be considered as a guide to such cases.

Spherical Bearings and Cylindrical Bearings for use as temporary devices during construction, for example during launching of the super-structure, are also beyond the scope of this code. However, this specification may well be considered as a guide to these cases.

2 DEFINITION OF PRODUCT AND INTENDED USE

2.1 Definition of the Product

Spherical Bearing

The Spherical Bearing consists of a pair of matching concave and convex steel spherical backing plates with a low friction sliding interface in between thereby permitting rotation by in-curve sliding as shown in **Fig. 1**. For the purpose of providing the movement ability, the bearings may be combined with flat sliding elements, guides and restraining rings as shown in **Fig. 2.**

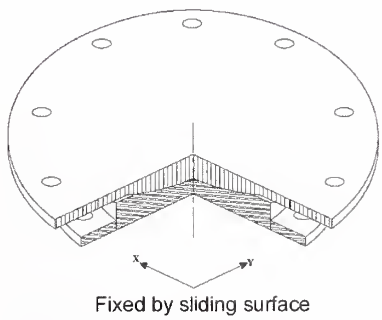
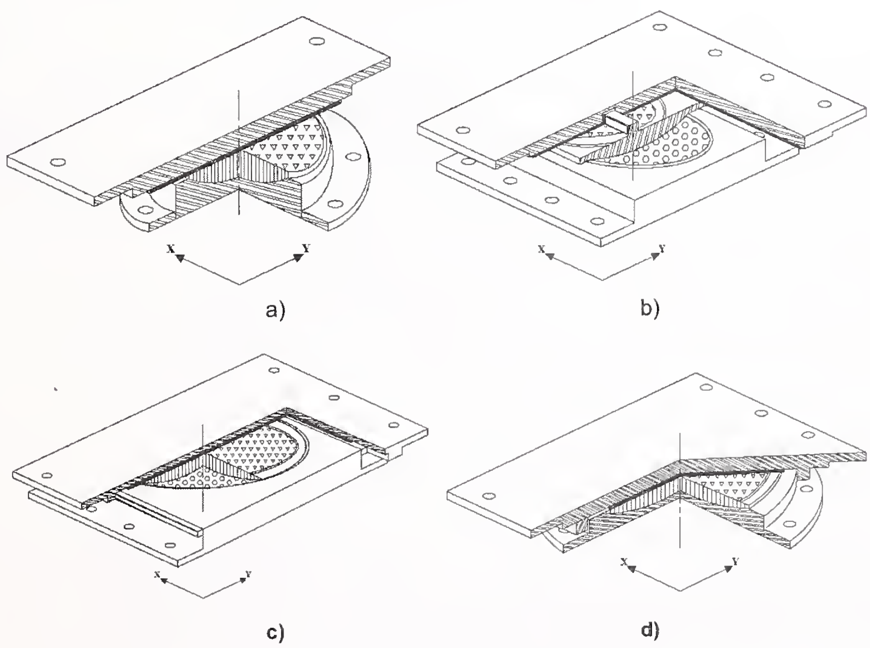


Fig. 1 Spherical Bearing



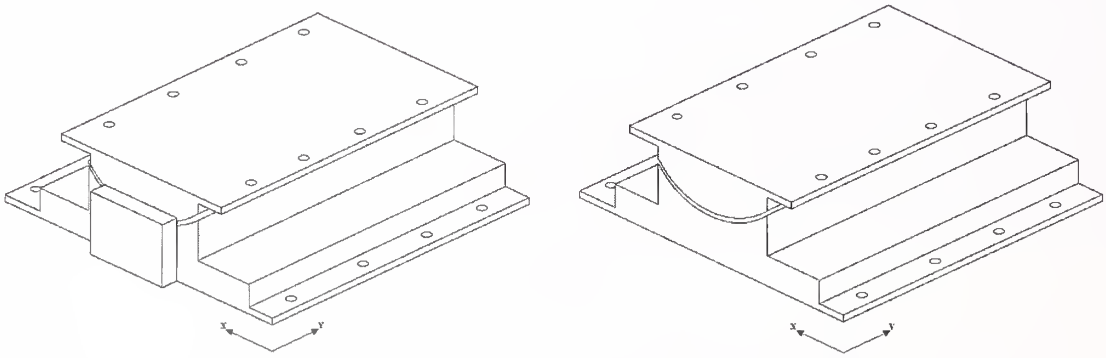
Key

a) free for displacements in any direction
b) internally guided for displacement in one direction
c) externally guided for displacement in one direction
d) fixed by a restraining ring

Fig. 2 Spherical Bearings Combined with Flat Sliding Elements

Cylindrical Bearing

The Cylindrical Bearing consists of a concave cylindrical metal backing plate affixed with a low friction sliding surface to provide friction less sliding against the matching convex cylindrical surface from another plate as shown in **Fig. 3**. Cylindrical Bearings are also used in combination with flat sliding elements and guides to form free or guided bearings as shown in **Fig. 4**.

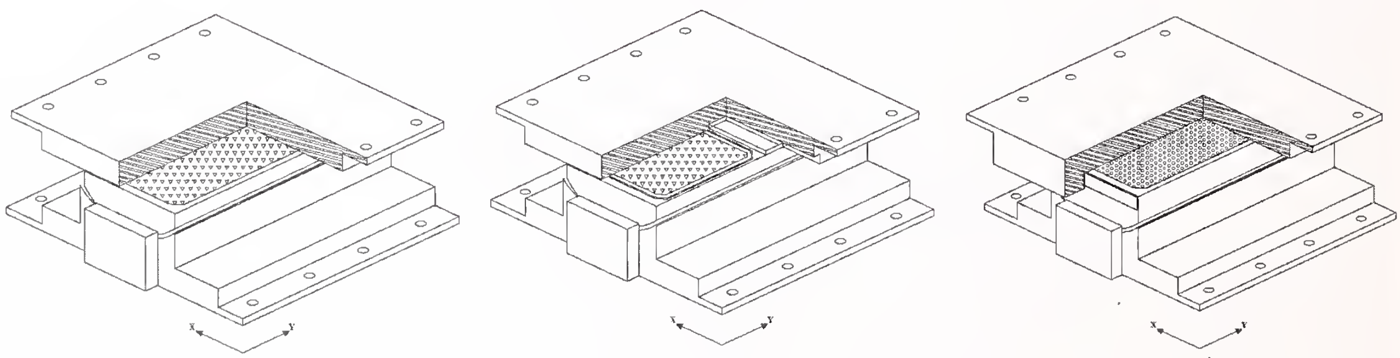


a) b)

Key

a) fixed by end stoppers and sliding surface
b) without end stoppers for displacements in y direction

Fig. 3 Cylindrical Bearings



a) b) c)

Key

a) free for displacements in any direction
b) guided by an internal guide for displacements in x direction
c) guided by external guides for displacements in x direction

Fig. 4 Cylindrical Bearings Combined with Flat Sliding Elements

2.2 Intended Use

Spherical Bearings are suitable for all types of structures especially for long span and continuous structures, Cable Stay and Suspension Bridges with relatively large and repetitive rotation and translation requirements caused by variable loads, and for superstructures that induce fast sliding displacements in bearings, e.g. in case of Road cum Railway Bridges.

3 TERMS OF REFERENCE AND SYMBOLS

3.1 Terms and Definition

Base Plate

Top and Bottom Steel Plates of the Bearing Assembly interfaced with the structure Concrete/Steel member.

Backing Plate

Steel Plates confining the low friction sliding material like PTFE/UHMWPE, etc.

Guides

Metallic projection from the Top Plate getting locked with the adjacent steel component or vice versa thereby restraining the movement of the Bearing in the direction perpendicular to that.

Mating Surface

Flat or curved hard smooth surface of stainless steel, polished steel or chrome plated sliding against the PTFE or other low friction sliding material.

Sliding Surface

PTFE or UHMWPE low friction thermoplastic material mounted on flat or curved backing plate providing low friction sliding to the mating surface.

Sliding Interface

Combination of Mating and Sliding Surfaces providing relative low friction sliding displacement.

Approval Documents e.g. ETA, FHWA or similar

The special approval documents acceptable under this code shall be that from International reputed approving bodies having proven experience of research and Testing in the field of Structural Bearings and covering within the approval document all aspects incl. design, material, manufacturing, tolerances and acceptance. Isolated approvals or qualification of individual components separately that proposed to be used inside the Bearing shall not be treated as approval document referred in this specification.

3.2 Notations and Symbols

The commonly used notations and symbols are defined here below. These notations and symbols uniquely or in combination used in the expressions in further clauses of this code are also defined at the places of their occurrence:

Notations

A geometrical area of flat sliding surface or projected area of the curved sliding surface/specified cross sectional area of the bolt

a effective weld size in mm (taking in account throat thickness)

a_b	minor side of the backing plate
A_P	compressed (un-deformed) sliding surface under load
A_r	reduced contact area of the sliding surface expressed by the expression, $A_r = A . \lambda$
b	distance (in elevation) between the sliding surface and x-section under consideration (refer **Fig. 5**)
b_b	major side of the backing plate
B_s	width of sliding surface (PTFE/UHMWPE/others) strip
B_x	width of guide bar
c	distance (in plan) between the interface resisting/transferring the horizontal force and the centre of the sliding surface (refer **Fig. 8**)
c_l	clearance between secondary sliding surface (guides)
d_b	diameter of the backing plate
D_i	internal dia of the restraining ring
e	eccentricity
E_c	short term static modulus of elasticity of concrete i. e. $5000 \sqrt{f_{ck}}$
E_{ce}	modulus of elasticity of concrete, for permanent load effects i.e. 0.5 E_c
E_s	modulus of elasticity of steel i.e. 210000.00 MPa
f	strength
f_k	characteristic compressive strength of Sliding Surface (PTFE/UHMWPE)
f_u	specified min. tensile strength of the material
f_y	specified min. yield strength of the material
h	projection of the flat/concave Sliding Surface above the recess
h_{f1}	force lever arm for restraining ring in fixed bearing (refer **Fig. 6**)
h_{f2}	force lever arm for guide bars in Guided Bearing (refer **Fig. 8**)
h_{rr}	depth of the restraining ring
k	reduction factor to reduce creep effects in sliding surface
L	diameter of the flat/projected diameter of the concave sliding surface
L_0	reference diameter = 300 mm
L_r	length of rocker strip
L_s	length of Sliding surface strip (PTFE/UHMWPE/others)
L_x	length of guide bar

n	number of bolts
N	vertical load
r	radius of curvature of the curved sliding surface
R_{rr}	radius of curvature of the contact surface with the restraining ring
R_{rs}	radius of curvature of the rocker strip contact surface with the bottom component
t	thickness
t_b	thickness of the backing plate
t'_b	equivalent constant thickness for concave backing plate
t_{rr}	thickness of the restraining ring
u	force free perimeter of PTFE/UHMWPE free to bulge
V	horizontal force
V_{pd}	design value of anchorage (bolt) resistance in shear
V_{Rd}	total resistance to sliding that including the anchorage strength and frictional resistance

Suffixes

P	PTFE (Polytetrafluoroethylene)
U	UHMWPE (Ultra High Molecular Weight Polyethylene)
b	backing plate
d	design value of movement at Strength/Ultimate (ULS) condition
k	design value of movement at Characteristic/fundamental/Service (SLS) condition
sd	design value of load/force at Strength/Ultimate (ULS) condition
sk	design value of load/force at Characteristic/fundamental/Service (SLS) condition
x	longitudinal axis
y	transverse axis
xy	resultant

Symbols

α	design rotation
α_d	maximum design rotation in ULS
β	angle between the vertical and the resultant applied horizontal load
β_w	Co-relation factor for Welds, to be taken as 0.9
θ	half included angle of the curved sliding surface
γ_m	partial safety factor

γ_{ms} partial safety factor for sliding

μ co-efficient of friction

μ_{fr} co-efficient of friction for secondary sliding surface

μ_k co-efficient of friction between the bearing and substrate, 0.4 for steel on steel and 0.6 for steel on concrete

σ pressure due to vertical load

σ_{ss} maximum average contact stress permitted on the sliding surface

λ coefficient used to work out reduced contact Area, Ar

Δz maximum deviation of plane or curved sliding surface from theoretical surface

Abbreviations

avg. average

max. maximum

min. minimum

perm. design permanent load/force

PTFE Poly tetra fluoro ethylene

UHMWPE Ultra High Molecular Weight Poly ethylene

ETA European Technical Approval

FHWA Federal Highway Administration

4 MATERIAL SPECIFICATION

4.1 Steel

Steel for bearing main components shall be rolled steel in accordance with IS:2062 Grade E350 min. or cast steel in accordance with IS:1030 Grade 340-570W except for calotte which shall be only fine grain rolled steel conforming to IS:2062 Grade E 350 or above. Stainless Steel if used in special cases for the Bearing main components including backing plates for flat and curved sliding interfaces shall be in accordance with AISI 304 or Duplex Steel (UNS S32205) of ASTM A240. Equivalent or superior grades as per other national and international specification with proven performance and suitability to application requirements shall also be acceptable. Steel for Dowels etc. shall be rolled steel in accordance with IS:2062 Grade E250 B min.

