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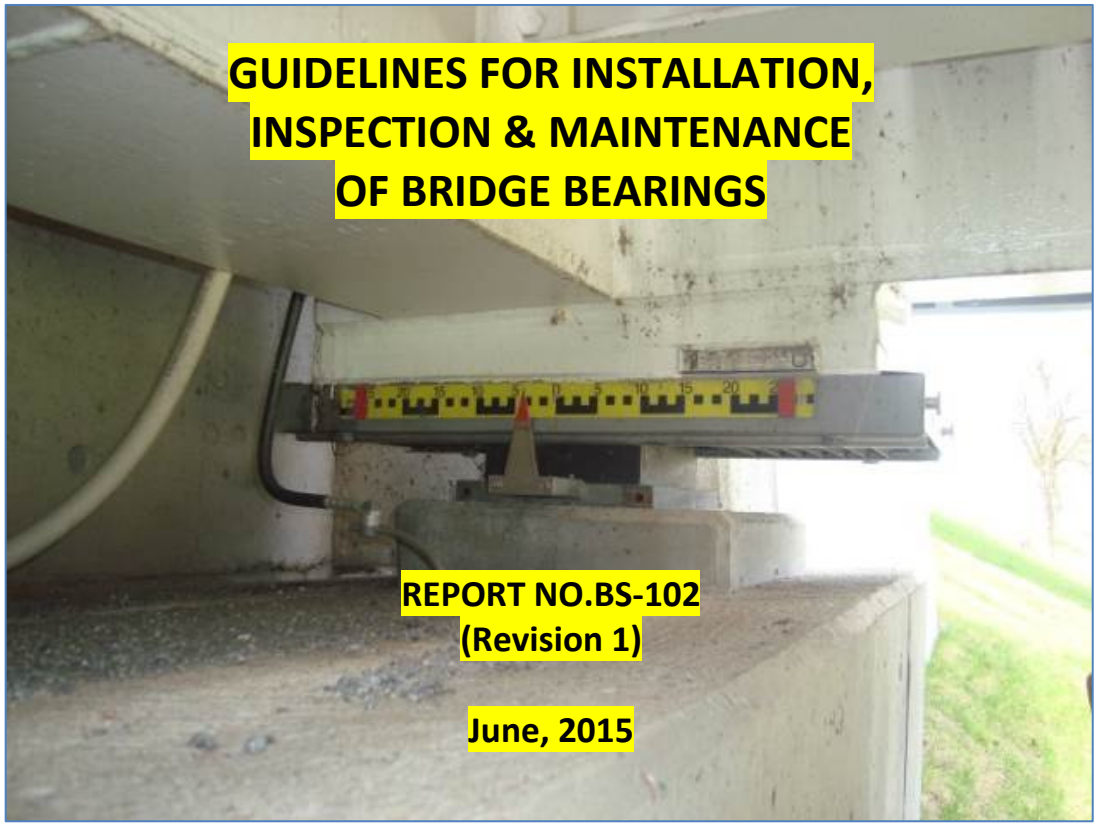
GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS



GUIDELINES FOR INSTALLATION, INSPECTION & MAINTENANCE OF BRIDGE BEARINGS

REPORT NO.BS-102
(Revision 1)

June, 2015

ISSUED BY

RESEARCH DESIGNS & STANDARDS ORGANIZATION

LUCKNOW-226011

FOREWORD TO REVISION 1

BS 102 was issued in 2009. This was welcomed in field as it provided essential guidance to field engineers regarding the inspection and maintenance of probably the most important component of bridges i.e. bearings. Over the years, RDSO has been getting many references regarding inspection and maintenance of elastomeric bearings, especially the life of these bearings. Since lots of problems of improper behaviour of bearings were linked to improper installation of the same, it was decided to include the instructions on installation of bearings also in this document. Further, now spherical bearings are also being provided in Jubilee Bridge/ Bogibeel bridge and therefore, it was decided to include these bearings also in this report to make it comprehensive.

The components of bearings and their design is not covered in this document which limits itself to being a guide in installation, inspection and maintenance aspects only. It is presumed that reader of this document is already conversant with the terminology and geometric configuration of different types of bearings. Those who wish to have more knowledge about other aspects of bearings, may refer to IRICEN's book on bearings, relevant design codes and other literature. However, occasionally, a need has been felt to explain why some aspect of design is important for the field engineer and those aspects have been explained so as to better explain the need for that particular inspection to the field engineer. As earlier, special bearings like pendulum bearings are not part of this document.

The report has been rewritten, also incorporating the above new areas, by Sh V B Sood, Director/B & S/SB-II RDSO who deserves to be thanked for his efforts.

Suggestions and feedback for improvement may kindly be sent to edbsrdso@gmail.com.

(A K Dadarya)
Executive Director/B&S

Date : 29th June, 2015

FOREWORD

Indian Railways are having about 1,28,000 bridges out of which about 16,000 are with steel girders. The bridges have been provided with different type of bearings. These bearings play an important role by allowing translation and rotational movement at supports besides transferring the vertical load to the substructure. The maintenance of these bearings is essentially required to ensure that stresses are released through these bearings and the functionality of the bridge is not adversely affected.

The guidelines cover all types of conventional bearings used in railway bridges except special type of bearings e.g. pendulum bearing for which designer manufacture's specific maintenance is required. Pot cum PTFE bearings are relatively new development and field engineers are generally less conversant about their functionality. These bearings have been covered in sufficient detail. The common problems associated with these bearings have also been discussed.

Shri R.K. Goel, Director/SB-I, Shri Hari Om Narayan, ADE/B&S and Shri R.N. Shukla, SSE/Design have made significant contribution to prepare these guidelines. It is expected that these guidelines shall serve as a useful tool in the hands of bridge engineers to maintain the bearings of girder bridges in good condition.

Suggestions and feed back for improvement shall be highly appreciated and gratefully acknowledged.

(Mahesh K Gupta)
Executive Director/B&S

Date: 16th September, 2009

TERMINOLOGY USED

Bed Block

The term 'bed block' is used to denote the top portion of the pier/ abutment on which the bearing is provided. This term, as used in this document, includes the concrete bed blocks which are cast on top of plain concrete sub-structures or the top portion of the RCC sub-structure. In some bridges, raised pedestals are provided to seat the bearings. In some old bridges, the bed blocks may be of stone also. The term 'bed block' refers to such pedestals and stone bed blocks also in this document.

Bed Plate

The term 'bed plate' refers to the bottom-most plate of a bearing. In some literature, the bed plates are also referred to as expansion base or sliding base. The term 'bed plate' in this document also includes fabricated steel stools provided under bearings. In this document, the term also refers to the bottom-most member such as POT in POT-PTFE bearings. The bed plates may be rectangular or circular depending on type of bearing.

Holding Down Bolts

'Holding down bolts' are the arrangements provided to connect the 'bed plate' of a bearing to 'bed block'. Normally the holding down bolts are headless steel rods with threaded ends provided in 'bed blocks' which pass through the 'bed plate' and are usually tightened with nuts on top. These provide resistance against sliding and uplift. This term also refers to other types of connections such as pins provided in expansion base of roller bearings and dowels provided under bed plates in some bearings. The 'holding down bolts' are either cast in concrete or are cement/ epoxy grouted in holes previously left in the 'bed block' or are tightened in the sleeves cast in 'bed blocks'.

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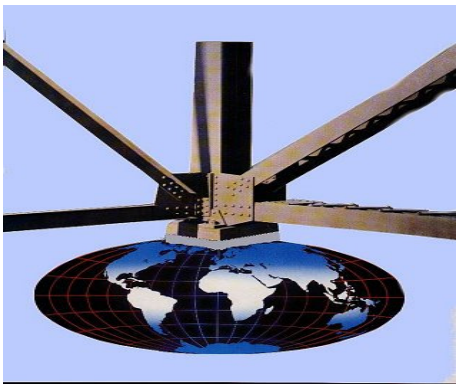
GUIDELINES FOR INSPECTION & MAINTENANCE OF BRIDGE BEARINGS



1. INTRODUCTION- FUNCTIONS OF BEARINGS: The bearings transfer the forces coming from superstructure of a bridge to the substructure. These also allow necessary movements in the super- structure which are caused by various reasons like temperature variations. Proper inspection and maintenance of bearings can be done only if the engineer has an understanding of the roles performed by bearings. These are outlined in brief below:

1.1 **Transfer of vertical loads:** Bearings shall safely transfer all the vertical loads from the superstructure i.e. self-weight of girder, superimposed loads like track, ballast, inspection arrangements etc, train loads, vertical components of seismic/ wind loads etc to sub-structure. This can be accomplished if the area of the bed plate of bearing is adequate to ensure that no portion of the bearing/ sub-structure is over-stressed.

1.2 **Allowing rotation of Girders**: Under vertical loads, the girders deflect, the value of which is higher in the middle. This causes rotation in the ends near supports. One of the primary functions of all types of bearings is to allow the rotation of girders to take place.

1.3 **Transfer of lateral/ longitudinal loads:** Bearings shall transfer all the lateral loads like centrifugal/ raking/ wind/ seismic loads etc to the sub-structure. For this the bearings shall have lateral restraints, especially in girder to bearings and bearings to sub-structure interfaces. For transferring the longitudinal loads like tractive/ braking forces and seismic forces etc, some of the bearings are required to be properly anchored to the sub-structure.

1.4 **Allowing certain movements:** One the main reasons for providing bearings is to allow the girders to expand/ contract under thermal variations. The bearings have sliding/ rolling components with some gaps to allow this change in girder lengths etc. These thermal expansions are in longitudinal directions (mostly) and in lateral directions (For wider girders, such as in case of Road Over Bridges). The bearings are designed to allow these movements while providing proper support to the super-structure.

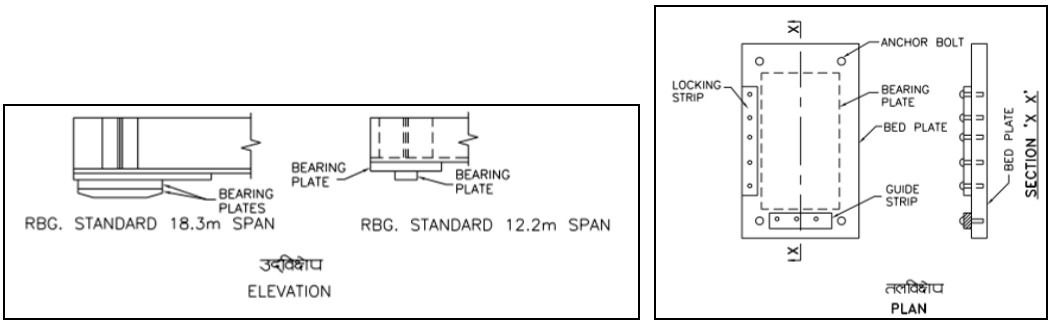
1.5 **Restricting certain movements:** In most cases, it is not desirable to have any vertical and lateral movements as these affect the track parameters which can affect the train running/safety.

2. **TYPES OF BEARINGS COMMONLY USED:** The following types of bearings are generally used on Indian Railways along with RDSO drawings where these bearings can be seen:

2.1 **Sliding bearings:** These consist of steel surfaces sliding one over the other. The steel surface connected to girder is called the bearing or bearing lug and the steel surface

connected to the bed block/ pier is called bed plate. There is no special component to permit rotations. The lateral/ longitudinal movements are restricted by guide/ locking strips. These are of three types:

- **Flat Bearings**, in which bearing has two flat steel surfaces only.
- **Centralized articulated bearings**, similar to flat bearing, but with bearing having planing at the end (also called articulation or chamfer) to accommodate rotation of the girders.
- **Phosphur Bronze Bearings**, which can be of either of the two types described above, but with a phosphor bronze plate inserted between the two steel surfaces. Phosphur bronze, a non-corroding and low coefficient of friction alloy, plate is inserted in bearings on one end of girder, which is the 'free' or 'expansion' end. The other end has steel to steel ungreased contact and acts as 'fixed' end. These bearings don't require greasing.



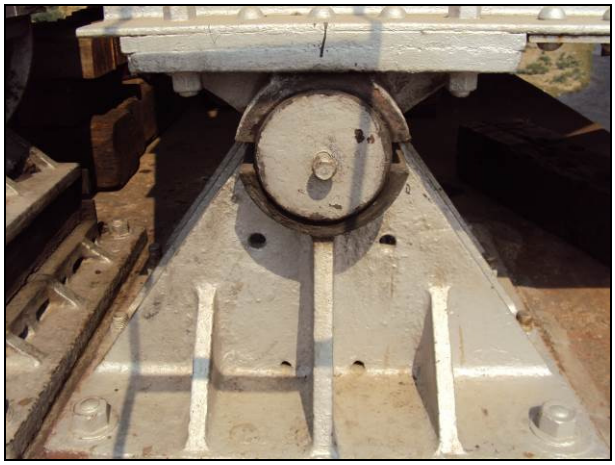
Sketch showing articulated and flat sliding bearings (Annexure 2/10 IRBM)


Typical sliding bearing with bed plate and holding down bolts

2.2 **Rocker and roller bearings:** These consist of a rocker which permits rotation of girder and two or more rollers which provide the sliding element. Lateral movements are prevented by guides/ sleeves in different components. These are of two types:

- **Roller-rocker bearings:** Fixed end has a rocker alone whereas the free end has a rocker as well as rollers.

- **Oil Bath bearings:** These are same as roller-rocker bearings except that the rollers are enclosed in a steel tank filled with oil so that the rollers do not need to be greased as these become self-lubricating under traffic movement. As per para 222 (1) (b) of IRBM, the oil bath shall generally be provided in spans 76.2 m and above. This may also be provided for all existing and new open web girder spans where it is considered difficult to lift the girders for periodic greasing.



Rocker bearing with pin as rocker;

Knuckle type Rocker;

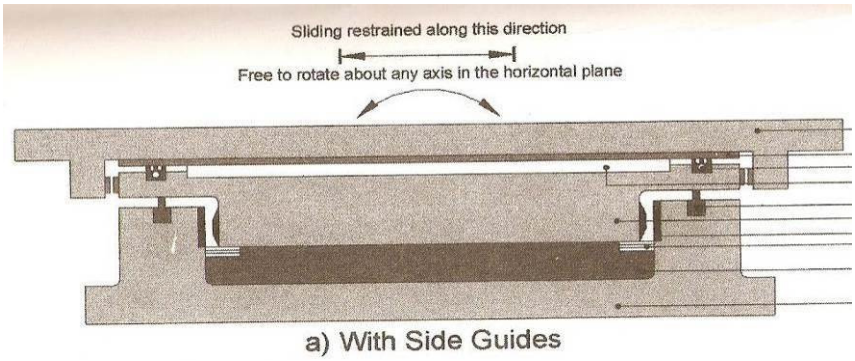
Close up of rollers (2 Nos per bearing)

Rollers enclosed in oil bath

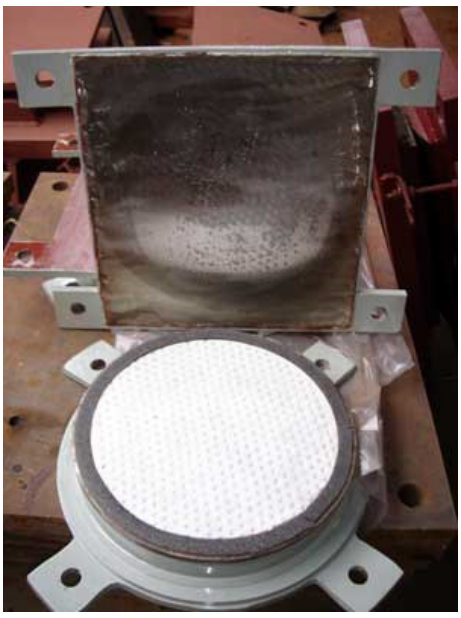
2.3 **Elastomeric bearings:** These consist of synthetic rubber layers reinforced with steel layers in between which provide the sliding as well as rotation capabilities. These bearings have no moving parts and require least maintenance. There is no arrangement to prevent lateral movements or to provide fixed end in these bearings., Separate arrangements have to be made if such a requirement is there.

Elastomeric bearing under PSC girder

2.4 **POT cum P.T.F.E. Bearings:** These have a cast steel pot which has non-reinforced rubber. This constitutes the POT that provides the rotation capability to the bearing. The sliding at the free ends is provided by Poly Tetra Fluoro Ethylene (PTFE) surface sliding over stainless steel surface. Slide guides provide restraint in the desired direction. The coefficient of friction in these bearings is quite low, at par with the friction in rollers. These are highly efficient bearings with minimum moving parts.

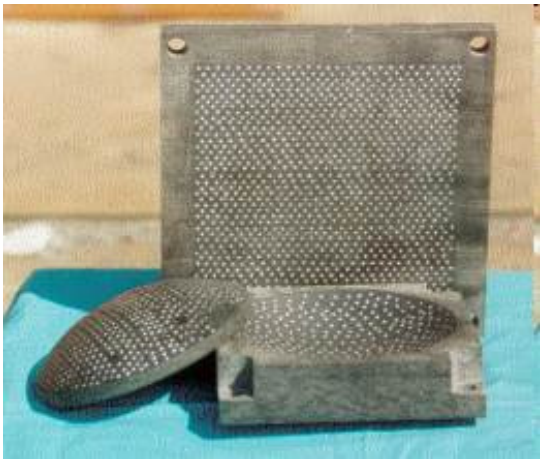


Cross-sectional view of POT cum PTFE bearing with side guides

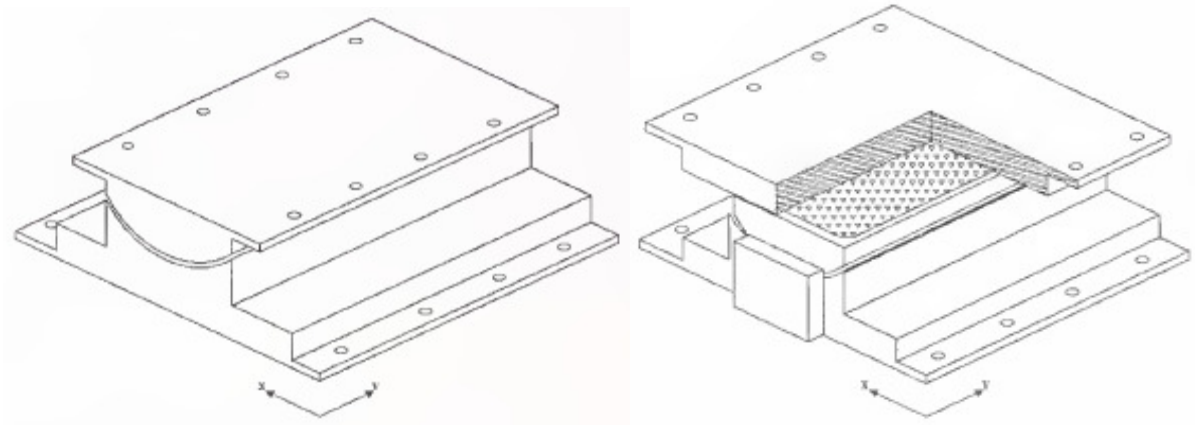


Sliding arrangement of a 'free' bearing- stainless steel as well as PTFE surfaces are seen

2.5 **Spherical/ Cylindrical Bearings:** These bearings consist of steel concave/ convex surfaces having low friction sliding interface in between which permits rotation by in-curve sliding. Spherical bearings allow rotation in all directions whereas cylindrical bearings allow rotation in one direction only. The sliding arrangement in both the bearing is similar to the one in POT-PTFE bearings and material for sliding interface may be PTFE or Ultra High Molecular Weight Polyethylene (UHMWPE). Slide guides provide restraint in the desired direction.



An opened spherical bearing with the rotation and sliding components both visible



Cylindrical bearing complete; And cut section view

2.6 **Suitability of Bearings for different types of girders:** Generally, the bearings described above are suitable for different loads as follows:

Type of bearing	Load (T)	Movement (mm) one way
Steel sliding plates	Upto 133	25
Roller- Rocker bearings	Upto 266	100
Elastomeric Bearings	30-220[$]	60

Type of bearing	Load (T)	Movement (mm) one way
POT-PTFE bearings/ Spherical Bearings	20-1780	No limit*
$ There is limitation of minimum loads for POT-PTFE and Elastomeric bearings as these require certain minimum load on the elastomer for these to function properly. *There is, however, limit on total distance a girder travels on its bearings through the sliding surface		

The above limits are given as indicative of the relative capacities of the different types of bearings. It is possible that for some applications, bearings can be designed beyond the above ranges. Based on above capabilities of different bearings, these bearings are recommended to be used by RDSO for different types of spans on Indian Railways as follows:

S No	Type of Bearing	Girders for which generally used
1	Sliding bearings	1. Plate Girders of spans upto 24.4 m. 2. Expansion end of stringers in open web girders wherever provided.
2	Phosphur Bronze bearings	1. Composite girders for roads as well as railway loadings (Old Drawings). 2. 30.5 m underslung girders(Old Drawings).
3	Roller-Rocker bearings	1. All open web girders. 2. 30.5 m underslung span latest drawings. 3. Composite girders 24.4 m and 30.5 m (Old Drawings).
4	Elastomeric Bearings	1. PSC Girders 9.15 m to 30.5 m spans (Not used under slabs). 2. Plate girders upto 30.5 m (With anti-slip device, as an alternative to sliding bearings). 3. Composite girders upto 30.5 m spans.
5	POT-PTFE Bearings	PSC Girders for spans more than 30.5 m
6	Spherical/ Cylindrical Bearings	1. Long span bridges (Span > 100 m) 2. Continuous girders 3. Cable stayed/ suspension bearings 4. Rail-cum-Road bearings

2.7 Bearing appurtenances: Appurtenances such as expansion joints in ballasted decks, seismic arrestors etc are also provided in bridges, which function with the bearings. These are not a focus area of this report.