4.2 Low Friction Thermo-Plastic Sliding Material (PTFE or UHMWPE)

The material shall be either pure polytetrafluoroethylene (PTFE), free sintered, without regenerated materials and fillers or Ultra High Molecular Weight Polyethylene (UHMWPE) having high material strength and low frictional properties. The pattern of dimples shall be as described in **Annexure-A** "Properties of Low Friction Sliding Material". The sliding surface shall be recessed in the metal backing plate compulsorily.

Use of Modified sliding material (UHMWPE) having frictional properties superior to that of PTFE combined with enhanced load bearing capacity and ability to provide high velocity displacement with longer service life can be considered for both Primary (flat or curved) and secondary (guides) sliding interfaces. However, this shall be subject to the availability of approval documents from International approving bodies like ETA, FHWA or similar, acceptance by other Leading International Specifications, references of its usage in the Bearings application, satisfactory and proven test and performance records etc.

4.3 Reduction Factor, (k) to Reduce Creep Effects

The characteristic compressive strengths of PTFE/UHMWPE are given in **Table 1** and valid for effective bearing temperatures upto 30°C for PTFE and 35°C for UHMWPE. For bearings exposed to a maximum effective bearing temperature in excess of above mentioned respective values, the aforementioned values shall be reduced by 2 percent per degree above 30°C/35°C in order to reduce creep effects of the PTFE/UHMWPE respectively.

Table 1 Characteristic Compressive Strength (f_k) of Sliding Materials

Material	Application Condition	Loading Condition	f_k (MPa)
PTFE	Main Bearing Surface	Permanent and Variable Loads	90
	Guides	Variable Loads	90
		Temperature, Shrinkage and Creep	30
		Permanent Loads	10
UHMWPE	Main Bearing Surface	Permanent and Variable Loads	180
	Guides	Variable Loads	180
		Permanent Loads, Effects of Temperature, Shrinkage and Creep	60
CM1	Guides	Permanent and Variable Loads	200
CM2	Guides	Permanent and Variable Loads	120

4.4 Stainless Steel

Stainless Steel for the Sliding Interface shall be in accordance with AISI 316L or $O_2Cr_{17}Ni_{12}Mo_2$ of IS:6911. The Stainless Steel sheet shall be attached to its backing plate either by bonding, counter screwing or by continuous fillet weld.

The thickness of the Stainless steel sheet shall be 1.5 mm if attached by bonding, minimum 1.5 mm or above if attached by continuous fillet weld and min. 2.5 mm when affixed by counter screwing.

Surface roughness (R_{y5i}) of the polished Stainless Steel sheet shall not exceed 1 μm in accordance with EN ISO 4287.

Care shall be taken to ensure that the Stainless steel sheet is fully in contact with the backing plate over the area which will be in contact with the sliding surface. To avoid the danger of air entrapment, air releasing spots of max 10 mm length on two opposite sides may be provided while attaching the stainless steel sheet to the backing plate by continuous fillet weld.

When attaching the Stainless steel sheet by counter screwing, corrosion resistant fasteners compatible with the Stainless 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 sliding surface with the maximum spacing limited to 300 mm Intermediate and 50 mm at the edges.

4.5 Hard Chromium Plated Surfaces

The entire curved surface of the convex steel plate mating with concave sliding surface shall be hard chromium plated. Hard chromium plating and the surface of its base shall be free from surface porosity, shrinkage cracks and inclusions. Small defects may be repaired e.g. by pinning prior to hard chromium plating.

The thickness of the hard chromium plating shall be at least 100 μm and the final surface roughness of the plated surface shall not exceed 3 μm.

Both the base material and hard chromium plating may be polished to achieve the finish less than the specified surface roughness.

4.6 Material Combinations

The permissible combination of the materials (sliding and mating surfaces) to be used for sliding interfaces shall be as given in **Table 2**. The sliding surface shall be lubricated in accordance with **Clause 4.8**.

Table 2 Permissible Combination of Materials for Permanent Applications as Sliding Interfaces for Spherical Bearings

<table>
<tr><th colspan="2">Plane Surface</th><th colspan="2">Curved Surface</th><th colspan="2">Guides</th></tr>
<tr><td rowspan="3">PTFE/UHMWPE (dimpled)</td><td rowspan="3">Stainless Steel</td><td rowspan="3">PTFE/UHMWPE (dimpled)</td><td>Stainless steel</td><td>PTFE/UHMWPE</td><td rowspan="3">Stainless Steel</td></tr>
<tr><td>Hard chromium plating</td><td rowspan="2">Composite Material (CM1 and CM2)</td></tr>
<tr><td>Aluminium Alloy*</td></tr>
</table>

* Use of aluminium alloy is permitted as mating surface for curved sliding interface only. The alloy shall be Al-Mg6M or Al-Si7MgTF in accordance with the requirements of ISO 3522 or as covered in the special approval documents like ETA, FHWA or simillar.

4.7 Composite Material

As an alternative for strips in guides, the composite material of type CM1 and CM2 having properties as per **Annexure-B** can also be used.

4.8 Lubricant

The Lubricant shall be such that it reduce the frictional resistance and wear of the low friction sliding material and its properties shall be retained through service range of temperature. The properties of the lubricant shall be as described in **Table 3**. For Silicon Grease, properties listed in IS:14383 shall also be referred.

Table 3 Physical and Chemical Properties of Lubricants

Properties	Testing Standard	Requirements
Worked penetration	ISO 2137	26.5 to 29.5 mm
Dropping point	ISO 2176	≥ 180°C
Oil Separation after 24 h at 100°C	Annex G of Eurocode EN 1337-2:2003	≤ 3 percent (mass)
Oxidation resistance Pressure drop after 100h 160°C	Annex H of Eurocode EN 1337-2:2003	≤ 0.1 MPa
Pour-point of base oil	ISO 3016	Below - 60°C

4.9 Anchoring Arrangement

Positive anchoring arrangement by way of Bolts passing through Bearing component and anchored to Dowels/Headed Stud connectors/Steel distribution plates shall be adopted for all Bearings. Bolts to be used for anchoring of the Bearings shall be of property class 8.8 or 10.9 in accordance with IS:1367. Steel for Dowels shall be rolled steel in accordance with IS:2062 Grade E250 min. Shear stud material to conform group SD1/SD2 of ISO 13918. For anchorage design, refer to **Clause 5.7**.

4.10 Corrosion Protection

The corrosion protection of the exposed steel surfaces including backing, intermediate plates and welding zone etc. shall be achieved by a protective coating system in accordance with the established specifications e.g. ISO 12944.

For applications in interior locations to be protected from general environmental factors, the protective system shall be designed for the durability "high" of more than 15 years in accordance with ISO 12944-5:2007 **Clause 5.5** for corrosivity category C4.

For locations which are more prone to corrosion e.g. applications in coastal or industrial areas, the protective coating system on the bearing shall be considered for the durability "very high" of more than 15 years in accordance with ISO 12944-5:2007 **Clause 5.5** for corrosivity category C5-I (I = Industrial) for inland locations and C5-M (M = Marine) for seaside locations.

Areas of Steel Components not exposed to outside i.e. in contact with or getting embedded inside the concrete need not be applied with full corrosion protection system. A zinc rich primer coat giving a total DFT of 50 microns min. shall deemed be adequate on such surfaces.

Adequate corrosion protection is very important for the performance and service life of bearings. The condition of corrosion protection shall be carefully inspected during the regular maintenance inspection. If corrosion is detected on any part of exterior exposed steel surface, the affected portion shall be Wire brushed to clean the rust and protective coating shall be re-applied immediately.

5 DESIGN REQUIREMENTS

5.1 General

Loads, forces, movements and rotation to be considered in designing the bearings shall be determined by global analysis of the structure with idealized boundary condition under the critical load combination that can co-exist. Resistance due to friction at the sliding interface of the bearing shall be ignored for idealizing the boundary conditions. However, induced force generated due to friction at sliding interface shall be considered in the design of bearings and adjacent (supported/supporting) structures.

For deriving the bearings design values for both SLS and ULS Conditions. Load combinations and factors shall be taken from IRC:6 or other relevant available specification as deemed necessary. Co-existing values of loads, forces and movement data for design of bearings shall be furnished for both Service and Ultimate Limit state condition for each type of bearings separately in the format given in **Annexure–C** "Bridge Bearing Design Questionnaire Form".

5.2 Rotation Capability

The Hard Chromium Plated convex mating surface shall fully cover the concave sliding surface under all rotation conditions and there shall be no contact (seizure) of concave and convex component or any other metallic component of the Bearings under full design rotation.

For the verification of the above conditions, the nominated design rotation value shall be increased by ± 0.005 radians or ± 10/r radians, whichever is greater.

5.3 Displacement Capacity

The stainless steel mating surface shall cover the flat sliding surface fully under max. design displacement and shall not cease or become unstable before providing the full design displacement.

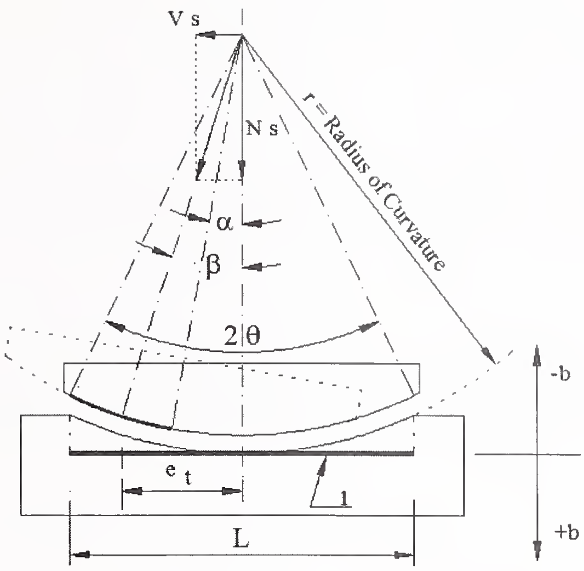
For the verification of the above conditions, the nominated design movement requirement shall be increased by ± 20 mm in both directions of movement with a min. total movement of ± 50 mm in bridge longitudinal direction and ± 25 mm in the bridge lateral direction unless restrained by guides.

***Note*:-** The increase in rotation and movement requirements as stated above shall however be applicable only for the purpose of calculating the practical rotational clearances between the components and movement capabilities without ceasing or failure and shall not be considered while calculating the stresses/applying design checks for rotation and movement ability of the bearing.

5.4 Design Verification for Curved Sliding Surfaces

When dimensioning sliding surfaces, the resultant of the co-existing active and induced horizontal forces generated due to sliding friction shall be considered.

The capacity of the Bearings restraint only by virtue of curvature of the sliding surface i.e. without restraining rings or external guides (reference **Figs. 1, 2a and 2b**) shall be checked for stability and separation against the Horizontal forces.



Key

1 Projected Area of the Curved Sliding Surface

Fig. 5 Verification Scheme for the Curved Sliding Surface (Example)

The capacity of the curved sliding surface as shown in **Fig. 5** for resisting the horizontal forces shall be checked by the following expression:

$$V_{xy,sk} \leq \pi \times r^2 \times \sigma_{ss} \times \sin^2(\theta - \beta - \alpha_d) \times \sin \beta$$

in which

$$\beta = \tan^{-1}(V_{xy,sk} / N_{sk,perm})$$

$$\theta = \sin^{-1}(L/2r)$$

where,

$V_{xy,sk}$	resultant horizontal force in SLS
L	projected diameter of the Sliding Surface perpendicular to the rotation axis
$N_{sk,perm}$	permanent vertical load in SLS
r	radius of curvature of the curved sliding surface
β	angle between the vertical and the resultant applied load
α_d	maximum design rotation in ULS
θ	subtended semi-angle of the curved sliding surface
σ_{ss}	maximum average contact stress permitted on the sliding surface i.e. $\sigma_{ss} = f_k \times k/\gamma m$

where,

γm = 1.4

f_k is the characteristic value of compressive strength according to **Table 1** and k is the reduction factor to reduce creep effects as described in **Clause 4.3**

Note: The above check is only applicable if the condition ($\theta - \beta - \alpha$) is positive value i.e. > 0.

If this condition is not satisfied i. e. the curvature of the sliding surface is inadequate to resist the resultant horizontal forces, the fixed and guided bearing shall be designed compulsorily with the steel restraining rings and external guides respectively (reference **Figs. 2c and 2d**). Vice-a-versa, this check shall not be applicable for Bearings those restrained against base.