3. HOW BEARINGS PERFORM THEIR FUNCTIONS: To summarize, bearings perform their functions as given below:

Bearing	Vertical Load transfer	Rotation	Lateral movements	Longitudinal movements	Lateral load transfer	Longitudinal load transfer	Remarks
Flat Bearings	Through bearing lug and Bed plate	No arrangement	No lateral movements allowed. 1-2 mm gap between guide strips and bearing lug	Sliding between lug and bed plate. 10-20 mm gap between location strips and bearing lug limits the maximum movement.	Through guide strips	Through friction between plates	Sliding bearings are generally not of fixed type. Only in phosphor bronze bearings, the end with non-greased steel to steel contact is fixed.
Central-ised articulated bearing		Chamfer in the end of bearing lug					
Roller-Rocker Bearings	Through bearing and Bed plate	Rocker arrangement	No lateral movements allowed. 1-2 mm gap between guides/collars and rockers/ rollers.	Rollers allow longitudinal movements. Fixed end restricts excessive movement.	Guides/ Collars at ends of knuckles and in center of rollers	Through rockers at the fixed end. A little amount of longitudinal load is transferred from roller end	Oil bath bearings are merely roller-rocker bearings having rollers immersed in oil bath.
Elastom-eric bearings	Mostly through elastomeric pad. Through bed plate, if provided.	Differential compression of elastomer layers	Lateral movement is not completely restrained in this case. However, these are designed with lateral dimension more than longitudinal dimension for higher lateral resistance.	Shear deformation of elastomeric pad	By shear deformation of elastomeric pad		Elastomeric bearings can't function as fixed bearings by themselves. But additional arrangements are provided to restrict movement to make the bearing function as fixed.
POT-PTFE Bearings	Through Pot base	Elastomer filled in POT acts like a pressurized fluid that can rotate in any direction	Stainless steel sliding over PTFE sheet provides sliding surface. Excess movement prevented by fixed bearings.		Guiding lugs (Internal or external) restrain the movement in whatever direction required and transfer the loads in that direction		POT PTFE and spherical/ cylindrical bearings are provided in different configuration like fixed, free, lateral guided, longitudinally guided etc as per design requirement.
Spherical/ Cylindrical bearings	Through base of concave plate	Rotation on the interface of concave-convex surfaces	Stainless steel (Or hard chromium plating) sliding over PTFE (or UHMWPE) sheet provides sliding surface. Excess movement prevented by fixed bearings.		Guiding lugs (Internal or external) restrain the movement in whatever direction required and transfer the loads in that direction		

4. **PROPER INSTALLATION OF BEARINGS:** Proper functioning of bearings requires proper installation of bearings. Proper installation of bearings means that the bearings are laid in proper position, at proper longitudinal / lateral levels and on proper support such as to ensure uniform load on all bearings and proper transfer of loads from girder to bearings and from bearings to the sub-structure. Bearings shall be installed properly as per the instructions given in the design codes/ drawings. The following precautions shall be taken to ensure proper installation of bearings (**The instructions below shall be read as a guide, only to supplement (Not over-rule) the mandatory codal provisions**):

4.1 **Location of pedestals/ bed blocks:** Once the bed block/ pedestals are ready, these shall be checked for their position. Bearing locations shall be marked relative to the center line of girder and track/ girder alignment required at the location. No edge of bed block/ pedestal shall be within the edge distance as per drawing (Normally minimum 150 mm) of the proposed location of bearing. Special care is to be exercised if the bridge is in curve or in skew, to mark the girder alignment as per design. E.g. for curved alignment, the exact offset of center line of girder from center line of curved alignment needs to be marked. This work shall be done carefully with proper surveying equipment.

4.2 **Levels of pedestals/ bed blocks:** The pedestals/ bed blocks shall all be at same level if the bridge is level or these shall have level difference if the bridge is having gradient/ curvature. If the bridge is on curvature, the pedestals on same sub-structure may have level difference. If the levels are not within ±1.5 mm of the theoretical required levels as per design/layout, suitable rectification shall be done.

4.3 **Slope of pedestals/ bed blocks:** The slope of pedestal shall be as per design i.e. perfectly level under the bearing for straight alignment and tilted at certain angle for bridges in curvature. Normally, even for bridges on longitudinal gradient, the pedestals are kept level. The permissible variation of slopes of top and bottom surfaces of bearing is 1 in 500[1]. Therefore, the actual slope of pedestals/ bed blocks shall be as per the design with permissible variation upto 1 in 1000. This variation shall be checked with minimum 500 mm long straight edge to check general slope. Slope shall be checked in different directions. For local undulations, 200 mm long straight edge shall be used and areas with variation beyond ±1 mm shall be marked.[2] Since this surface will not be easily accessible for inspections and maintenance subsequently, any defects shall be rectified before the bearings are put in place. These problems, if not rectified at this stage, can cause major problems later on.

Note: *All these details about location/ levels/ slope of pedestals/ bed blocks shall be taken from drawings and the designer may be consulted if anything is not clear*

4.4 **Dressing of pedestals/ bed blocks Surface:** After identifying the problems, the pedestals/ bed blocks shall then be dressed for installation of bearings. The dressing of the pedestals/ bed blocks surface shall be done as follows:

[1] Para 920.4 of IRC 83 Part II
[2] Para 920.4, IRC 83 Part II

I. If some portion of surface is projecting above the general slope or the complete level of top of bed block/ pedestal is required to be lowered, the same shall be accomplished by chipping off the required volume. The chipping depth shall normally not exceed 10 mm or so, such that the cover to reinforcement is not adversely affected. The chipping shall be done with small hammer, 1 to 1.5 Kg weight only, as heavy hammering may cause cracks in the concrete beyond the chipped depth. To ensure no excess chipping, the surface shall be regularly checked with straight edge. This work may be done by grinding also.

Important Note: *During hammering, if hollowness is noticed or the material gets chipped off too easily, the strength of concrete shall be reviewed.*

II. If some portion of surface is below the general slope or the complete level of top of bed block/ pedestal is required to be raised, the same shall be accomplished by providing appropriate filler. For smaller depths upto 10 mm or so, normal epoxies are good material and the depth can be made good with epoxy mortar (Composed of epoxy and silica sand, refer RDSO report no BS 48 for guidance). For larger depths, steel plates can be inserted below the bearing or special epoxies/ polymer modified concrete etc can be provided. Steel plates are generally good for uniform raising even though trapezoidal plates can also be fabricated. When using steel plates, epoxy mortar can be used to fill up local undulations. The special materials like epoxies/polymer concrete etc to be used for making good the larger depths shall be selected as per load requirements and provided as per manufacturer recommendations. Extra care needs to be taken to ensure quality as working space availability is quite less and problems might arise in such works, as can be seen in photograph below:

Defective epoxy concrete under a bearing

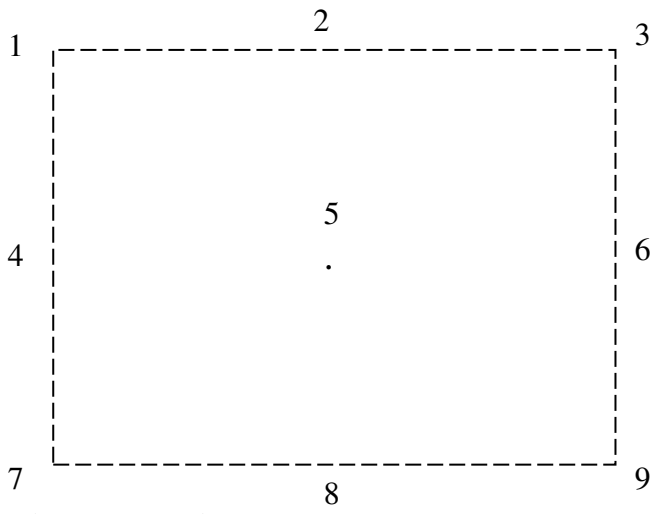
4.5 **Checking Holes for Holding Down bolts:** The holding down bolts are present in most of the bearings except some elastomeric bearings. Holding down bolts are either

provided in sleeves cast in concrete or grouted later on in the holes left in concrete. Casting of sleeves in concrete reduces flexibility later on for casting/ other defects/mistakes in which case care shall be exercised to minimize the tolerances in fabrication etc. Holes in sleeves shall be plugged during concreting and later cleaned. The location of the holes left in concrete shall also be checked for position with template matching holes in bearing to ensure that the holding down bolts can be inserted with sufficient gap all around. If there is some problem, the hole can be slightly widened in required direction. In certain cases, the holes are drilled in concrete after placing the bearing in final position. In these cases, the reinforcement shall be arranged with sufficient margin on either side so that the holes can be drilled without encountering steel.

Holes in sleeves being cleaned for installation of bearing

4.6 **Preparation of Underside of Girder:** Similar to the preparation of bed block/ pedestal top is the preparation of the underside of the girder. In steel girders, the distortion of bottom flange/chord at bearing location needs to be checked and in concrete girders, finish needs to be checked. For precast girders, finally assembled girder shall be inspected before launching. For this inspection, girder(s) shall be supported at jacking points or adjacent to the bearing locations to keep the bearing locations free. The checking of undulations on underside of girder shall be done with 200 mm long straight edge and any variation beyond ±1 mm shall be marked for rectification.[3] To check slope of underside of the girder, water level or sophisticated surveying equipment shall be used to measure levels at different points on each of the bearing locations on underside of girders indicated in sketch below:

[3] Para 920.4, IRC 83 Part II



Locations on bearing seat where levels shall be measured

If girder is proposed to be cast in situ, the shuttering plates for geometry and scaffolds for support need to be inspected carefully to ensure that the final girder profile matches that of bearings. Special care is required to determine methodology for removal of scaffolds and shuttering.

The holes/ bolts provided in girders for providing bearings shall be checked with suitable templates to verify their positions.

4.7 **Dressing of Underside of Girder:** This is a slightly difficult task and better avoided. Rather, it is better to exercise proper control during fabrication of the girders. For steel girders, the rectification of distortion of members shall be done by as per procedures laid down in IRS B1. The steel surface can be rectified for local undulations by light grinding. If distortion is seen, rectification shall be done by using approved methods. For concrete girders, control shall be exercised at the stage of fabrication and erection of shuttering and any defects shall be rectified in shuttering itself. The surface irregularities after casting shall be rectified by chipping off surface or grinding or by applying epoxy mortar as described in para (iv) above. If the girder is slightly twisted, or slope of the underside at bearing location is not proper, use of steel plates is better as applying epoxy etc in the overhead condition is quite difficult. If twist is noticed in the support points of girders, the casting/assembly process shall be reviewed. The designer shall be consulted for rectification of any twist exceeding 3 mm.[4]

4.8 **Placing/Casting of Girder On Bearings:** It is generally not desirable to place or cast the girder on bearings because there is every chance of the bearing getting displaced/ disturbed/ damaged during placing/ casting activities. It is preferable that the girders are placed/ cast on hard wood packing and after the complete assembly of girders, this packing be replaced with proper bearing. However, in certain cases such as

[4] Derived from Appendix II, IRS B1 and limits given in IRC codes for bearings.

continuous girders or other special circumstances, it might be decided to place/ cast the girders directly on bearings. In such cases, extra precautions must be taken to ensure that bearings are neither damaged nor disturbed. The precautions include:

I. The bearings shall be placed at proper location, matching the marks on bearing with the theoretical required location on the bed blocks such that any difference between the marks is not more than ±1.5 mm. Holding down bolts shall be provided to secure the bearing properly. The bearings shall be provided in proper orientation, taking extra care that the sliding direction is proper as per drawing. This is especially important for POT PTFE type bearings in which different bearings may allow movements in different directions.

II. When placing precast girders on bearings, the bearings shall be protected against accidental hits, preferably by providing wooden or other packing of same height as the bearing. The girder shall be brought to proper alignment and 20-25 mm above the required height. Once the girder alignment is verified to be correct, the same shall be gently lowered on to the bearing taking care not to disturb or displace the bearings.

III. When casting the girder over the bearings, the shuttering shall be specially prepared to leave adequate gap for the bearing. The joint between shuttering and bearing needs to be made leak proof for which special measures shall be taken. The joint shall be properly sealed to prevent any slurry etc leaking on the bearing. It is difficult to support shuttering around the bearing for which it might be required to provide a sand box around the bearing. If sand box is provided, care must be taken to ensure that sand does not contaminate the moving parts of bearing. The water used for curing can initiate corrosion in the bearing for which extra care needs to be exercised.