Even if the capacity of the Bearings curved sliding surface alone satisfies the check for stability and separation against the Horizontal forces. It is recommended to design the bearing with the steel restraining ring/external guides for additional safety against separation and sliding off under unforeseen conditions (refer **Figs. 6 and 8**).

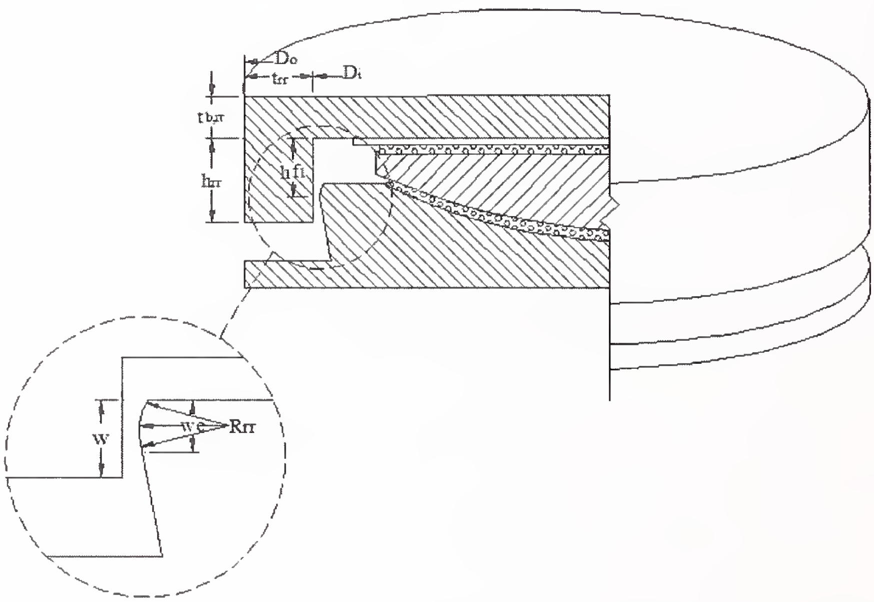


Fig. 6 Arrangement of Restraining Ring in Fixed Spherical Bearing (Typical)

5.4.1 *Restraining rings*

For design and verification of the steel restraining ring capacity to withstand the effect of applied horizontal forces, following design rules shall be followed:

5.4.1.1 *Direct tensile stress, ($\sigma_{t,rr}$) in the restraining ring cross-section shall satisfy:*

$$\frac{V_{xy,\,sd}}{2 \times t_{rr} \times h_{rr}} \leq f_y/\gamma_m \qquad \text{where } \gamma_m = 1.25$$

5.4.1.2 *Shear stress, ($T_{s,rr}$) at restraining ring and base interface shall satisfy:*

$$\frac{1.5 \times V_{xy,sd}}{D_i \times t_{rr}} \leq f_y/\sqrt{3} \times \gamma_m \qquad \text{where } \gamma_m = 1.0$$

5.4.1.3 *Bending stress, ($\sigma_{b,rr}$) at restraining ring and base interface shall satisfy:*

$$\frac{1.5 \times V_{xy,sd} \times hf_1 \times 6}{D_i \times t_{rr}^2} \leq f_y/\gamma_m \qquad \text{where } \gamma_m = 1.0$$

5.4.1.4 *Direct tensile stress, ($\sigma_{t,brr}$) in the restraining ring base plate shall satisfy:*

$$\frac{V_{xy,sd}}{D_o \times t_{b,rr}} \leq f_y/\gamma_m \qquad \text{where } \gamma_m = 1.25$$

5.4.1.5 *Base plate when connected (within) to the full depth restraining ring by full penetration butt weld (refer **Fig. 7a**) shall satisfy:*

$$\frac{V_{xy,sd}}{D_i \times t_{b,rr}} \leq f_y/\gamma_m \qquad \text{where } \gamma_m = 1.25$$

5.4.1.6 *Base plate when connected (within) to the full depth restraining ring by partial penetration butt weld (refer **Fig. 7b**) shall satisfy:*

$$\frac{V_{xy,sd}}{D_i \times a} \leq f_u/\beta_w \times \sqrt{3} \times \gamma_m \qquad \text{where } \gamma_m = 1.25$$

5.4.1.7 *Restraining ring when connected to the Base plate (surface) by fillet weld (refer **Fig. 7c**) shall satisfy:*

$$\frac{V_{xy,sd}}{D_i \times a} \leq f_u/\beta_w \times \sqrt{3} \times \gamma_m \qquad \text{where } \gamma_m = 1.25$$

Note: Since the welded connection requires high degree of workmanship, skill and precision. The welded option of Restraining Rings shall only be adopted by manufacturers certified according to EN 1090-2/ISO 3834-2/AISC.

5.4.1.8 *The interface of the bottom component with the restraining ring shall be provided in radius to uniformly transfer the Horizontal Forces without causing the edge concentration.*

$$V_{xy,sd} \leq \frac{15 \times R_{rr} \times D_i \times f_u^2}{E_s \times \gamma_m^2} \qquad \text{where } \gamma_m = 1.0$$

5.4.1.9 Effective width of the contact surface (we) shall be calculated by the following expression

$$we \geq 3.04 \times \sqrt{\{(1.5 \times V_{xy,sd} \times R_{rr})/(E_s \times D_i)\}}$$

also,

$$w \geq we + (\max,\alpha_d \times D_i)$$

where,

$V_{xy,sd}$ Resultant acting Horizontal Force in N

D_i Internal dia of the Restraining Ring in mm

D_o Outer dia of the Restraining Ring base plate in mm

t_{rr} Thickness of the Restraining Ring in mm

$t_{b,rr}$ Thickness of the Restraining Ring base plate in mm

a effective weld size in mm (taking in account throat thickness)

R_{rr} Radius of curvature of the contact surface with the Restraining Ring

hf_1	Distance between the point of force application and the Restraining Ring Base in mm
h_{rr}	Depth of the Restraining Ring in mm
E_s	Modulus of Elasticity of Steel i.e. 210000.00 MPa
f_y	Specified min. yield strength of the steel material in MPa
f_u	Specified min. tensile strength of the steel material in MPa
β_w	Co-relation factor for Welds, to be taken as 0.9
γ_m	Partial factor of Safety

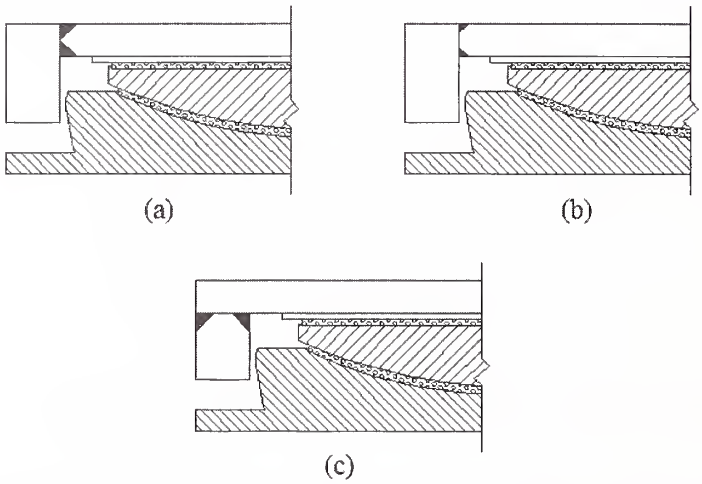


Fig. 7 Types of Weld Connection between Restraining Ring and Base Plate (Typical)

5.4.2 *Compressive stress verification*

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

$$N_{sd,max} \leq \frac{f_k}{\gamma_m} \,.\, A_r \,.\, k$$

where,

N_{sd}	is the design axial force at ultimate limit state
f_k	is the characteristic value of compressive strength as per **Table 1**
γ_m	partial safety factor for materials. The recommended value of γ_m shall be taken as 1.4, unless stated otherwise
k	Reduction factor as described in **Clause 4.3**
A_r*	reduced contact area of the sliding surface expressed by the expression, $A_r = A \,.\, \lambda$
A	contact area for flat sliding surface or projected area of the curved sliding surface i.e. $A = \pi L^2/4$
λ	is a coefficient worked out by the expression, $\lambda = 1 - 0.75\,\pi\, e_t/L$
* 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.

For the purpose of compressive stress verification the curved sliding surface shall be replaced by its projection on a plane surface 'L' as shown in **Fig. 5**.

5.4.3 *Eccentricities*

Internal forces and moments acting on the curved sliding surface due to frictional resistance, externally applied horizontal forces 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'.

The resulting total eccentricity, 'e_t' shall be the algebraic sum of the several eccentricities that may occur simultaneously in a cross-section under consideration.

Thus,

$$e_t = e_1 + e_2 + e_3 + e_4 \text{ (as applicable depending on the condition)}$$

The different eccentricities for working out the resulting total eccentricity shall be calculated as per the expressions below:

5.4.3.1 *Curved sliding surfaces*

In the presence of rotational movements at curved surfaces, 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:

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

For bearings with sliding surface as given in **Table 2**, the coefficient of friction μ_{max}, for verification of the bearing and the structure in which it is incorporated shall be calculated as per expression given below. The effect of friction at the sliding interface shall not be used to relieve the effects of externally applied horizontal forces.

a) Coefficient of friction for PTFE

For curved sliding interfaces combined with dimpled and lubricated PTFE sheets and stainless steel/hard chromium plating, the coefficient of friction μ_{max} is determined as a function of the average pressure σ_{PTFE} [MPa] under maximum vertical load in ULS condition, as follows:

$$0.025 < \mu_{max} = \frac{1.2}{10 + \sigma_p} < 0.08$$

b) Coefficient of friction for UHMWPE

For curved sliding interfaces combined with dimpled and lubricated UHMWPE sheets and stainless steel/hard chromium plating, the coefficient of friction μ_{max} is determined as a function of the average pressure σ_{UHMWPE} [MPa] under maximum vertical load in ULS condition, as follows:

$$0.020 < \mu_{max} = \frac{1.6}{15 + \sigma_U} < 0.08$$

Notes:

i) For zones where the minimum effective bearing temperature doesn't fall below – 5°C, the co-efficient of friction values for PTFE and UHMWPE sliding surfaces as worked out from the above expressions may be reduced by 30 percent and 25 percent respectively.

ii) In case aluminium alloy used as mating surface for curved sliding interface, the stated limits and also the actual value worked out from the expression above in a) and b) shall be enhanced by a factor of 1.5.

5.4.3.2 Sliding surfaces with external guides and restraining rings

For the spherical bearings designed to resist horizontal forces through external guides or restraining rings, (refer **Figs. 2c and d**) and not by the curvature of the sliding surface, rotational movements produces an eccentricity 'e_2' which shall only be considered in the designing of the adjacent structural members (i.e. pedestal, beam etc) and the anchoring devices:

$$e_2 = \frac{V_{xy,sd}}{N_{sd,max}} \cdot \mu_{fr} . c$$

where,

c distance (in plan) between the Interface resisting/transferring the horizontal force and the centre of the sliding surface. (refer **Fig. 8**).

μ_{fr} Co-efficient of friction for Secondary Sliding surface in case of Guided Bearings and at the restraining ring in case of Fixed Bearing

For bearings with sliding surface in guides as per **Table 2**, the coefficient of friction shall be considered to be independent of contact pressure. The coefficient of friction 'μfr' shall be taken from **Table 4** below:

Table 4 Co-efficient of Friction (μ_{fr}) for Secondary Sliding Surfaces

Application	Sliding Interface	(μ_{fr})
Guided Bearings	SS - PTFE/UHMWPE	0.10
	SS - Composite Material (CM1/CM2)	0.20
Fixed Bearing	Steel - Steel	0.20

5.4.3.3 Rotation

In all the types of bearings with two sliding surfaces, a rotation angle, 'α' produces an eccentricity 'e_3' of the vertical load on the curved surface which is:

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

where,

b distance (in elevation) between the cross-section under consideration and the sliding surface (refer **Fig. 5**).

At any rate, eccentricity 'e3' shall act in the opposite direction to the eccentricities calculated in the **Clauses 5.4.3.1 and 5.4.3.2.**

In the type of bearings equipped with only one sliding surface, 'e3' occurs only in the curved sliding surface and, furthermore, only when said sheet is attached to the convex backing plate.

5.4.3.4 Lateral forces

Lateral forces acting on to the Bearings are the result from horizontal actions and the frictional resistance of the other bearings in the structure. This eccentricity is not applicable for the curved sliding interface in the bearings where lateral forces are transmitted by external guides or restraining rings. In bearings of the fixed type with only one sliding surface or with internal/ central guides, the horizontal load $V_{xy,sd}$ produces an eccentricity 'e_4' which is:

$$e_4 = \frac{V_{xy,sd}}{N_{sd,max}} (r + b)$$

5.4.3.5 *Additional eccentricity due to horizontal force bending moment*

In all cases, as the lines of application of lateral action and reaction are not coincident, the resulting couple (force lever arm) causes an eccentricity that shall be additionally taken into account.

5.4.4 *Separation of sliding surface*

With the exception of guides, it shall be verified that the edge pressure "σ" over PTFE/ UHMWPE ≥ 0 under SLS condition of Loading. This condition is satisfied when the total eccentricity 'e_t' falls within the kernel of the projected area. For the purpose of Separation Check, the values of different eccentricities viz. e_1, e_3 and e_4 etc. shall also be calculated as per the above expressions but using the values in SLS condition for vertical load ($N_{sk,max}$), horizontal forces ($V_{xy,sk}$), rotation (α_k) etc. Also, the average pressure "σ" over PTFE/UHMWPE for calculating "μ_{max}" for eccentricity "e_1" shall be worked out using minimum vertical load ($N_{sk,min}$) in SLS condition.

For circular sheets this condition is satisfied when:

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

where,

L projected diameter (refer **Fig. 5**)

5.5 Guides

In the design of the Bearings where, externally applied horizontal forces are to be resisted, Guides either externally attached and projecting from the top sliding plate or internally located projecting from the Calotte and sliding inside the recess in the top sliding plate shall be used. The sliding interface shall be fixed on to the Guides and its adjacent surface for low friction sliding movement. While the Stainless steel strips shall be affixed by continuous fillet weld, the sliding surface strips shall be either bonded with confinement or screwed to assist assembling. Composite materials shall be attached by bonding supplemented by mechanical attachment.

In order to facilitate lateral rotation freely, the sliding surface adjacent to Guides shall be placed into a steel rocker strip backside of which shall be curved to provide smooth full surface contact at the sliding interface even under rotation condition (refer **Fig. 8** for details).

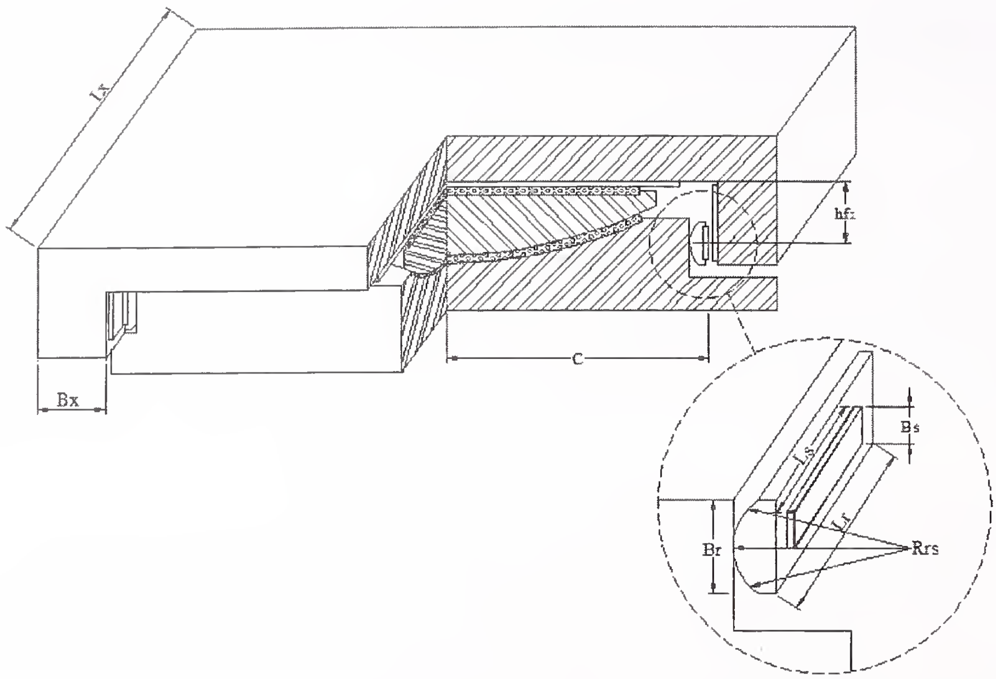


Fig. 8 Arrangement of Rocker Strip (Secondary Sliding Surface) in Guided Spherical Bearing (Typical)

The following conditions shall be verified while designing the Guides for a Guided Bearing:

5.5.1 *Radius of curvature for the rocker strip shall satisfy:*

$$V_{y,sd} \leq \frac{23 \times R_{rs} \times L_r \times f_u^2}{E_s \times \gamma m^2} \qquad \text{where } \gamma_m = 1.0$$

5.5.2 *PTFE/UHMWPE strip dimension shall satisfy:*

$$V_{y,sd} \leq L_s \times B_s \times k \times f_k / \gamma_m \qquad \text{where } \gamma_m = 1.4$$

5.5.3 The Guide Bars when monolithically constructed with its parent component shall satisfy the following expressions:

5.5.3.1 *Bending stress, ($\sigma_{b,gb}$) in the guide bar shall satisfy:*

$$\frac{V_{y,sd} \times hf_2 \times 6}{L_{x,eff.} \times B_x^2} \leq f_y / \gamma_m \qquad \text{where } \gamma_m = 1.0$$

5.5.3.2 *Shear stress, ($\tau_{s,gb}$) in the guide bar shall satisfy:*

$$\frac{V_{y,sd}}{L_{x,eff.} \times B_x} \leq f_y / \sqrt{3} \times \gamma_m \qquad \text{where } \gamma_m = 1.0$$

5.5.3.3 *Equivalent stress, ($\sigma_{v,gb}$) in the guide bar shall satisfy:*

$$\left[\frac{\sigma_{1,gb}}{f_y/\gamma_m} + \left\{\frac{2\tau_{s,gb}}{\left(f_y/\sqrt{3}\gamma_m\right)} - 1\right\}^2\right] \leq 1.0 \qquad \text{where } \gamma_m = 1.0$$

5.5.4 In cases where the Guide Bar is weld attached to its parent component (Refer **Fig. 14**), shall satisfy:

5.5.4.1 Bending stress, ($\sigma_{b,gb}$) in the guide bar shall satisfy:

$$\frac{V_{y,sd} \times hf_2}{a \times L_{x,eff.} \times B_x} \leq f_u/\gamma_m \qquad \text{where } \gamma_m = 1.25$$

5.5.4.2 Shear stress, ($\tau_{s,gb}$) in the guide bar shall satisfy:

$$\frac{V_{y,sd}}{2 \times L_{x,eff.} \times a} + \sigma_{1,gb} \leq f_u/\beta_w \times \sqrt{3} \times \gamma_m \qquad \text{where } \gamma_m = 1.25$$

5.5.4.3 Equivalent stress, ($\sigma_{v,gb}$) in the guide bar shall satisfy:

$$\sqrt{\left(\sigma_{1,gb}{}^2 + 3 \times \tau_{s,gb}{}^2\right)} \leq f_u / \beta_w \times \gamma_m \qquad \text{where } \gamma_m = 1.25$$

Note: Since the welded connection requires high degree of workmanship, skill and precision. The welded option of Guide Bars shall only be adopted by manufacturers certified according to EN 1090-2/ISO 3834-2/AISC.

5.5.6 *Clearance 'c_l' between sliding components in unused condition shall meet the following criterion:*

$$c_l \leq 1.0 \text{ mm} + \frac{L}{1000}$$

where,

- $V_{y,sd}$ Acting transverse horizontal force in N
- R_{rs} Radius of curvature of the Rocker Strip curved surface facing the backing component in mm
- L_r Length of Rocker Strip in mm
- L_s Length of Sliding surface (PTFE/UHMWPE/Others) Strip in mm
- B_s Width of Sliding surface (PTFE/UHMWPE/Others) Strip in mm
- L_x Length of Guide Bar in mm
- $L_{x,eff.}$ Effective Length of Guide Bar derived from 45° load distribution i.e. (L_s + 2*B_x) or the length of Guide Bar, whichever is lesser in mm
- B_x Width of Guide Bar in mm
- a effective weld size in mm (taking in account throat thickness)
- hf_2 Distance between the point of force application and the Guide Bar interface with parent component in mm
- E_s Modulus of Elasticity of Steel i.e. 210000.00 MPa
- f_y Specified min. yield strength of the steel material in MPa
- f_u Specified min. tensile strength of the steel material in MPa
- f_k Characteristic value of compressive strength according to **Table 1**
- k Reduction factor as described in **Clause 4.3**

β_w Co-relation factor for Welds, to be taken as 0.9

γ_m Partial factor of Safety

$\sigma_{1,gb}$ $\frac{\sigma_{b,gb}}{\sqrt{2}}$

5.6 Design Verification of Backing Plates

Both the sliding and the mating surfaces shall be supported by metal backing plates. In order to avoid unacceptably small clearance due to deformation under loads and stresses at the sliding interface, which could otherwise create unacceptably small clearance between the adjacent backing plates and as a result, cease the Bearing rotation ability causing higher wear, the clearance between the adjacent backing plates shall be checked.

However, in Spherical and Cylindrical Bearings, the flat sliding surface is confined/mounted on a thick convex backing plate which apparently has high stiffness and rigidity against deformations as shown in **Fig. 9**. Thus only the deformation "$\Delta w,_{act}$" of the backing plates to flat mating surface i.e. bearing top plate and concave sliding surface i.e. bearing bottom plate shall be calculated separately as per the expression given in **Clause 5.6.1** and both shall satisfy the condition given below:

$$\Delta w,_{act.} \leq \Delta w,_{perms.}$$

where,

$\Delta w,_{perms}$ $h\ (0.45 - 2\sqrt{(h/L)}\ )$

L diameter of the flat/concave Sliding Surface (mm)

h projection of the flat/concave Sliding Surface above the recess (mm)

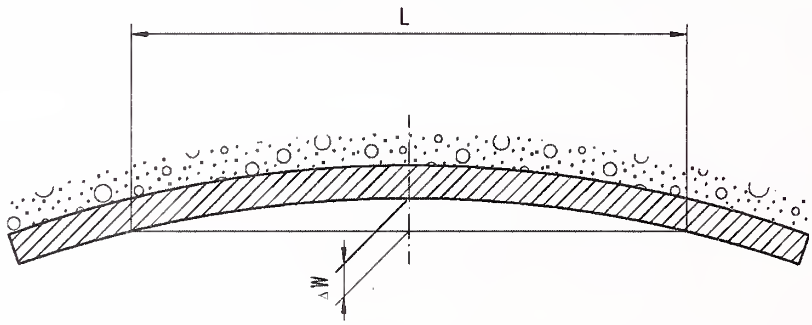


Fig. 9 Deformations of Backing Plates

The stress in the backing plate induced by the respective deformation shall not exceed the elastic limit in order to avoid permanent deformations.

5.6.1 *Actual deformation of the backing plate*

The maximum relative deformation "$\Delta w,_{act.}$" in the backing plate over the diameter 'L' shall be calculated from the following expression:

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

where,

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

k_c = 1.1 if $d_b > 2 \cdot L_0$

$$\alpha_c = \frac{N_{sk,max}}{E_c} + \frac{N_{sk,perm}}{E_{ce}}$$

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,

d_b	Diameter of the backing plate or 1.13 a_b (a_b being the side of the square plate or the minor side of the rectangular 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 $t'_b = t_{b,\,min} + 0.6\,(t_{b,\,max} - t_{b,\,min})$
L	Diameter of the flat/concave Sliding Surface (mm)
L_0	Reference diameter = 300 mm
$N_{sk,max}$	Maximum Vertical Design Load in SLS condition
$N_{sk,perm}$	Vertical Load due to permanent actions in SLS condition
E_c	Short term static modulus of elasticity of concrete i. e. $5000 \sqrt{f_{ck}}$
E_{ce}	Modulus of elasticity of concrete, for permanent load effects i. e. 1/3 E_c

The structural concrete members to which the backing plates are attached shall be of min. M 35 Grade. Use of Mortar Layers between concrete and steel plate of equivalent or higher strength than concrete is also allowed. Similarly material for steel backing plates shall be steel grade having the yield strength as 340 MPa min.

The above also applies when using lower concrete strength classes and/or steel grades, provided the "$\Delta w,_{perms}$." value as calculated above is reduced by a factor of:

0.90 when using concrete grade less than M 35 but limited to M 30

0.67 when using steel having yield strength less than 340 MPa but limited to 250 MPa

0.60 when using both concrete grade less than M 35 and steel with yield strength less than 340 MPa but both limited to minimum M 30 Grade and 250 MPa respectively

5.6.2 *Thickness of the backing plate*

The thickness $t_{b,min}$ of the backing plate for concave sliding surface i.e. Bearing Bottom Plate shall not be less than 12 mm.