IV. Other precautions in placement of bearings before casting are similar to the ones mentioned in para 4.9 below.

Bearing installed without opening transportation clamp

Special Note for POT-PTFE/ Spherical Bearings: *Performance of these bearings is affected by ingress of water/ moisture and foreign particles etc in the sliding surface. These bearings are, therefore, dispatched with 'transportation' clamps to hold different components together.* ***These bearings are not supposed to be opened during transportation/ storage etc. However, just before the bearings are called upon to take loads/ movements, these transportation clamps are required to be opened.*** *In cast in situ girders, the transportation clamps are to be opened immediately after the shuttering is removed. In precast girders, these clamps shall be opened before the load is imposed on the bearings.*

4.9 **Placing of Bearings:** If the girders are cast/ placed on wooden packing, the same shall be released and proper bearings provided after all other works are over. Steps and precautions for the same are as follows:

I. The girders shall be handled at nominated points with jacks of sufficient capacity. Only one end of girder shall be lifted at a time. If there are multiple girder leaves, then all leaves shall be lifted simultaneously.

II. Lifting shall be sufficient for the height of bearing as well as some extra margin for working depending on dimensions of the bearing.

III. The hard wood packing shall be removed and new bearings shall be inserted at proper position. The center lines in either direction marked on the bearing as well as on bed block shall serve as guide in this activity. The distance between the two center lines shall be set as per drawings with maximum tolerance of ±1.5 mm. Parallax error shall be avoided in this activity.

IV. After the bearing is at proper location and alignment, the bolts connecting bearing to the girder shall be provided/ tightened. Before bolt tightening is undertaken, however, it shall be checked if the bearing is in proper orientation, taking care that the sliding direction is proper as per drawing.

V. The holding down bolts shall then be provided in sleeves already left or these shall be provided in the holes already left in bed block. If the holding down bolts are to be grouted in holes, then the bearing shall be properly set as per temperature prevailing. If the temperature prevailing is lower than the mean temperature, the bearing base shall be away from center of the girder and vice versa. If the sleeves are provided, it shall be verified that the center of sliding surface is at proper location as per prevailing temperature.

VI. The center line of the top portion of bearing and center line of the sub-structure shall be clearly marked with paint or suitably engraved. This shall serve as reference for inspections. Graduated scale as shown in photograph accompanying para 10 (c) below may also be provided which is an excellent aid in measurement of movement of girder/ bearing.

4.10 **Final Inspection:** After complete installation of the bearing, the arrangement shall be inspected. It shall be checked that all bearings are properly resting, the gaps between components are as per drawing and there are no signs of distress or uneven load in individual components. This is important as tolerances in different components might add up adversely in some cases. Any further rectification required may be done at this stage.

5. FREQUENCY OF INSPECTION OF BEARINGS

5.1 **Initial Inspection:** As per para 107 (1) (a) of IRBM, the Bridge Inspector shall inspect all welded, RCC, PSC and composite girders **and their bearing** within one year of installation. The initial inspection of bearings is very important. *The reason for this is that bearings require care in proper placement and transfer of loads for their proper*

functioning and proper control on quality of material and fabrication process alone may not guarantee proper functioning of the bearings in service.

5.2 **Regular Inspections:** The bearings shall be regularly inspected at frequency given as follows:

5.2.1 **Inspection by open line ADEN:** The open line ADEN shall inspect the bearings along with the complete bridge during his inspection annually after monsoons. (Para 102 (a) of Bridge Manual)

5.2.2 **Inspection by SSE/Works:** The open line SSE/Works shall inspect the bearings along with the complete bridge during his inspection annually before monsoons. (Para 117(1)(e) of Bridge Manual). In certain railways, this inspection is to be done by SSE(P-Way).

5.2.3 **Inspection by SSE/Bridges:** The open line SSE/ Bridges shall inspect the bearings along with the complete bridge during his detailed technical inspection once in five years. (Para 107(1)(d) of Bridge Manual)

5.2.4 **Inspection by ADEN/Bridges:** The open line ADEN/Bridges shall inspect the bearings along with the complete bridge during 10% test check of the detailed technical inspection done by SSE/Bridges or where bearings/ girders have been referred for some problem by the SSE/Bridges. (Para 105 (2)(c) and 105(2) (b) of Bridge Manual)

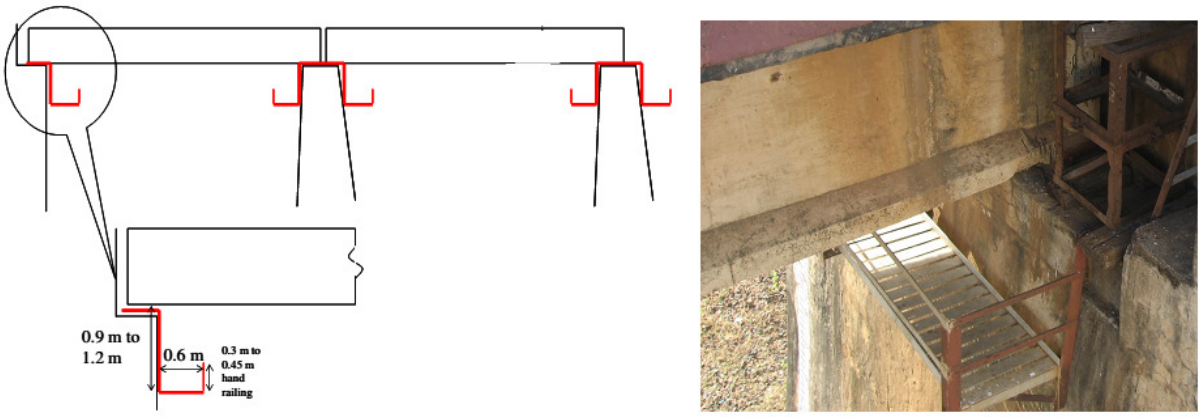
5.2.5 As per para 4.5.7 (ii) (e) of LWR manual, if LWR/CWR is continued through, the bearings shall be inspected during months of March and October.

5.2.6 In addition, the bearings shall be inspected by other officers during their inspections.

5.3 **Special Inspections:** Special inspections of bearings shall be conducted after major events like earthquakes, heavy floods that touch the girders, fires etc which have the potential to damage/ dislodge the girders and bearings. Special inspections/studies on bearings might also be required in case problems like unusual vibrations are reported on the girders during passage of trains.

6. WHAT TO INSPECT - GENERAL

Special Note: For larger bearings like roller-rocker bearings, inspection is easy and just providing access to the pier/ abutment top through a ladder might be adequate and the inspection can be carried out by standing on the pier/ abutment top itself. For all other types of bearings, it will be better to provide access to the engineer so that the inspecting engineer can have the bearing at eye level. A platform at about 0.9 m to 1.2 m below the bottom of girder can enable the inspecting engineer to see elements of bearing closely and take required measurements for proper inspections (See report BS 113 for details).



One type of arrangement for inspection of bearings (Schematic and actual)

There are certain common items which shall be inspected in all the types of bearings. These are listed below (Special care to be exercised in individual bearing types is given later on):

6.1 **Planning of Inspection:** Before inspecting any bearing, the details such as type of girder, type of bearing, peculiar features of the arrangement, year of placement, past history of the bearing, date of last inspection, last cleaning, last greasing, last maintenance, last replacement etc shall be seen. Any overdue maintenance shall be recorded as part of inspection and the inspection shall be planned based on the particular arrangement on a bridge, its history and general guidance provided by this document.

6.2 **Cleanliness:** Debris, vegetation growth, ballast etc are commonly found fouling the bearing areas. The debris can affect the free movement of bearings and so, the area around bearings should generally be cleaned annually.

6.3 **Corrosion of bearing and nearby area:** Corrosion of bearing components including bed plates/ holding down bolts etc and the corrosion in the girder/ sub structure around the bearings shall be seen. If any evidence of water stagnating near or under the bearings is noticed, action shall be taken to prevent the same as it can lead to damage to the bed block/ bearing in the long term.

A bearing with corrosion initiated

6.4 **Support condition of bearing:** All bearings depend on firm, non-yielding support for their functioning. Following shall, therefore, be checked:

I. if the bed blocks/ bed stones/ sub-structure top are providing firm support or not. This can be checked by looking for any cracks, powdered material coming out, water splashing during passage of trains etc.

II. unusual gaps between bearing and girder and/or between bearing and sub-structure and/or between bearing components and/or sag in track are indicators of settlement of sub-structure and need to be inspected.

6.5 **Other Visual Observations:** These include:

I. observing displacement of bearing or its components and unusual marks on bearing components can indicate that the girder has been hit by some vehicle or ship etc underneath.

II. observing wear in parts of bearings or marks indicating touching/ hitting of bearing/ girder with other components which may be indicative of excess movement beyond that permitted by the bearing arrangement at site.

6.6 **Connection of bearings with Sub-Structure:** The bearings are often attached to sub-structure through holding down bolts. In case these are present, following shall be checked:

I. that the holding down bolts are not broken.

II. that the holding down bolts are not loose.

III. that there is no gap between the nuts and top of bed plates or between the shank of bolts and corresponding hole in the bed plates.

The holding down bolts/ anchors in fixed bearings are subjected to more lateral loads and, consequently, are more prone to getting loose/ shaken etc. However, all bearings are subjected to vertical loads and the holding down bolts can get loose if the bearing support is not proper.

6.7 **Condition of girder/ sub-structure near bearings:** If a bearing is not performing its functions properly, girder or sub-structure adjoining can get overstressed. Therefore, inspection of bearings also includes inspection of adjoining areas in girder/ sub-structure for problems such as cracks, wear, gaps etc.

6.8 **Behaviour of bearing under load:** Observation of bearing under load can provide **valuable** information including whether the bearing is moving freely. Following may be observed:

I. movement of bearing when the load passes over the bridge shall be observed. In longer spans, the movement of bearing and girder can be easily seen whereas in smaller girders, this might be a bit difficult to observe.

II. observing 'noise' which may come either at the instance a load enters the span or during the passage of load. The 'noise' may indicate improper seating of girder on

bearing or some obstruction in the moving surfaces and often needs further investigation.

6.9 **Condition of expansion Joint:** The bearings function in conjunction with expansion joint in case of ballasted deck girders. If the expansion joint is clogged or damaged, the free movement of bearing cannot take place. This can cause damage to the expansion joint and, in some extreme cases, the girder. Inspection of expansion joint shall be generally done from underside. During detailed inspections, ballast may be removed to inspect the expansion joint from top also.

6.10 **Evidence of trespass or vandalism:** During bearing inspection, as with all bridge inspection, an eye shall be kept for signs of trespass and vandalism including theft. Suitable action shall be taken to prevent such instances.