The equivalent constant thickness t'_b for backing plate of concave sliding surface and t_b for backing plate of flat mating surface (SS) shall satisfy:

$$t_b \geq 0.040 \cdot \sqrt{a^2{}_b + b^2{}_b}$$

or 12 mm, whichever is greater,

where,

a_b is the minor side of backing plate and

b_b is the major side of backing plate

5.7 Design Verification of Anchorages Against Sliding Under Horizontal Force

Irrespective of the Bearing type (fixed or movable), the bearings shall be adequately anchored using Positive anchoring arrangement e.g. Bolts passing through Bearing component and anchored to Dowels, Headed Stud connectors (Shear or Tension), Steel distribution plates embedded in the adjoining concrete structure or anchored to the intermediate steel plates welded to the adjoining structure in case of steel construction.

The safety and adequacy of the anchoring mechanism against sliding under the application of horizontal force shall be checked at the ultimate limit state in accordance with the stipulations described in **Annexure–E** "Bearing Anchorage Design Rules".

In the case of dynamically loaded structures where extreme load fluctuations can occur, e.g. structures in high seismic zones (Zones IV and V), contribution due to friction shall not be taken into consideration while designing the anchorages i.e. μ_k shall be taken as zero.

5.8 Verification of the Stresses in the Adjoining Concrete Structure

The strength of the concrete structure adjoining to the Bearings shall be checked so as to ensure safe bearing and transmitting the loads and forces that from the Bearings. The concreting of the Bearing seating (Pedestal) and superstructure soffit above the Bearing shall be carefully done to avoid the voids/honeycombing underneath the Bearing which may result in undue deformation of the Bearing components or even premature Bearing failure. The stress in the concrete structure shall be checked against the expression described in **Annexure–F** "Check for Permissible Stresses on the Adjacent Concrete Structure".

6 MANUFACTURING

6.1 Dimensional Tolerance of Steel Components and Bearing Overall

The tolerances as listed in **Table 5** shall be applicable for the finished Bearings and its components:

Table 5 Tolerance on Dimension of Steel Components and Bearing

S. No.	Parameter		Tolerance
i)	Overall Plan Dimension		
	a) Machined	:	0 to + 5 mm or 0.5 percent of the drawing dimension whichever is higher
	b) Un-machined (flange portion)	:	0 to + 10 mm or 1.0 percent of the drawing dimension, whichever is higher
ii)	Overall Height	:	0 to + 5 mm or 1.0 percent of the drawing dimension, which is higher
iii)	Parallelism of Bearing top surface w.r.t. bottom surface as datum	:	1 in 200
iv)	Height of individual machined steel component	:	± 1 mm
v)	Radius of Curvature for the concave machined steel component	:	0 to + 0.25 mm
vi)	Radius of Curvature for the convex machined steel component	:	– 0.25 to 0 mm

6.2 Curved Backing Plate

a) Dimensional Limitation and Tolerance

The thickness $t_{b,\ min}$ of the curved backing plate housing the concave sliding surface shall be 12 mm and the space available on sides shall be min. 20 mm on radius (refer **Fig.10**)

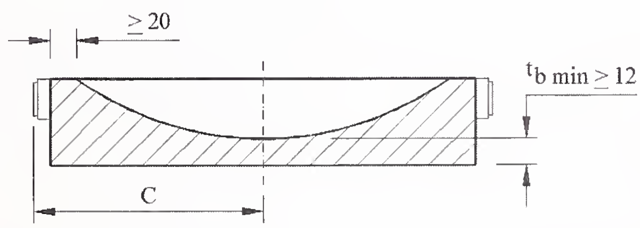
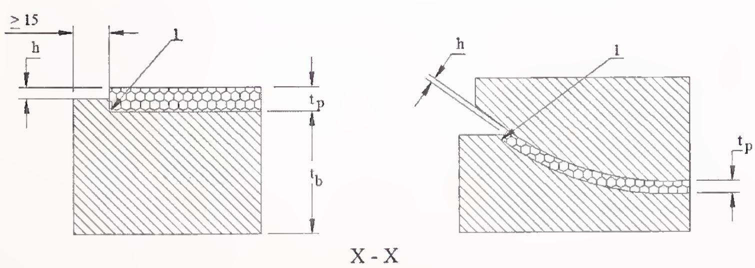


Fig. 10 Dimensional Limitations of Concave Backing Plate

b) Recess in the Backing Plate for Confinement of the Sliding Surface

The shoulders of the recess shall be sharp and square to restrict the flow of the sliding surface and the radius at the root of the recess shall not exceed 1 mm (refer **Fig. 11**).

Dimensions in millimeters



Key

1 Sharp edge

Fig. 11 Details of Recess for Sliding Surface

The sliding surface shall ideally fit in the recess without clearance. The maximum permissible tolerance on the fit of sliding surface inside the recess shall not exceed values specified in **Table 6**.

Table 6 Tolerance on Fit of Sliding Surface in the Recess

Dimension L (mm)	Gap (mm)
75 - 500	0.5
501 - 1000	1.0
1001 - 1500	1.5

where,

L projected diameter (refer **Fig. 5**)

c) Flatness

Surface of the curved backing plate to receive the concave sliding surface shall be finished in such a way that the maximum deviation Δz from theoretical plane surface shall not exceed $0.0003 \cdot d$ or 0.2 mm, whichever is greater.

6.3 Sliding Surface

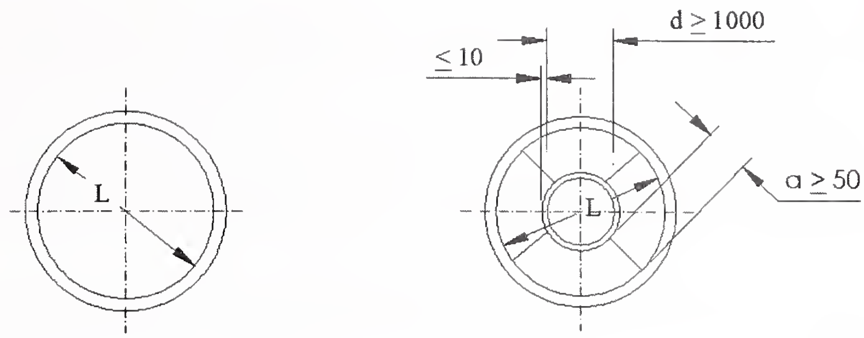
The thickness 't_p' of the sliding surface and it's protrusion 'h' in the unloaded condition with corrosion protection shall meet the conditions given in **Table 7**.

Table 7 Thickness 't_p' and Protrusion 'h' of the Sliding Surface

Design Values	Flat and Curved Sliding Surfaces	Guides
Thickness 't_p' in mm	$2.25 \cdot h \leq t_p \leq 8.0$; with 'h' in mm	$5.0 \leq t_p \leq 8.0$
Protrusion 'h' in mm	$h = 2.00 + \frac{L}{1500}$ 'L' diameter of the projected area of the sliding surface in mm	$h = 2.0 \pm 0.2$

The tolerance on the protrusion 'h' is ± 0.2 mm for 'L' less than or equal to 750 mm and ± 0.3 mm for 'L' greater than 750 mm. The protrusion 'h' shall be verified at atleast three marked measuring points spread circumferentially, where the corrosion protection coating shall not exceed 200 µm. The admissible tolerance on thickness of single sheet or associated multiple sheets of the sliding surface is + 0.3, - 0.0 mm for sheets with a diameter 'L' less than 750 mm and + 0.5, - 0.0 mm for larger sheets.

Curved sliding surface sheets shall be circular and may be sub-divided into a disc and an annulus. The disc, if sub-divided, 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 sub-divided into max. four 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. **Fig. 12** shows the configurations of curved sliding surface sheets for Spherical Bearings.



Dimensions in millimeters

Fig. 12 Sub-division of Recessed Spherical Sliding Surface Sheets

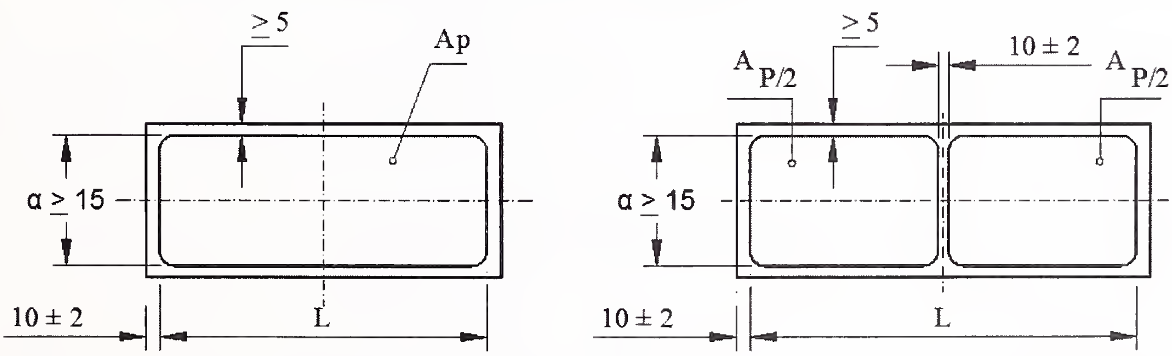
6.4 Sliding Surface for Guides

Dimension 'a' shall not be less than 15 mm and the modified shape factor shall be greater than 4 (see **Fig. 13**).

$$S = \frac{A_P}{u \cdot h} \cdot \frac{t_P - h}{h}$$

where,

- h Projection of PTFE/UHMWPE above the recessed portion
- u Perimeter of PTFE/UHMWPE free to bulge
- A_P Area of the sliding surface (PTFE/UHMWPE) in contact i.e. under load



Dimensions in millimeters

Fig. 13 Examples of Recessed Sliding Surface Sheets for Guides

6.5 Hard Chromium Surface

The hard chromium surface shall be visually inspected for cracks and pores. In addition to the visual inspection, the absence of defects shall be verified by any suitable non-destructive test e.g. Ferroxyl Test in accordance with **Annexure-D** "Ferroxyl Test for Hard Chromium Plating" of this specification. If any defects in the small portion are detected in the test, the hard chrome plating shall be reworked and the test shall be applied on the entire chrome plated surface and if the defects are still noticed, the hard chrome plating shall be rejected.

Since hard chromium plating is not resistant to chlorides in acid solution or to fluorines and can be damaged by air borne particles, such as occur in industrial environment, special provision shall be made to protect the surfaces in those conditions.

6.6 Restraining Rings and Guides

Restraining Ring and Guides monolithic with their parent component shall be preferred as far as possible unless excessive dimension, cost of machining and material wastage etc. overrules the condition. In such cases option of welded Restraining Rings and Guides can be considered subject to fulfillment of the respective design requirements mentioned in this documents and the following conditions:

i) The Ring/Guides shall be positioned and locked with its parent component by tongue and groove shaped machining/using the Allen-key bolts. Further, to achieve the desired strength to resist the horizontal forces, continuous welding (all sides) shall be done (refer **Fig. 14**).

ii) The weld size and dimensions shall satisfy the acting loads and forces and checked against the applicable cases viz. shear, bending, tension and combined effects etc.

iii) In case the acting horizontal forces is too high to resist by welding, option with monolithic Ring or Guides shall be adopted.

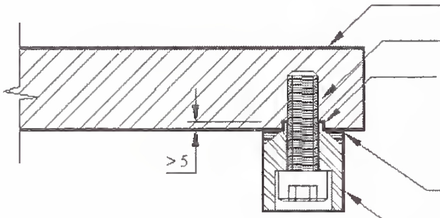


Fig. 14 Guide Bar Weld Connection with Top Plate (Typical)

6.7 Fasteners

Fasteners shall conform to their relevant IS/IRC Specifications.

6.8 Welding

All welding shall conform to IS:816 and IS:9595 with electrodes of suitable grade as per IS:814. Preheating and post weld stress reliving shall be done as necessary.

The backing plate shall extend beyond the edge of Stainless Steel sheet to accommodate the weld. TIG welding of Stainless Steel sheet is recommended.

6.9 Protection Against Corrosion and Contamination

While doing the corrosion protection as specified in **Clause 4.10** of this Specification. Following care shall be taken:

Where the stainless steel sheet is attached to it's backing plate by continuous fillet weld, the area of the backing plate covered by the stainless steel sheet need not be provided with the complete corrosion protection system. However, the area should be thoroughly cleaned and carefully examined to be free from dust, foreign particles, and sign of rust or rust inducing agents prior to the welding of the SS Sheet.

Where the stainless steel sheet is attached by screwing, counterpunched screwing or riveting the full corrosion protection system shall be applied to the backing plate behind the stainless steel sheet.

Provision against contamination of the sliding surface shall be made by suitable devices e.g. wiper seal, rubber apron or bellows. Such protection devices shall be easily removable for replacement and/or maintenance inspection purpose.

All other metallic components including Bolts, Fasteners and Washers etc. shall also be adequately protected against corrosion.

6.10 Assembly

Prior to assembly the sliding surfaces shall be cleaned.

After cleaning and prior to assembly, the dimpled sliding surface shall be lubricated with lubricant according to **Clause 4.8** in a way ensuring that all the dimples are filled without air entrapment. For guides the sliding material shall be initially lubricated by rubbing a small amount of lubricant into the surface and wiping off the remainder.

During assembly process, precautions shall be taken against contamination of lubricated surfaces.

The bearing may be provided with a movement indicator scale which is to be fixed on the side face of the top sliding plate with a pointer pointing to it from the Bearing bottom component.

7 ACCEPTANCE, CERTIFICATION AND MARKING

Stipulations of this clause regarding the Acceptance Testing, Certification and Marking shall be strictly adhered which forming the basis of Product conformance and acceptance for the Spherical and Cylindrical Bearings.

7.1 System of Attestation and Conformity

Following will form the basis of acceptance of the Spherical and Cylindrical Bearings:

a) Tasks of the manufacturer:
   1) Raw Material Acceptance/Testing
   2) Factory production control/in-process testing
   3) In-house Test on Finished Bearing

b) Tasks of the accepting/inspection authority:
   1) Initial inspection of factory and of factory production control
   2) Surprise/audit inspection on process of production and conformance test on raw materials and production in-process, if deemed necessary
   3) Witness of final acceptance testing of finished product.

7.2 Lot Classification

For the purpose of Lot classification, following definitions shall be applicable

- A lot shall comprise of the total number of Bearings manufactured together, of the type and load capacity as defined below, and offered for the Inspection at a time to the Inspecting/Accepting Authority. However, the maximum number of Bearings in one lot shall be limited to 24. Bearings in excess of 24 Nos. shall be treated as separate lot.

- The fixed and movable Bearings shall be classified as separate lots. However, the movable bearings irrespective of uni-directional and bi-directional movement abilities shall be placed under the same lot.
- In terms of Load capacity, Bearings with max. design vertical load less than 500 MT shall be considered as one lot and Bearings with more than 500 MT vertical load capacity shall be considered as separate lot.

7.3 Manufacturer Internal Testing

Apart from the Raw material and In-process Inspection to be carried out and documented for all Bearings and their Components. The Bearings thus manufactured shall be subjected to rigorous In-house Testing by the manufacturer prior to offering for the Acceptance Testing. Following In-house/internal testing on the finished Bearings shall be performed by the Manufacturer:

i) All Bearings shall be checked for surface finish or any other discernible superficial defects.

ii) All the Bearings shall be checked for overall dimensions as per the manufacturing tolerances specified in this code and the relevant contract Specifications.

iii) At least 20 percent Bearings subject to a minimum of 04 and maximum of 20 numbers selected randomly out of the entire production quantity to be offered for acceptance shall be subjected to vertical test load at 1.10 times the maximum design vertical load in SLS condition as shown in the drawings and simultaneously the rotation of 0.02 radians or design rotation whichever is higher.

iv) From the entire production quantity to be offered for acceptance, One Bearing each selected at random shall be tested for Co-efficient of Friction at maximum design vertical load in SLS condition and Combined Vertical and Horizontal Load test (at 1.10 times the maximum SLS design loads), as the case applicable.

7.4 Acceptance Test by Inspecting Authority

Bearings passing the In-house Test requirements are then offered to the Accepting/Inspection Authority for Acceptance Testing. Following Acceptance tests in presence of the Inspection authority shall be performed on the components of the bearings or the bearing as a whole, as applicable.

7.4.1 *Tests for conformance of raw materials and its processing*

i) In addition to the certificates of Raw materials from the supplier/manufacturer forming the initial basis of acceptance. Random sampling and testing at

Independent NABL accredited lab for the material used in the production of the Bearings like steel, sliding surface, stainless steel, Bolts etc. shall be done. The inspection/accepting authority at his discretion shall relax and not insist on conducting the above test subject to availability of the satisfactory test data for the similar test conducted on materials of bearings recently manufactured and supplied for other projects within a period of six months preceding the date of Testing.

ii) Ultrasonic inspection of the steel components

iii) Test on welding e. g. Dye Penetration Test

iv) Test on hard chromium plating e. g. Ferroxyl Test

v) Surface finish of the stainless steel sheet

vi) Thickness of the anti-corrosive treatment etc.

7.4.2 *Acceptance test on finished bearings*

i) Surface Finish

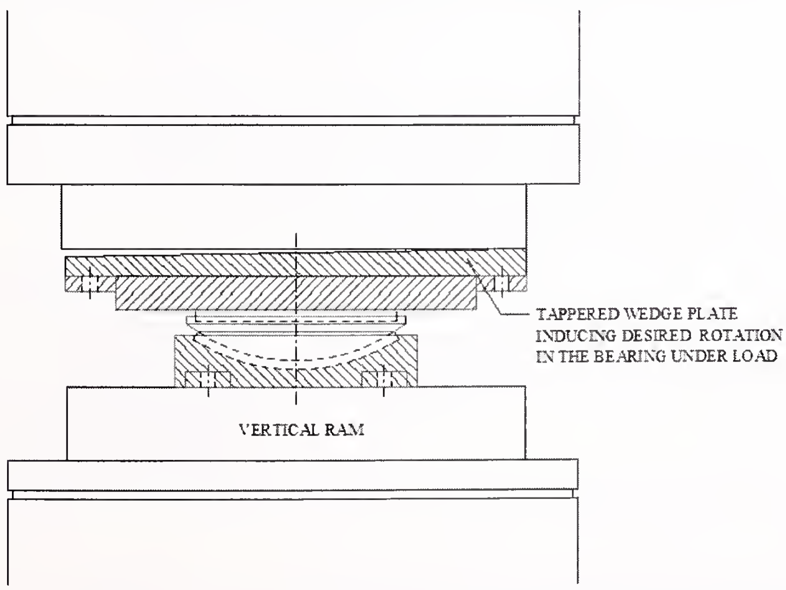
Bearings shall be randomly checked for surface finish or any other discernible superficial defects.

ii) Dimension

Bearings shall be randomly checked for overall dimensions as per the Manufacturing tolerances specified in this code and the relevant contract Specifications.

iii) Compression (Vertical Load) Test

One Bearing selected at random from the lot under acceptance shall be simultaneously subjected to vertical test load of 1.10 times the maximum design vertical load in serviceability condition as shown in the drawings and rotation of 0.02 radians or design rotation, whichever is higher. (**Fig. 15**)



Typical

Fig. 15 Vertical Load Test Set-up for Spherical Bearings

iv) Friction Test

For movable Bearings (Free Float and Slide Guide Types), One Bearing selected at random per lot shall be tested in order to determine the co-efficient of friction at maximum design Vertical Load in serviceability condition, the value of friction shall not exceed 0.03 under lubricated condition (**Fig. 16**).

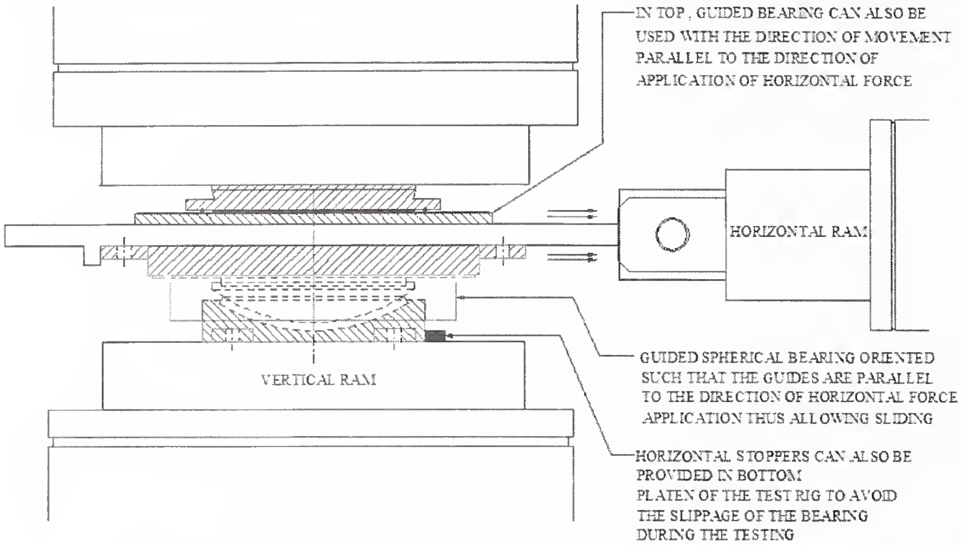


Fig. 16 Coefficient of Friction Load Test Setup Details for Spherical Guided Bearing

v) Combined Vertical and Horizontal Load Test

For Bearings required to resist Horizontal Forces (Fixed and Slide Guide Types), One Bearing selected at random from each lot shall be subjected to combined Vertical and Horizontal Load Test to 1.10 times of the respective maximum design loads and forces in serviceability condition (**Fig. 17**).

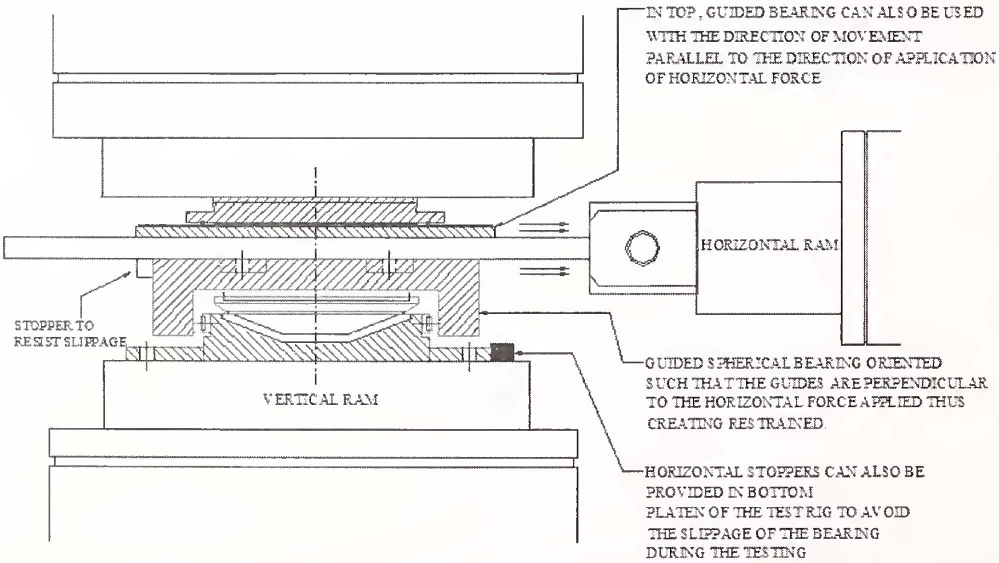


Fig. 17 HOR Load Test Setup Details for Spherical Guided Bearing

Notes :

- For tests specified under iii) and iv) of **Clause 7.3** except for co-efficient of Friction test and under iii) and v) of **Clause 7.4.2**, the Bearings shall be held under Load for a period of 10 minutes.

- All testing shall be done for SLS Loading.
- Additional pre-fabricated taper plates inducing the desired rotation into the Bearing shall be used in the Test assembly for the Vertical Load test.
- In order to ensure that the Test Bearing having curved sliding surface do not topple, either the flat sliding surface on top as shown in the test assembly figures shall be used or else suitable supporting/clamping arrangement to hold the Bearing in place during assembly/testing shall be considered for friction and combined tests.
- Acceptance Test on Finished Bearings as per **Clauses 7.3 and 7.4** may be exempted for Bearings supplied with “CE Certification”.

7.5 Observation

During the Testing, the inspecting/accepting authority shall examine the behavior of the Bearings for any signs of Deformation or Crack on the Sliding surface and/or mating surface, Separation/Lift-off between the sliding interface or seizure of the Bearing Components, deformation or cracks in weld. After the above tests are completed, the tested bearings shall be removed from the test machine, dismantled and the components shall be examined for any signs of distress, permanent deformation in the components especially the sliding surface, warping, swelling, cracks or other permanent defects which may affect the serviceability or durability of the bearing.

The inspecting/acceptance authority apart from witnessing the above test on finished Bearings shall also inspect the documents and reports submitted by the manufacturer about the internal factory production control i. e. raw material, in-process production and internal testing of finished product carried out by the manufacturer.

7.6 Inspection Report

The details of the tests and inspection carried out both in house and in the presence of the Witnessing Authority shall be recorded in the standard testing formats alongwith their observations. These filled up formats alongwith the raw material test certificates, reports of the tests done inprocess e.g. welding (DPT), hard chromium plating (Ferroxyl Test), mating surface hardness test, ultrasonic test, S/S surface finish and Paint DFT etc. shall be compiled and submitted to the Inspecting/Acceptance Authority as Test Reports.