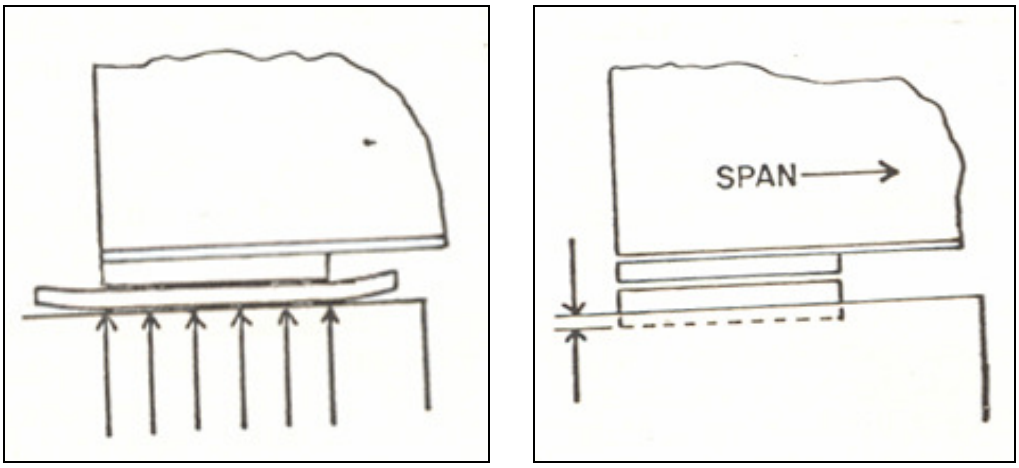
6.11 **Condition of other associated Structures:** Certain structures are provided in bridges which work in conjunction with bearings or are required for maintenance of bearings. These include lifting arrangements of girders, attachments to bearings, seismic arrestors, holding down devices, dust covers etc. These shall be inspected along with the bearing inspection.

7. COMMON REPAIR/ MAINTENANCE ACTIVITIES IN ALL TYPES OF BEARINGS: There are certain repair/ maintenance activities which are common to all types of bearings, these are enumerated below. (The specific maintenance in different bearings is given subsequently)

7.1 **Cleaning of Bearings:** All foreign matter like ballast, paper, polythene etc fallen from trains/ thrown by passersby on bearings shall be removed regularly and staff shall be deputed for the same. The cleaning of bearings shall normally be done annually or at increased frequency if rate of accumulation of dust/ debris is higher. Bearings situated near roads/ walkways etc generally are subject to more debris. If required, suitable guards may be provided to protect the bearings from the debris coming in.

7.2 **Painting of Bearings:** The steel components of bearings shall be painted along with the painting activity for the girder, or if corrosion is seen during inspections. This is regular activity for sliding and roller-rocker bearings. The POT-PTFE and spherical bearings etc are generally epoxy coated and these might not require painting for a long period after installation.

7.3 **Repairs to sunk or deformed bed plate:** A problem most commonly seen in sliding bearings, but may be present in other type of bearings also is sinking of bed plate into the bed block or deformation of bed plate which might attain a ‘saucer’ shape or the edges might lift up. There are many reasons for this:



Schematic representations of bed plate a) lifted at edges due to deformation and b)sunk into bed block

Bed plate missing holding down bolt;

Cracked bed block with stool sunk

I. **Improper seating of girder:** Gap between part of bearing and bed plate or load on edge of the bearing can lead to local overstressing and cause failure of the bed block material. If all bearings are not sharing the load equally, there may be overloading of few of them, causing failure.

II. **Failure of material in bed block:** Bed block shall have minimum strength to take the loads. If the material of bed block is of inadequate strength either due to poor or inadequate construction or due to age, it can fail. Accumulation of water due to poor drainage can also lead/ contribute to problems on this count.

III. **Improper size/ shape of bearing lug and/or bed plate:** The design of bearing lug is done on steel to steel contact basis. Sometimes, this can lead to local overstressing, often assisted by inadequate bed plate thickness. In non-chamfered bearings, the transfer of load to edge of the lug during bending of the girder under load can also lead to overstressing.

Repairs: During inspections, if sunk/ deformed bed plates are seen, the problem shall be diagnosed looking at the contributing factors enumerated above. If the correct reason is not diagnosed, it is possible that the bed plates keep giving repeated trouble. Factors like

proper seating of girder can only be observed by watching the bearings during passage of trains. Another factor to be seen is whether the failure is taking place in only one or two spans/ locations or it is taking place in many different spans/ locations. This can help decide if the local factors are predominant or there is some design issue involved. After correct reason(s) for the failure has been identified and rectified, the repairs to sunk/ deformed bed plates shall be done as follows:

I. Bed plate shall be carefully inspected and if the deformation is excessive, new bed plate shall be got fabricated. If the bed plate is not deformed or only edges are deformed, the same may be retained.

II. Bed block shall be repaired and any cracks etc accessible from outside the bed plates shall be grouted with non-shrink cement/ epoxy grout.

III. Under suitable speed restriction, not exceeding 45 KMPH, nuts of holding down bolts shall be opened and area around the bed plate shall be dressed by removing all loose material from bed block top. If the holding down bolts are loose/ corroded, it may be planned to replace these also along with the bed plate and the existing holding down bolts can be cut.

IV. In a traffic block, the girder shall be lifted from proper lifting points to release the load on bed plate. The bearing/ bed plate shall be removed by lifting it above the holding down bolts or by sliding it out.

V. The area below bed plate shall be thoroughly chipped off to remove all loose material. It is preferable to dress up the affected area in rectangular shape, with minimum 8-10 mm depth, to ensure that the repaired material has some strength.

VI. The lost volume shall be made up by providing steel packing plates (Minimum thickness 8 mm) if a large flat area is affected. For surfaces with unequal depth to be made up, cement mortar with iron filings or epoxy mortar (refer para 209 of IRBM for epoxy mortar/ grout details) shall be used. New or existing bed plate shall be brought and placed over the repairs after allowing for setting time of the mortar.

VII. Suitable tubes for epoxy/ cement grouting shall be fixed in the bed block below the bed plate and on all sides of the bed plate.

VIII. Traffic shall be allowed at 20 KMPH.

IX. In the time margin between trains or in complete block, the bed block area below the bed plate shall be grouted with non-shrink cement/ epoxy grouts. After complete setting of the grout, traffic shall be resumed at full speed.

7.4 **Repairs to loose/ ineffective holding down bolts:** The loose/ ineffective holding down bolts is a major problem with sliding bearings, though the problem can be there in other type of bearings also. Ineffective holding down bolts have gap between bottom of nut and the bed plate or large annular space between hole in bed plate and the bolt shank. Attempts at tightening the holding down bolts may lead to breakage of bolt at the interface between the bed plate and bed block due to corrosion in bolt shank at

the interface between bed plate and bed block. The repairs can be done in various ways:

I. Packing may be provided between bed plate and the nut of holding down bolt to make the holding down bolts effective, as shown in photograph.

Packing under nut to make holding down bolt effective

II. The annular space between bed plate and holding down bolt may be rectified by welding a steel packing piece (thickness 16-20 mm, having appropriate hole for the holding down bolt) to the bed plate.

III. If existing holding down bolts are broken, the shank left in bed block may be drilled out using special tools that drill through steel as well as concrete and new holding down bolts may be provided in the existing holes only.

IV. If existing holding down bolts are broken, and if space is not there to drill out the existing bolts, or if the special drill bits are not available, holding down bolts may be provided at new locations. If space is there in existing bed plate, holes may be drilled in the same and holding down bolts may be provided. Else, the bed plate may be extended by welding plates on side, and new holding down bolts shall be provided in holes in these extension pieces.

Missing holding down bolt;

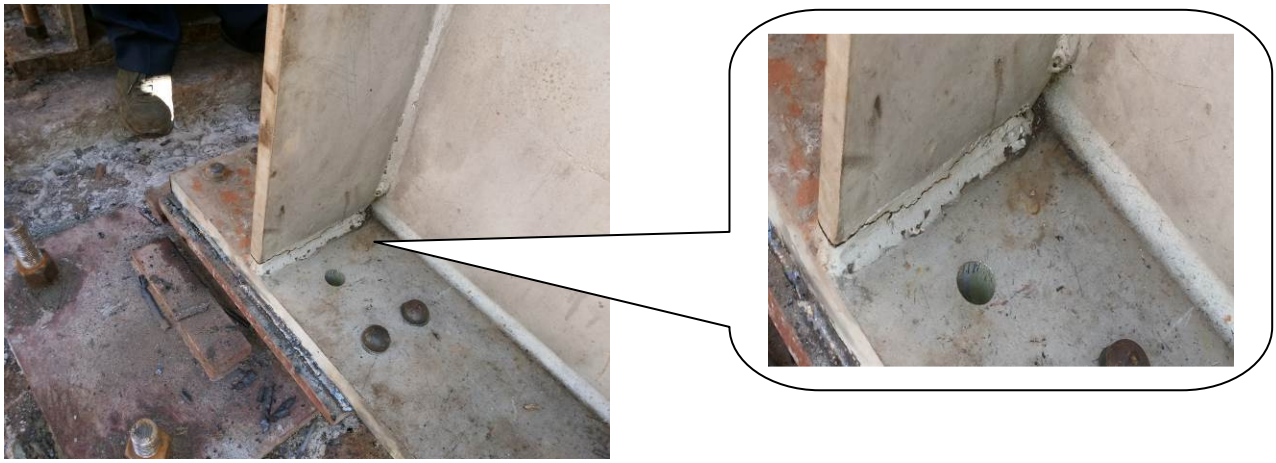
Extra Holding down bolts in extension of bed plate

V. For broken holding bolts, another option is to provide inverted hook bolts outside the bed plate leaving the existing holding down bolts in place. The strength of existing holding down bolts available, and the effectiveness of the inverted hook bolt in resisting loads shall be accounted for in design.

8. Special Items for Inspection of Sliding Bearings: In addition to items mentioned in para 6 above, the following items are required to be inspected in sliding bearings:

8.1 **Visual Inspection of Bearing:** Visual inspection of sliding bearings shall be done to look for defects such as corrosion, cracks in welds in guide strips/ locking strips, cracks in bearing, excess wear and tear of bearing, improper seating of bearing, cracks in bearing stiffener or girder flange connection with web near bearing etc.

Corroded and bulged sliding bearing and bearing stiffener – cracks may also be there



Crack in weld connecting bearing stiffener to bottom flange

8.2 **Gap between bearing lug and guide/ location strips:** During detailed technical inspection by SSE/Bridges, these gaps between bearing lug and different strips shall be noted down along with the prevailing atmospheric temperature. These readings will give idea about any functioning of the bearings.

8.3 **Condition of greasing of sliding surface:** Greasing is important to reduce the coefficient of friction between steel surfaces. If proper greasing is not done, the coefficient of friction will go up significantly and the sub-structure will be subjected to unduly high forces which may lead to failure. In extreme cases, we can have a case where bearing plate and bed plate have got 'jammed' due to excess corrosion. Condition of grease shall be seen on moving surface of bearing. For this purpose,

some visible grease shall be removed and analysed visually to see the extent of contamination/caking of grease and whether it is gives oily feeling on rubbing.

8.4 **Condition of phosphor bronze plate:** Some sliding bearings, especially those provided under Road Over Bridges, underslung girders, expansion end of stringers etc may have a phosphor bronze plate between the bearing and bed plates. This plate is corrosion resistant and provides low coefficient of friction without need for greasing. This plate shall be inspected

I. To ensure that the plate is not broken/ excessively worn out, and

II. To ensure that the plate is properly cleaned in areas visible.

8.5 **Important Design Issue regarding bed block damage in sliding bearings:** In sliding bearings, the damage to bed block/ girder due to improper support is important. This may be due to poor strength of the concrete/ stone etc supporting bed plate which may also lead to tilting/ sinking/ deformation etc of bed plates. An important issue to be seen is the design of bearing. Following are important design aspects of sliding bearings:

I. Many girders are designed with narrower bearing lugs (50 to 70 mm) which can't have chamfers. The small width and absence of chamfer leads to lots of stress at edge of the lug when the girder rotates under vertical load. This may lead to cracks in bottom flange of steel girders or in welds near bearing. Increasing the width of lug and providing chamfer might be required in such cases.

II. If the bed plate is thin (less than 32 mm may be considered suspect), it can't bridge across the small gaps that might be there in support. The resulting saucer shape of bed plate can cause the holding down bolts or remaining support area to be overstressed. If failure takes place repeatedly after repairs, increasing the thickness of bed plate may be explored.