7.7 Certification

The approving/accepting authority after getting satisfied with the Quality of the Product manufactured shall issue Certificate of conformity of the product stating the conformity with the provisions of this Specification and clearance to the Manufacturer to effect the shipment of the Bearings to the job site.

7.8 Marking

All Bearings shall have suitable identification plates permanently affixed which shall be visible after installation, identifying the following information:

- Name of Manufacturer

- Month and Last two digits of the year in which the Bearing Manufactured (mm/yy)
- Serial Number of the Bearing
- Bearing Designation and Type
- Design Performance parameters viz. Load, Movement etc.

Besides this, the Bearing Top Surface shall also be marked with the following information to facilitate their correct installation at site:

- Centerline Marking
- Bearing Designation and Type
- Orientation Marking to facilitate correct placement on the Pedestal
- Direction of Major and Minor movement, as appropriate
- Preset Marking, if applicable.
- Location Number upon each support (If required)

8 PACKAGING, TRANSPORT AND STORAGE

The bearing shall be labeled by the manufacturer with the marking requirement as stated in **Clause 7.8**. The marking shall only be applied when the pre-requisites, regarding manufacturing, testing and acceptance in accordance with **Clauses 6 and 7** are fulfilled in all respect.

Bearings being made up of several components, which are not rigidly fixed together, shall be temporarily clamped together at the place of manufacture. Such clamps shall be sufficiently strong to hold the various bearing components in their correct positions during handling and transportation. They shall be marked/painted with a clear distinguish colour from that of the Bearing paint for easy identification. The Transportation Bracket shall be easily removable after installation or designed to break once the bearing starts to function, without damaging the bearing.

All Bearings that are too heavy to be handled manually shall have provision for the lifting devices.

Bearings shall be wrapped under heavy duty polythene sheets and secured on wooden pallets or inside boxes strong enough to withstand the handling and transportation. Bearings shall then be transported to the Job Site under secured and horizontal condition.

The Bearings at the Job Site shall be placed horizontally above the Ground Level on wooden pallets under covered space (well ventilated) to avoid spoilage by rain water and dust etc. Ventilation helps in avoiding high humidity and condensation that could affect the Bearing component finishes.

9 ASPECTS RELATED TO BEARING PERFORMANCE AND INSTALLATION

In order to ensure bearing alignment and placement in accordance with the contract plan and Specifications, a reference index marking shall be provided on the Bearings Bottom and Top Component. The following limits of Deviation shall be maximum permissible in the Installation of the Bearings:

Level of Seating	:	± 3 mm max. from actual level specified in the drawings (maximum level difference between any two Bearings installed under the same line of support shall also not exceed 3 mm)
In Plan Deviation	:	± 3 mm max. in either direction.
Alignment of Sliding Surface	:	0.3 percent of Bearing Slide Plate Dimension in the direction of movement
Parallelism of Bearing Top Component w.r.t. to bottom	:	0.1 percent Slope max.

9.1 Installation

Bearings are to be installed with due care to ensure their correct functioning in accordance with the design of the Structure. The primary factors to be considered during the Installation of the Bearings are:

Design Based Aspects

- Provision of the Bearings in the structure shall be so made so as to have the least chances of dust and dirt accumulation and also spoilage from rain water seepage that may affect their performance.
- Provision for Jacking Points and adequate space and clearances to accommodate the jacking arrangements shall be made during the design/construction of the Structure to allow repair, replacement of bearings, if required during service.
- Consultation with the Bearing manufacture shall be done at an early stage of the Bridge design to avoid the hassles of Pre- Stressing Tendons and anchor blocks fouling with the Bearing Dowels.

Transportation and Site Handling Aspects

- Transport Brackets are not to be relied upon for the Lifting of the Bearings.
- On receipt of the Bearings at Site, the Contractor shall have a visual Examination of the Bearings to ensure that no damage or displacement

of the Bearing components is taken place during the transportation. Any rectification or re-assembly if required shall be done strictly in the presence of the Manufacturer's Representative.

Installation Aspects

- Bearings shall be installed truly horizontal with Top and Bottom Components of the Bearings perfectly parallel to each other, unless otherwise stated.
- For pre-cast construction, the positioning of the Bolts and Dowels embedded in the Sub-structure/Superstructure shall be made strictly as per the Shop Drawings.
- The Dowels/Distribution Plates shall be properly grouted with suitable grout material ensuring no voids, honeycombing underneath and above the Bearing bottom and top plates respectively. In case of Movable Bearings, particular care shall be taken to ensure the correct orientation of the Bearings.
- For In-situ type of Construction the Bearings shall be covered from all sides to avoid the ingress of cement slurry etc. inside the Bearing Components.
- In case of Pre-cast Construction, extreme care is to be taken to avoid impact loading onto the Bearings while launching the Girders/Superstructure. Girders shall not be rested freely over the Bearings i.e without any additional temporary support as this may cause the overturning of the Girders due to pendulum effect.
- Transport brackets shall be removed at an appropriate time after the casting of the cross diaphragm and setting of the Superstructure Concrete.
- Bearings and its components shall be checked for any dust, dirt or Cement Slurry Deposit etc. and the surrounding area shall be cleaned thoroughly once the process of Bearing installation is finished.

9.2 Maintenance

Bearings shall be designed and manufactured to make them virtually maintenance free so that the undesirable effects caused by extreme atmosphere or aggressive environmental condition/unforeseen events can be eliminated to a great extent. However, the surrounding area of the Bearings shall always be kept clean and dry to avoid damage to the Bearings.

Provisions for suitable easy access to the Bearing shall be made in the construction drawings for the purpose of inspection and maintenance.

Inspection of Bearing at site is required to be carried out 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 of the Bearings. The Bearings are generally required to be inspected at an interval of approx. one year for the first five years and at an interval of two years thereafter or as agreed between the client and the contractor. However, the Bearings shall also be examined carefully after unusual occurrences, like heavy traffic, earthquakes, cyclones and battering from debris in high floods.

The inspection shall be preceded by careful cleaning of the Bearings as well as its surrounding space, depending on the actual conditions around the Bearings, e.g. deposit of salt, debris, dust or other foreign material.

Elements of Inspection

The following are recommended inspection elements and actions which are considered necessary to monitor and upkeep the Bearings:

1) **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 is satisfactory. To ascertain maximum movement, measurement should be taken once during peak winter (early morning) and once during peak summer (afternoon) and corresponding atmospheric temperature should be recorded. The recorded value of movement shall be compared with the design values.

2) **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.

3) **Evidence of locked in Condition:** If any movable or rotating part of a Bearing is found to be in locked - in/jammed condition, necessary rectification measures shall be taken immediately.

4) **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 analyzed and proper actions should be taken to avoid recurrence of the problem.

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

5) **Condition of the adjacent Bridge Structure:** The condition of the structure adjacent to the Bearings is also required to be inspected for any damage and necessary actions to repair the same, should be taken immediately.

Results and Actions

The result of every inspection has to be recorded in the inspection report and shall be deeply discussed with the project Consultants and the Bearing Manufacturer and classified in different categories depending upon the action required to be taken like:

1) Re-inspection and/or monitoring is required.
2) Further measurements/long-term monitoring or design analysis needed (e.g. considering extreme temperatures/exposures, variation of loads, etc.).
3) Minor repair works e.g. cleaning, repainting, etc.
4) Repair or replacement of entire Bearings or parts of the Bearings.

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 shall be consulted.

Annexure-A

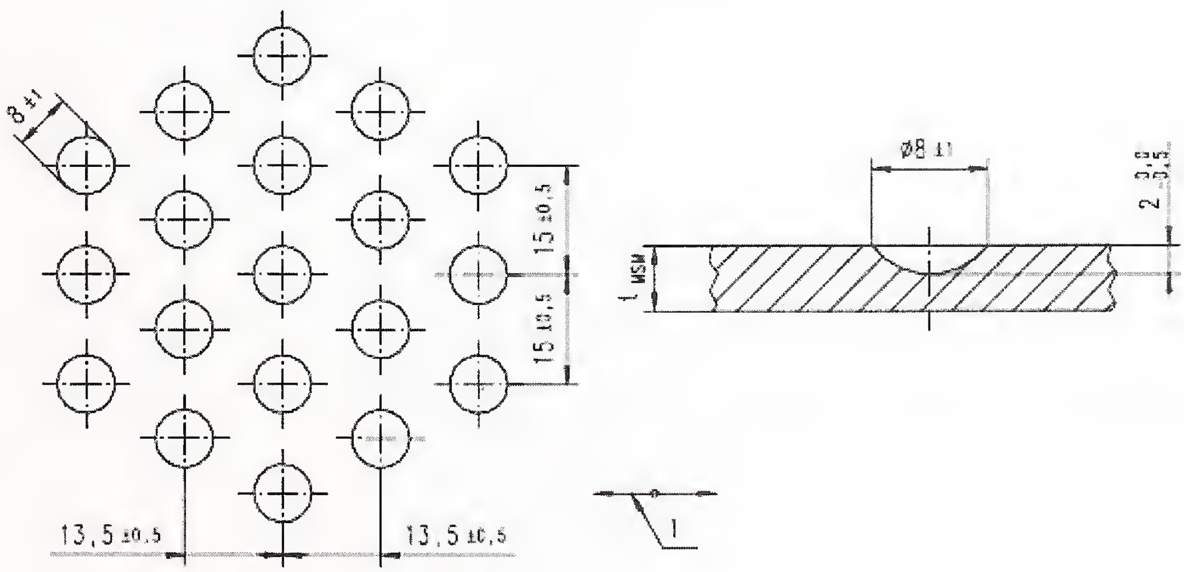
(Refer Clause 4.2)

A.0 Properties of Low Friction Thermo-plastic Sliding Material (PTFE or UHMWPE)

A.1 Pattern of Dimples

Fully molded sheets with cavities or dimples for lubrication shall be used for flat/curved sliding surfaces. The dimples shall be formed by hot pressing or molding and strictly not by machining or drilling. Where dimples are produced by hot pressing, the temperature during the pressing process shall not exceed 200ºC for PTFE and 80 percent of the melting temperature in case of UHMWPE. The pattern of dimples shall be as shown in **Fig. A.1**.

Dimension in Millimeters



Key

1 Main direction of sliding

Fig. A.1 Pattern of Dimples in Recessed PTFE/UHMWPE Sheet

Note :

The information for UHMWPE as given in this annexure and elsewhere in this code are the gist only and merely to serve as a information guide to the Design and Accepting Authorities about the availability of such materials as an option.

The manufacture and use of UHMWPE material inside the Bearings may be governed by Patent Control Rights. The responsibility of acquiring such materials legally for use in the Bearing applications and if required, proving the license rights to use such materials within the offered product shall be solely of the supplier/manufacturer of Bearings. For detailed information, specific approval document for the material issued from International approving bodies like ETA, FHWA, CALTRANS or similar shall be referred.

Annexure-B

(Refer Clause 4.7)

B.0 Properties of Composite Materials for Secondary Sliding Surfaces

B.1 Composite Material CM1

This is a composite material consisting of three layers; a bronze backing strip and a sintered interlocking porous matrix, impregnated and overlaid with a PTFE/lead mixture.

The material shall conform to the characteristics listed in **Table B.1**.

In addition, the condition of the material and its surface finish shall be checked visually.

Table B.1 Characteristics of CM1

Bronze backing	material: CuSn 6				
	composition by mass	Sn		5 to 7.50	%
		P	≤	0.35	%
		Pb	≤	0.10	%
		Fe	≤	0.10	%
		Zn + Ni	≤	0.50	%
		others	≤	0.30	%
		Remainder Cu			
	thickness			(2.1 ± 0.15)	mm
	hardness HB - ISO 6506 (all parts)			80 to 160	
Bronze interlayer	material: CuSn 10				
	Composition by mass	Sn		10 to 12	%
		Pb	≤	1.00	%
		P		0.25 to 0.4	%
		Si	≤	0.17	%
		Fe	≤	0.15	%
		Ni	≤	0.15	%
		others	≤	0.50	%
	saturation with PTFE - Pb		≥	25	%
	thickness			$0.25^{+0.15}_{0.0}$	mm
Composite material surface layer	material : PTFE + Pb Pb 49% to 62%,				
	composition by mass	remainder PTFE			
	Thickness			$0.01^{+0.02}_{0.0}$	mm
	total thickness			2048 ± 0.015	mm
	Overlay adhesion – ISO 2409			minimum GT2	

B.2 Composite Material CM2

The material shall consist of a flexible metal mesh which is sintered into a PTFE compound with the bearing or sliding surface having the thicker PTFE coat.

The metal mesh shall be CuSn6 stabilized mesh from 0.25 mm diameter wires which are linked at intersections and which has a thickness after calendaring of approximately 0.4 mm. The mesh count in warp and weft direction shall be 16 ± 1 per 10 mm.

The PTFE compound shall be PTFE with 30 percent ± 2 percent filler content, consisting of glass fibers and graphite.

The material is to conform to the characteristics listed in **Table B.2**.

In addition, the condition of the material and its surface finish shall be checked visually.

Table B.2 Characteristic of CM2

Density	4100 kg/m^3 to 4400 kg/m^3
Tensile Strength	> 45 MPa
Elongation	> 10 %
Thickness	(0.48± 0.02) mm
Overlay adhesion ISO 2409	minimum GT2

Annexure-C

(Refer Clause 5.1)

Bridge Bearing Design Questionnaire Form

Project/Structure Name								
Bearing Identification Mark/Number								
Qty. required for each type								
Seating Material	Upper Surface							
	Lower Surface							
Allowable* Contact Pressure (N/mm^2)	Upper Surface		Serviceability					
			Ultimate					
	Lower Surface		Serviceability					
			Ultimate					
Design Load (MT)	Serviceability Limit State		Vertical	Max.				
				Permanent				
				Min.				
			Longitudinal					
			Transverse					
	Ultimate Limit State		Vertical	Max.				
				Min.				
			Longitudinal					
			Transverse					
Translation (mm)	Serviceability Limit State	Irreversible	Longitudinal					
			Transverse					
		Reversible	Longitudinal					
			Transverse					
	Ultimate Limit State	Irreversible	Longitudinal					
			Transverse					
		Reversible	Longitudinal					
			Transverse					
Whether Pre-setting allowed (A)/Not-allowed (NA)								
Rotation (Rad)	Serviceability Limit State	Irreversible	Longitudinal					
			Transverse					
		Reversible	Longitudinal					
			Transverse					
Maximum available Structure Dimensions for Dispersion	Upper Surface		Longitudinal					
			Transverse					
	Lower Surface		Longitudinal					
			Transverse					
	Overall Height Clearance (Pedestal + Brg.)							
Bearing Dimensions Restrictions (If any)	Upper Surface		Longitudinal					
			Transverse					
	Lower Surface		Longitudinal					
			Transverse					
	Overall Height							
Type of fixing required (Eg. Dowels/Studs/ Distribution Plate			Upper face					
			Lower face					

- * In case the allowable concrete pressure is not determined or known, then the grade of Concrete/steel/other material shall be specified for both the Upper and Lower Surface.
- Attach separate sheets to state additional requirements viz. Bearing Material, pre-determined pedestal size (if available), cement mortar, epoxy, in situ concrete, precast concrete, steel etc.
- The Bearing Schedule should accompany General Arrangement Drawings showing Typical Support Plan Details, Layout of Structure with schematic arrangement of Bearings on Support, Sub and Superstructure details adjoining Bearing Location.

Annexure-D

(Refer Clause 6.5)

D.0 Ferroxyl Test for Hard Chromium Plating

D.1 Purpose of the Test

The Test objective is to ascertain the soundness and integrity of the Hard Chromium Plating at the curved mating surface.

D.2 Principle

The test method is based on the principle that cracks and porosity extending through the hard chromium layer to the steel substrate will be revealed as blue marks due to the reaction of Fe-II-ions with the indicator solution of potassium ferrocyanide III and sodium chloride.

D.3 Indicator Solution Composition

The ferroxyl indicator solution is composed of 10g K_3 $[Fe(CN)_6]$ and 30g NaCl in 1 l of distilled water or water completely desalinated by ion exchange.

Note: As skin contact with indicator solution shall be avoided, skin protection is required and food shall not be consumed while handling the indicator solution. The indicator solution in contact with acids releases extremely toxic prussic (hydrocyanic) acid.

D.4 Test Specimen and Preparation

The test shall be performed on min. 20 percent of the contact area of the surface.

The test shall be carried out at a temperature between 5°C and 40°C.

In order to prevent false indications, the atmosphere in the vicinity of the test shall be free from ferrous particles and the test sample shall be covered and protected from dust and foreign material.

Immediately before the test, the hard chromium layer shall be cleaned with an acid-free degreasing agent.

D.5 Test Procedure

The hard chromium area to be tested shall be covered with white blotting paper impregnated with the indicator solution. The wet paper shall adhere firmly to the hard chromium surface without wrinkles or blisters.

The solution shall remain in contact with the surface for 1 hour min. At the end of the test period, before removing the blotting paper, it shall be identified and checked for changes in colour.

Defective areas in the hard chromium layer will be indicated as blue-coloured marks on the paper. After the test, the indicator solution shall be completely removed from the sample by means of water or alcohol and then the surface shall be dried.

D.6 Test Results and its Reporting

The test report shall include at least the following items:

a) Identification of the test pieces (name of manufacture, origin and number of manufacturing batch) and the unique serial number of the bearing, if applicable.

b) Condition of the test pieces prior to and after testing (visual damages).

c) Date, duration and temperature of test.

d) Test results (in case of damage, the recordings shall be enclosed with the test report).

e) Any operating procedures not described in this clause and any abnormal incidents occurring during the test.

Annexure-E

E.0 Bearing Anchorage Design Rules

E.1 Anchor Bolt Design:

Bolts of property **Class 8.8/10.9** shall be used for positive anchoring of the Bearings with the adjoining structure. The diameter, grade and number of the anchor bolts shall be so chosen such that it satisfy the below expressions:

E.1.1 *Resistance in Shear:*

$$V_{xy,sd} \leq V_{Rd}$$

where,

$$V_{Rd} = \frac{\mu_k}{\gamma_{ms}} \cdot N_{sd,min} + V_{pd}$$

and

$$V_{pd} = n \times \frac{C_1 \times f_u \times A}{\gamma_m}$$

where,

γ_m	=	1.25
$V_{xy,sd}$		Design resultant horizontal force at ULS
V_{Rd}		Total resistance to force that including the anchorage strength and frictional resistance
V_{pd}		Design value of anchorage resistance in shear
$N_{Sd,min}$		Minimum vertical load acting onto the Bearing in ULS
μ_k		Friction coefficient between the Bearing and adjoining structure, 0.4 for steel on steel and 0.6 for steel on concrete
γ_{ms}		Partial factor of safety against sliding, 2.0 for steel on steel and 1.2 for steel on concrete
n		Number of Bolts
c_1		constant, for cases where shear plane passes through the threaded portion of the bolt, 0.6 applicable for class 8.8 and 0.5 for 10.9; for cases where shear plane passes through unthreaded portion, 0.6 for all bolt classes
f_u		Specified nominal tensile strength of the bolt material in MPa
A		For cases where shear plane passes through the threads, specified nominal area under stress and for cases where shear plane passes through unthreaded portion, gross cross sectional area of the Bolt in mm^2
γ_m		Partial factor of Safety

In the case of dynamically loaded structures where extreme load fluctuations can occur, e.g. structures in high seismic zones (Zones IV and V), contribution due to friction shall not be taken into consideration while designing the anchorages i.e. μ_k shall be taken as zero.

The centre-to-centre distance between the adjacent bolt holes shall not be less than 2.5 times the dia. of bolt hole. Similarly, the distance from the edge of plate to the bolt hole centre shall be minimum 1.5 times the hole dia.

E.2 Inserts in Concrete

The forces through the anchor bolts shall be transferred to the adjoining concrete structure by means of suitable concrete inserts in the form of Dowels (ferrules), Headed Stud Connectors or Steel distribution plates.

E.2.1 *Headed Stud connectors – resistance in Shear*

Concrete Inserts when adopted in the form of Headed Shear Stud shall be minimum 16 mm and maximum 25 mm in diameter. Also the nominal length of the stud shall be atleast 3 times the stud diameter in any case. Headed Shear Studs should be welded as per Arc Stud Welding Method in compliance with ISO 14555 and ISO 13918.

The design shear resistance (P_{Rd}) of the headed studs embedded inside the concrete shall meet or exceed the total shear force as per the expression below:

$$V_{xy,sd} \leq \frac{\mu_k}{\gamma_{ms}} . N_{sd,min} + n.P_{Rd}$$

The value of shear resistance of the headed stud shall be the lesser one of the two that calculated from the below expressions:

$$P_{Rd} = \frac{0.8 \text{ x } f_u \text{ x } \pi \text{ x } d^2/4}{\gamma_m} \qquad \text{where } \gamma_m = 1.25$$

$$\text{and, } = \frac{0.29 \text{ x } c_2 \text{ x } d^2 \text{ x } (0.8 f_{ck} \text{ x } E_c}{\gamma_m} \qquad \text{where } \gamma_m = 1.25$$

where,

P_{Rd}	Design resistance of the headed stud in shear
$V_{xy,sd}$	Design resultant horizontal force at ULS
$N_{Sd,min}$	Minimum vertical load acting onto the Bearing in ULS
μ_k	Friction coefficient between the stud backing plate and adjoining structure, ı 0.6 for steel on concrete. The backing plate shall be embedded in the concrete flushed with the finish surface and not projecting out from the concrete face.
γ_{ms}	Partial factor of safety against sliding, 1.2 for steel on concrete
n	Number of Bolts
f_u	Specified min. ultimate tensile strength of the stud material but in no case exceeding than 500 MPa

d	Stud shank diameter
n	Number of Studs
c_2	coefficient depending on the stud length to diameter ratio, 0.8 for ratio of 3 and 1.0 for ratio of 4 and above
E_c	Short term static modulus of elasticity of concrete i. e. $5000 \sqrt{f_{ck}}$
f_{ck}	is the characteristic compressive strength of the 28 day concrete cube
γ_m	Partial factor of Safety

For cases of special requirements where in addition to shear, tension or bending resistance of the anchorage (both bolts and concrete inserts including dowels/sleeves/ferrules with threaded connection housing anchor bolts) to be verified, relevant design checks from established specifications like EN 1993-1-1, EN 1993-1-8, EN 1994-1 and ACI 318 shall be referred.

Headed Shear Studs shall be spaced at a center to center distance of minimum 5 d along direction of force and 2.5 d in the other direction.

Annexure-F

(Refer Clause 5.8)

F.0 Check for Permissible Stresses on the Adjacent Concrete Structure

The load transfer from the Bearing to the adjacent structure shall be concentrated but uniformly distributed load for which the resistance of the adjoining concrete structure in ultimate load condition is to be determined which shall meet or exceed the acting load values. The resistance of the concrete structure shall be calculated from the below expression:

$$F_{Rdu} = A_{co} \times f_{cd} \times \sqrt{(A_{c1}/A_{c0})}$$

where,

F_{Rdu} resistance offered by concrete in ULS condition loading

A_{co} loaded area.

f_{cd} permissible direct compressive strength of concrete, calculated as:

$f_{cd} = 0.8 \times f_{ck}/1.5$

f_{ck} characteristic compressive strength of the 28 day concrete cube

Ac_1 dispersed area, maximum area possible in the plane of A_{c1} which is concentric and geometrically similar to the loaded area Aco; width of dispersed area in either direction (longitudinal or transverse) shall be limited to maximum three times the width of loaded area in the same direction. Also, the height of the dispersion shall be in no case less than the difference of the width of dispersed area and the loaded area (refer **Fig. F.1**).

also, $\sqrt{(A_{c1}/A_{c0})} \leq 3.0$

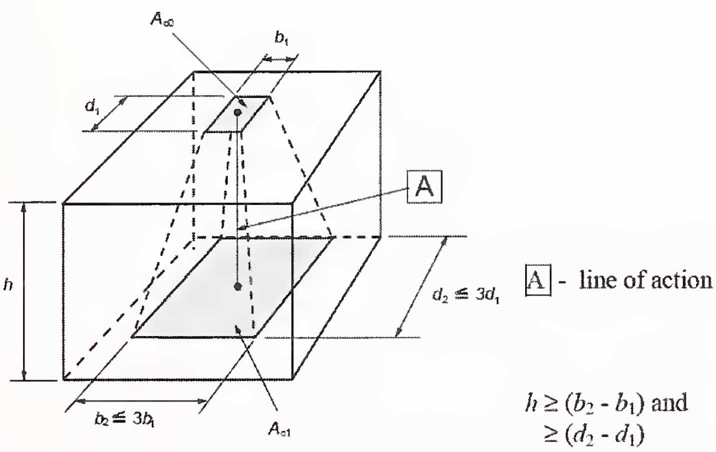


Fig. F.1 Pattern of Load Dispersion and Distribution Area

The projection of the adjacent structure beyond the loaded area face shall not be less than 150 mm all round. Adequate reinforcement in the bearing adjoining concrete portion shall be provided to prevent the spalling and bursting effects due to acting heavy loads and forces.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)