9. ROUTINE MAINTENANCE ITEMS FOR SLIDING BEARINGS: In addition to items mentioned in para 7 above, the following maintenance items are important in sliding bearings:

9.1 **Greasing of Bearings:** Sliding bearings except those provided with phosphor bronze require regular greasing to ensure that the coefficient of friction between bearing plate and bed plate does not exceed the design limits.

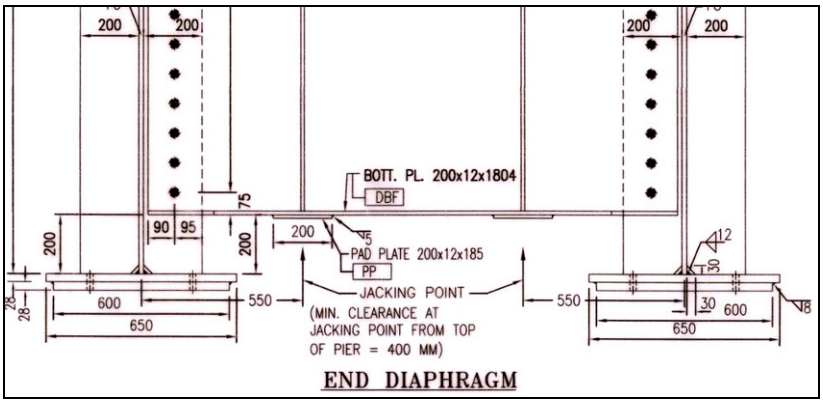
9.1.1 **Frequency:** As per para 222(2) (a) of IRBM, greasing is required to be done once in three years. Greasing may also be done if any problems of improper greasing or if any improper movement is noted during inspection.

9.1.2 **Frequency if LWR is continued:** As per para 4.5.7 (ii) (e) of LWR manual, if LWR is continued through, bearings shall be thoroughly cleaned of all foreign materials in every March and October. For such bridges, greasing of bearings shall be done once in 2 years.

9.1.3 Procedure for Greasing of Plate Girders:

I. Greasing is to be done to the sliding surfaces. For this, the girder is required to be lifted by 6 to 8 mm only (so that girder alignment always remains guided by the guide strips provided in the bed plates).

II. Lifting shall be done by providing jacks at suitable location. The suitable lifting arrangement may be in the end diaphragm or flange brackets attached to end stiffeners. Normally two jacks are used at one end, so each jack shall have minimum capacity equal to 30-35% of the total weight of girder including track and superimposed loads on the girder, if any. If single jack is used, the jack capacity shall be minimum 55%-60% of total load expected.



Lifting arrangement for 24.4 m plate girder as per RDSO/B-16016/2R

III. The total time required for greasing of one bearing is about 20-25 minutes. Suitable block and speed restriction protection shall be arranged accordingly.

IV. After lifting the girder, the bearing surfaces shall be thoroughly cleaned with a mixture of kerosene oil and black oil.

V. Grease and graphite in a working proportion shall be applied on bearing surfaces. Grease graphite Grade-3 conforming to IS-508 should be used.

VI. The girder shall be lowered and alignment of track shall be verified to be correct before the normal traffic is resumed.

VII. The position of sliding bearings with respect to location strips should be noted and compared with the earlier readings and the expected location as per the atmospheric temperature at the time of greasing.

VIII. If the position of bearing is not correct, the same shall be rectified in separate block taken for this purpose.

9.1.4 Care to Be Taken in Greasing of sliding bearings:

I. Safety must be ensured by working with proper track protection. Suitable block shall be availed.

II. No trains shall be allowed when the girder is on jacks.

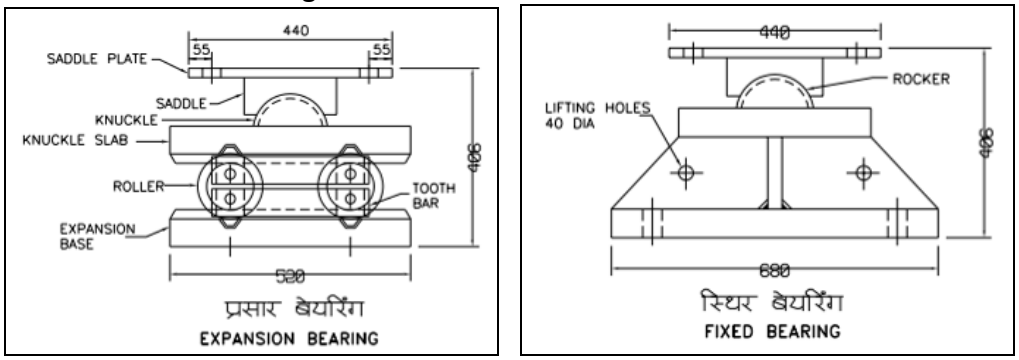
III. Girder must not be lifted beyond the height of the guide strips to ensure that guidance is available to the girder even in case of failure of jack(s).

IV. In certain cases, weight on jacks is increased due to continuous track, so it may be required to loosen a few hook bolts on adjoining spans before greasing.

V. SSE/P-way or his representative must be present at site during greasing. This is especially important in case LWR/CWR is continued through on the bridge.

VI. Where trolley refuge is attached with girder, there are chances of the same toppling over during jacking. If necessary, the connection of trolley refugee shall be removed temporarily.

10. **SPECIAL ITEMS FOR INSPECTION OF ROLLER-ROCKER BEARINGS:** In addition to the general items for inspection mentioned in para 6 above, the following important items shall be inspected in roller-rocker bearings:



Parts and dimensions of Roller-Rocker bearing (Annexure 2/11 IRBM)

10.1 **Condition of rockers:** Rockers shall be inspected for any cracks or deformation of the saddle/ saddle plate or other components. Ingress of any foreign material inside rockers shall also be seen. Other problems include improper seating of bearing, broken/missing bolts etc

Cracked saddle of roller-rocker bearing;

Improperly seated rocker

10.2 **Condition of Rollers:** The oil in oil bath, if provided, shall be drained for carrying out inspections. The rollers shall be inspected for the following:

I. Any signs of excess wear and tear

II. Presence of any foreign particles inside the rollers affecting their free movement.

III. Any missing parts like link plates, bolts, tooth bars etc.

IV. Any damage to rollers such as flattening/ cracks etc visible from outside.

V. Any misalignment of rollers, unusual gaps etc.

10.3 **Measurement of Tilt of rollers:** The ambient temperature at the time of inspection shall be noted. This temperature shall be compared with the ambient temperature at which the rollers were set vertical during the last greasing. If the temperature at the time of inspection is more than that at the time of setting, the girder shall be longer than earlier and the rollers shall tilt away from the span and vice versa. The tilt shall be noted by measuring the movement of the top plate with respect to the bed plate. For this purpose, a permanent indicator shall be fixed to the bed plate and a mark shall be made with paint in the top plate at the time of greasing to indicate the vertical position of the roller at average temperature. The indicator can be similar to an arrangement provided in elastomeric bearing shown below (graduated scale is optional):

Pointer provided in an elastomeric bearing to indicate movement of superstructure

Exact quantification of the tilt might not be required, but qualitative assessment of the tilt measured shall be done. If tilt is found excessive or in wrong direction, the cause shall be investigated. Possible reasons for such improper tilt can be:

- Improper setting of rollers during previous greasing.
- Settlement of sub-structure.
- Failure of members of girder or loss of camber etc.

10.4 **Condition of greasing of rockers as well as rollers:** Greasing is important to reduce the coefficient of friction and also to ensure that the rollers are inspected for any

damage regularly. The condition of greasing can be checked in a manner similar to the method described in para 8.3 above for sliding bearings.

10.5 **Condition of oil bath and oil:** If oil bath has been provided, the following needs to be seen:

I. **Level of oil** in the oil bath bearing. As per para 222 (2) (f) of IRBM, oil level shall be checked annually. During this inspection, any water accumulated in the oil bath shall be removed and any shortfall in oil shall be replenished.

II. **Age of oil**. As per para 222 (2) (f) of IRBM, oil shall be completely replaced once in five years.

III. **Condition of oil** in the bath. This shall be done by taking some oil in hand and assessing its viscosity and extent of contamination by foreign particles. Since the oil at bottom has maximum settled debris, water etc, so if some problems in oil are noted, some oil shall be drained out to access oil at higher levels and the quality of oil coming out shall be seen again.

IV. **Condition** of oil bath, oil level indicator etc including corrosion of steel members.

V. Whether the oil bath is functioning properly and whether there is any leakage of oil or any ingress of water, dust etc inside the oil bath, and reason(s) thereof.

VI. Evidence of any vandalism or attempts at theft of oil etc.

11. ROUTINE MAINTENANCE OF ROLLER-ROCKER BEARINGS

11.1 Greasing of Rockers and rollers: Greasing is an important activity to ensure that the rollers/ rockers have coefficient of friction within limits as per design. It also facilitates inspection of bearing components.

11.1.1 **Frequency:** As per para 222(2) (a) of IRBM, greasing is required to be done once in three years. Greasing may also be done if any problems of improper greasing or if any improper movement is noted during inspection.

11.1.2 Procedure for Greasing of Rocker end of Open Web Girders:

I. Greasing is to be done to the rotating surface of pins/ knuckle/saddle which act as rockers. For this, the girder is required to be lifted by 6 to 8 mm only(So that girder is always guided by sleeves of the knuckle).

II. Lifting shall be done by providing jacks at suitable location. Normally, the end cross girders of open web girders are designed to serve as lifting arrangement also. In end cross-girder, extra stiffeners are provided in such cases. Normally two jacks are used at one end, so each jack shall have capacity equal to 30-35% of the total weight of girder including track and other superimposed loads on the girder, if any.

III. The total time required for greasing of one rocker bearing is about 30 to 45 minutes, for which suitable blocks and speed restrictions shall be arranged.

IV. After lifting the girder, moving surfaces of rocker shall be thoroughly cleaned with a mixture of kerosene oil and black oil.

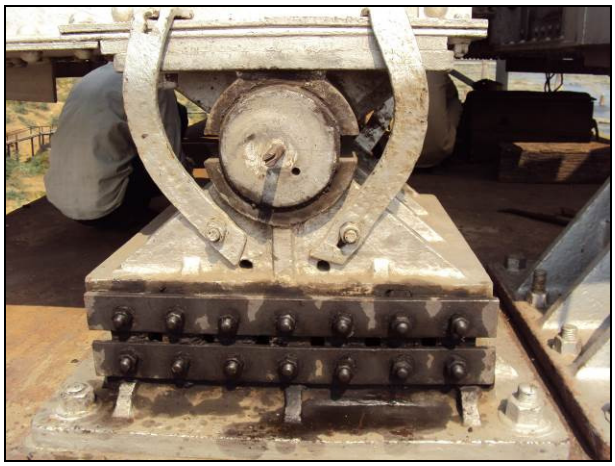
V. Grease and graphite in a working proportion shall be applied on bearing surfaces. Grease graphite Grade-3 conforming to IS-508 should be used.

VI. The girder shall be lowered and alignment of track shall be verified to be correct before the normal traffic is resumed.

11.1.3 Procedure for Greasing of Roller end of Open Web Girders:

I. The roller end is required to be lifted twice. Once for greasing of rocker and once for greasing of rollers. The block time for greasing rocker and roller both shall be about 1 hour. For greasing of rockers, the procedure mentioned in para (ii) above.

II. After greasing of rockers is over, the slinging arrangement in the form of lifting plates (or wire ropes) shall be fastened in the holes provided for the same in bearing as shown in photo below. Now the knuckle slab will lift along with the girder and load on rollers will be relieved. The link plates and tooth bars of rollers shall be opened to free the rollers.



Lifting plates provided to lift knuckle slab with girder

III. Once again the girder shall be lifted by 6 to 8 mm only (so that girder is always guided by guide strip in middle of the rollers).

IV. Half the rollers shall be brought out from one side longitudinally. These shall be scraped, polished with zero grade sand paper and grease graphite in sufficient quantity applied evenly over the same.

V. Then the other half of the rollers shall be brought out from other side and shall be similarly scraped, polished and greased.

VI. The rollers shall be set at proper tilt with respect to vertical. For this, the ambient temperature shall be measured and compared with the mean temperature at the bridge. The rollers shall be set away from center of span if the ambient temperature is more than mean temperature and towards the center if the ambient temperature is less than mean temperature. The amount of difference shall be computed at the rate of 0.012 mm per degree difference per meter span of girder. E.g. for a 32 m long girder, and +5 degree difference, the top of roller

shall be set 0.012*32*5 = 1.92 ~ 2 mm away from true vertical position of the roller.

VII. The tooth bars and link plates shall be provided and then the girder shall be lowered.

11.1.4 Care to Be Taken in Greasing of Rockers and Rollers:

I. Safety must be ensured by working with proper track protection. Suitable block shall be availed.

II. No trains shall be allowed when the girder is on jacks.

III. Girder must not be lifted beyond the height of the guides provided in knuckles/rollers to ensure that guidance is available to the girder even in case of failure of jack(s).

IV. When lifting the fixed end bearing, the free end (that having rollers) shall be suitably jammed with wooden packing with the next girder/ abutment etc to ensure that the girder does not move if the jack is eccentrically loaded or if the jack slips.

V. When greasing the rollers, care shall be taken to provide stoppers before rollers are attempted to be brought out. Otherwise, there are chances of rollers rolling into the river bed.

VI. All rollers shall not be brought out simultaneously so that the girder has some support underneath it at all times.

VII. The rollers shall be set properly. These shall not be skew to the axis of movement.

VIII. It is preferable that greasing work not be done by keeping the girder on jacks for prolonged periods. The girder shall be lowered on to hard wood or other packing and then greasing work shall be done. The packing can be released after the greasing work by slightly lifting the jacks.

IX. Standby jacks must be available at site when greasing of rollers is being done as failure of jacks can lead to bursting of blocks.

X. SSE/P-way or his representative must be present at site during greasing.

11.2 **Maintenance of Oil Bath Bearings:** The oil in oil bath bearing is important as it continuously lubricates the rollers. As per IRBM para 222 (2) (f), oil level shall be checked and replenished for any shortfall annually, and complete oil shall be replaced once in five years. The maintenance activities in this respect include:

11.2.1 **Preventing leakage of oil from oil bath.** Some bolted joints are required as the oil bath is supposed to be opened periodically and oil is commonly found leaking through these joints. Maintenance includes inserting suitable flexible packing material like oil resistant rubber, felt etc between steel members which are bolted together so that oil does not leak through these joints.

11.2.2 **Rectifying defects in oil drain and level indicating pipes:** Oil bath bearings shall have a pipe near the bottom of bath for draining the oil. Perpendicular to this

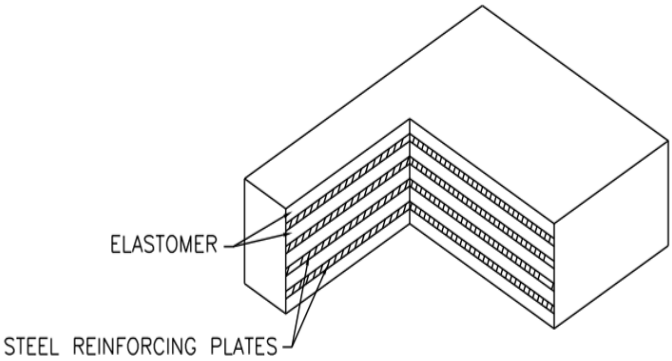
pipe, another pipe is provided which acts as oil level indicator. Ends of these pipes are sealed with stoppers. Leakage of oil through joints/ ends etc needs to be rectified.

11.2.3 **Anti-Theft measures:** The design of oil bath shall be such as to facilitate easy inspection of rollers by removing minimum number of members. For this most of the oil bath shall be welded and the threads of nuts shall be destroyed in bolts connecting few members that are required to be bolted

11.2.4 **Replenishment of Oil:** The oil in oil bath bearing shall be replenished by Shell Omala 320, Shell Mecoma 320, Bharat Amacom 320 (BPCL), Parthan EP 320 (HPCL), Protomac SP ISO VG 320 (Balmer-Lawrie) or Servomesh SP 320 (IOCL) as per IS:8406/89 with four Ball Test and 12th Stage FZG Niemann tests. All these oils are intermixable. (As per M & C Dte, RDSO's letter no M&C/Lub/VI/4/A Dated 17/18.03.2005)

12. **SPECIAL ITEMS FOR INSPECTION OF ELASTOMERIC BEARINGS:** Elastomeric bearings are supposed to be maintenance free since these don't have any moving parts. But the bearings may give trouble if these are not properly fabricated or are improperly installed. More than the inspection, there is a problem as to how to inspect the elastomeric bearings as these bearings have very small height and their dimensions are commonly lesser the flanges of girders. These are, therefore, not visible even if the inspecting officials stand on the piers/ abutments. Suitable inspection cradles or ladders etc are, therefore, especially required on sub-structure to allow the inspecting official to stand with eyes at level of bearings. BS 113 issued by RDSO gives details of inspection arrangement required for proper inspection of bearings.

Typical Elastomeric Bearing;



Cross-sectional view(Annexure 2/12, IRBM)

Special Design Note on Functioning of Elastomeric Bearings: *Elastomeric bearings for railway bridges are made from synthetic rubber vulcanized in-situ with steel plate reinforcements in alternate layers to reduce bulging. These are very stiff in resisting volume change but are very flexible when subjected to shear. In bridges, these permit moderate longitudinal movements and small rotations at the ends and hence can be used for moderate span lengths (IRS Concrete Bridge code para 16.9.13 states that "Use of elastomeric bearing in prestress concrete bridges should preferably be restricted up to maximum clear span of 30.5m"). Elastomeric bearings transfer all load through shear deformation and this shall be kept in mind by inspecting officials. So,* ***there shall be no un-necessary alarm if small deformations are seen in elastomeric bearings.***

12.1 **Visual Inspection of Elastomeric Bearings:** Elastomeric bearings shall be closely inspected for the following:

I. Position of bearing with respect to girder and sub-structure to identify if the bearing is correctly placed and/or has got shifted.
II. Defects in rubber layer such as small cracks in rubber layer, separation of rubber layers from steel reinforcement layers, separation of elastomeric cover etc.
III. Shear deformation of the bearing including bulging of rubber layers.
IV. More compression of one area/ corner of bearing as compared to other areas, offloading of edge of bearing etc.
V. Gap between bearing and bed block.

The visual inspections will give idea about the behaviour of bearing in general. Individual items of inspection and their combined effect both shall be assessed during visual examination. Some photographs indicating types of defects are:

Tilted Bearing with rubber cracked in one layer;

Bearing with separation of rubber from steel

The far edge of bearing is having more load (as seen by deformation of rubber layers)

Separation of cover is seen in middle portion

12.2 **Measurement of Defects in Elastomeric Bearings:** In order to allow meaningful conclusions to be drawn from inspections, quantification of condition of bearing needs be done. This is especially very important for elastomeric bearings. Terms like

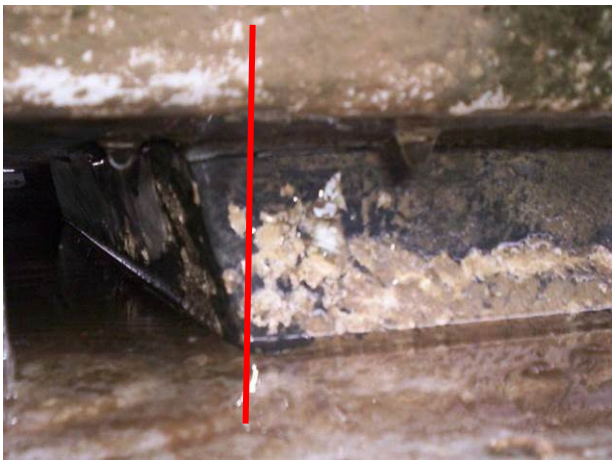
"Excessive Deformation", "Excessive bulging", "Bulging", "Torn" etc can lead to erroneous conclusions. The measurements shall be done as follows:

I. For measuring the correct position of bearing, proper location of center lines of bearings in both directions shall be marked on girder as well as sub-structure. The bearing center shall be compared with these markings and any difference shall be recorded.

II. The defects like cracks and separation of layers etc shall be quantified to the extent possible. E.g. the extent of problem i.e. faces affected, layers affected, whether full face/ layer is affected etc shall help in quantification. Even percentage area of face affected can be estimated and noted down. This information shall be supplemented by photographs.

III. Height of bearing shall be measured using small piece of scale slightly less in height than the height of bearing and use of feeler gauge with this scale.

IV. Tilt in bearing and bulging of the bearings shall be quantified by measuring the same against a straight edge. For this, inspecting official shall have a straight edge slightly less in height than the height of bearing, as shown in photo below.



A tilted bearing (The tilt from vertical shall be quantified);

Bulging being measured with wooden straight edge & scale

V. The area of bearing offloaded and area which looks more stressed than others shall also be quantified to the extent possible and supplemented by photographs.

Bearing with edge off-loaded

12.3 **Identification of Defective Bearings:** A bearing shall be considered defective, if it meets the following criteria (ref para 1107(4) (a) (viii) of IRBM, para 921 of IRC 83 Part II):

I. Shear deformation more than 50% of height of elastomeric pad
II. Compression more than 5% of height of the pad.
III. Rotation leading to off-loading of an edge.
IV. Significant cracks in rubber and significant separation of rubber layers.

Design Notes:

- *Some of the above values are based on design maximum shear strain of 70% (IRC 83 Part II para 916.3.4 (1)). Accordingly, the total tilting of bearing, therefore, shall be limited to 50% of total height and the total bulging of individual layer shall be limited to 50% of thickness of layers.*
- *The elastomeric bearing must have uniform vertical load because the coefficient of friction depends on this and the minimum vertical load is 2 MPa whereas maximum vertical load is 10 MPa. If the bearing is not uniformly loaded (or offloaded), the bearing cannot serve its function properly. (Para 916.3.6 of IRC 83 Part II and Para 4.3.3.1/4.3.3.2 of UIC 772-2R 1989).*

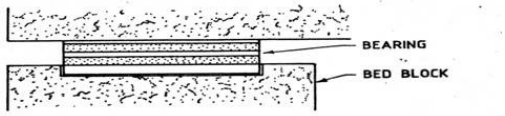


FIG. 4.7 ANTI-SLIP DEVICE BY PLACEMENT IN RECESS

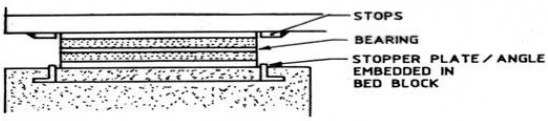


FIG. 4.9a ANTI-SLIP DEVICE BY STOPPER PLATE

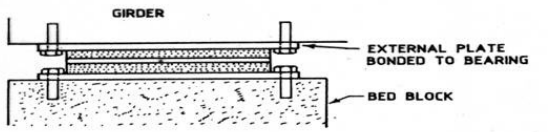


FIG. 4.9 b ANTI- SLIP DEVICE BY BOLTING

12.4 **Condition of Anti-slip device:** Due to the limitation of minimum vertical loads, the elastomeric bearings are not recommended for use in light structures like steel plate girders or for smaller spans. If, however, these are to be used, suitable anti-slip device shall be provided which shall not permit the bearing to get loose. These anti-slip devices can be positive attachment with steel plates or stopping arrangement like recess or physical stopper, as shown in figures alongside.

13. **COMMON REPAIR/ MAINTENANCE ACTIVITIES IN ELASTOMERIC BEARINGS:** The elastomeric bearings are generally maintenance free. However, the following activities (in addition to the common items given in para 7 above) are required to be done:

13.1 **Relieving locked up deformation:** New elastomeric bearings may show huge deformations especially if these are provided under newly cast girders. This is due to change in concrete dimensions due to creep/ shrinkage etc. The girder may be lifted to allow the elastomeric bearings to return to their original dimension and then lowered (Para 5.4 and 6.2 of UIC 772-2R). Note under IRC 83 Part II para 921.2.1, however, warns that this shall be done under strict control to prevent any mis-alignment. Care shall be taken that in the effort to remove the deformation of bearing, it may not get out of position.

13.2 **Replacement of bearings:** Normally, a defective bearing cannot be rectified and it has to be replaced. For replacement, a few things shall be kept in mind:

13.2.1 The decision for replacement of elastomeric bearing shall be taken if:

I. The deformation of rubber is beyond permissible limits (shear strain>50% or permanent deformation>5%) which cannot be rectified even by lifting of girders.

II. The bond between rubber and steel laminates is lost and there is a crack at the interface, except when the length of crack is considered insignificant or repairable.

III. Rubber is cracked such as to create doubt about the performance as well as durability of bearings. If the cracks are in a small portion of bearing, engineer may decide about retaining the bearing with repairs.

13.2.2 **When a bearing is to be replaced, all the bearings in that line of support in one girder have to be replaced together (Para 921.2 of IRC 83 Part II).** This is required to ensure that all bearings in a line of support have the same stiffness. Bearings age with time and the stiffness keeps going up. Hence mixing some old and some new bearings in a line of support may result in excess load on some bearings.

13.2.3 Lifting shall be done at nominated lifting points only, appropriate capacity jacks shall be used and in girders connected by diaphragms/slabs, care shall be exercised to ensure that all jacks act simultaneously (It is preferable to use synchronous jacks operated by single pump). Handling girders at wrong locations can lead to damage to girder and differential lifting by jacks can lead to failure of diaphragms/slabs etc.

13.3 Repair of Minor Damage: Fine surface cracks in rubber (Covering a small portion of bearing face) or few minor cracks upto 5 cm long between rubber and steel plates in bearing which doesn't have any other defects can be rectified with cold in-situ vulcanizing compounds. Literature and manufacturer guidelines shall be followed for carrying out such repairs. **These repairs shall be done only after it has been determined that the defects in bearing are superficial, minor and local which are not increasing with time and are not having any other defects.**

13.4 **Rectification of offloading or improper loading on bearing:** If the shape of bearing under load indicates that some portions are more deformed as compared to others or

if offloading of edge(s)/corner(s) of the bearing is taking place, steps shall be taken to ensure proper load transfer evenly to the entire bearing. Rectification may be done by chipping off projecting materials from girder bottom or bed blocks or by making good some portion using principles described in para 4 above for installation of new bearings. Sometimes, this problem may be due to material of bearing not behaving properly in which case, replacement of bearing may be required.

13.5 **Rectification of bearing misalignment:** If bearing is out of position or is not fully in contact either with girder or bed block, the bearing alignment may be rectified. For this, the girder shall be lifted taking care as mentioned above. One end of girder shall be completely lifted even if only one or two bearings are to be rectified. For bearings simply resting on the bed block, these can simply be shifted to proper location and girder lowered. For bearings with anti-slip device, action needs to be taken about the anti-slip arrangement and holding down bolts etc also.

13.6 **Defects for which no rectification is required:** Normally, no rectification is required if the elastomeric bearing cover is peeled off from the underlying steel/rubber portion but there is no other defect in the bearing. Such bearings are required to be kept under watch during regular inspections. The area from which cover has peeling off shall be clearly marked to determine if the problem is increasing in extent.

Important Note: *If signs of corrosion appear in the steel plates in the bearing, the bearing requires replacement. This condition shall not be confused with other cases where the bearing material starts flowing out between the plates which also manifests as bulging in the face of bearing.*

14. **WHAT TO INSPECT – POT/PTFE, SPHERICAL AND CYLINDRICAL BEARINGS?:** The POT/PTFE, spherical and cylindrical bearings are quite similar except that POT has a non-reinforced elastomer disk which acts as a pressurized fluid and facilitates rotation in any direction. The inspection principles are quite similar, hence these bearings are discussed together. Here it is important to point out that spherical/cylindrical bearings have not been adopted on many bridges on Indian Railways and any guidance provided here is theoretical only. This document will be modified further as experience with these bearings improves.

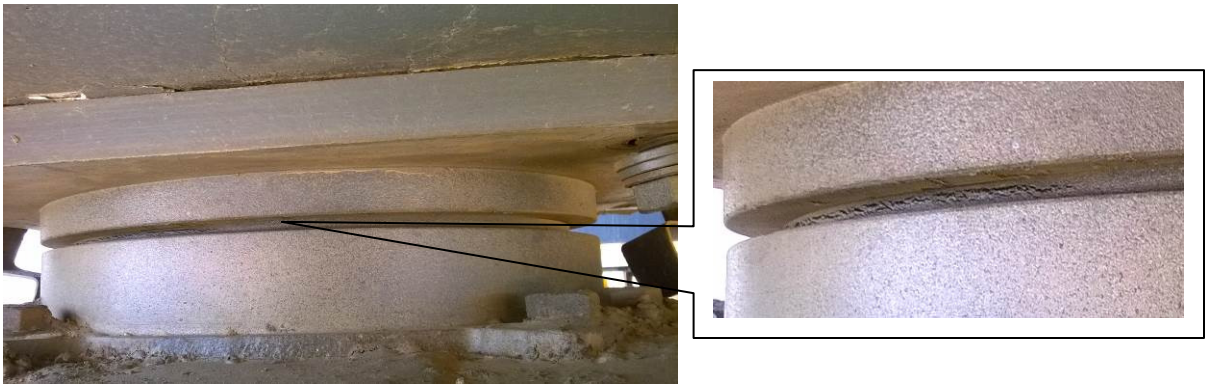
Special Note: *Inspection of these bearings is quite different from other types of bearings. Important components/surfaces of these bearings are sealed and not available for inspection as against all other bearings whose main components can be seen from outside. These bearings are not supposed to be opened during the service life as ingress of moisture/ dust/ debris etc can affect the components and performance of bearing. Therefore, the inferences regarding proper functioning of the bearings have to be drawn from indirect external observations/ measurements only.*

The main items of inspection for these bearings (in addition to the common items given in para 6 above) are as follows:

14.1 **Condition of Bearing:** The bearing shall be observed closely for any signs of damage, jamming etc. Any signs of wear and tear of parts, misalignment of parts, loosening of holding down bolts etc might indicate that bearing is not functioning properly. Unusual gaps between parts also indicates problems which need to be investigated. Cracks in POT/ guides etc, bending of plates etc are also important aspects of visual inspection of condition of bearing.

Gap in One side of POT PTFE Bearing

14.2 **Condition of seals and any protrusions:** If any internal component like elastomeric pad, or PTFE/ UHMWPE is distressed, it will try to protrude out from the openings. All openings are protected with dust seal/ wiper seal etc. These seals are normally of rubber and any signs of cracks/ protrusions etc in the seals need to be further investigated.



Cracked Seal of a POT-PTFE bearing

14.3 **Position of expansion end w.r.t. mean position:** Proper indication that a bearing is functioning is given by the position of girder w.r.t. sub-structure. This shall be seen by observing the position of marks of center line of top portion and that of lower portion of expansion bearing which are marked at the time of initial installation. If the graduated scale as suggested in para 10.3 above is provided, then the measurement of the relative position is easier. As in other types of bearings, rough computations shall be done to see whether the girder is expected to be shorter or longer than average length at the ambient temperature at the time of inspection.

15. **HOW TO IDENTIFY REASONS FOR THE PROBLEMS IN POT CUM PTFE AND SPHERICAL/ CYLINDRICAL BEARINGS?:** Rectification of defects in POT-PTFE/ spherical/cylindrical bearings is a difficult task and quite often, the manufacturer has to be involved. In some cases, a few bearings might be required to be taken out and inspected to identify the cause for defects. Normally, in case of defects arising in these bearings, complete or partial replacement of bearings/ components needs to be done. However,

understanding the reasons for the defects is important to identify the course of action to be taken. The main reasons for defects in these bearings are as follows:

15.1 **Improper installation:** Proper installation is the most common cause of problems in these bearings. If the bearing is not installed at proper location or in proper slope as per design, then bearing components will be subjected to non-uniform loads and bending moments. This internal bending induced can cause local overstressing which can lead to failure of components. Once local failure takes place and foreign particles enter the sliding/ rotating surface, the problems in bearing keep increasing and it can even get totally jammed, incapable of sliding or rotation. Similar is the effect of allowing ingress of external material in the sliding/ rotating interfaces during initial installation.

Wrong practice - Bearing opened during installation

15.2 **Improper fabrication:** Another important aspect to ensure trouble free service from these bearings is that the fabrication shall be done to close tolerances and with proper materials. Following are important in this respect:

15.2.1 **Material Quality:** For this, the quality assurance during supply becomes very important. Material test certificates of all materials used for fabrication of bearings, measurements of all individual members, workmanship in welding/machining etc and inspection of assembly in shop are very important to ensure quality of the bearings.

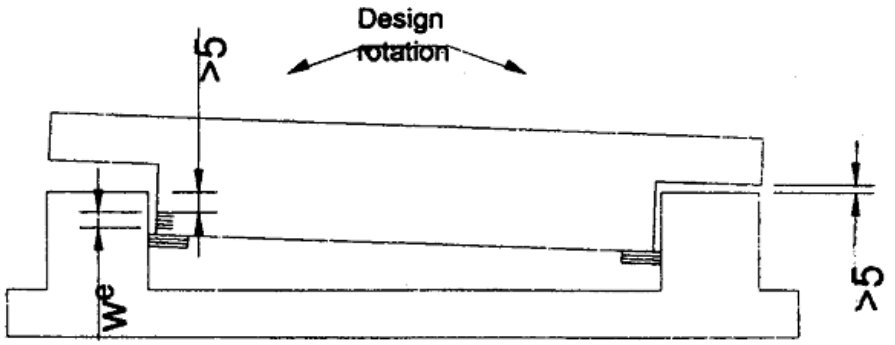
15.2.2 **Tolerances:** Any material/ connection failed due to quality issues or any lack of fit of members due to tolerance issues is also likely cause problems in the bearings in service. Tolerances are quite tight and affect both ways. For example, if the steel piston in a POT-PTFE bearing is manufactured with positive tolerance relative to the inside dia of base POT, a condition of steel-to-steel contact may develop, which may inhibit rotational capacity of the bearing. When the piston is manufactured with a negative tolerance

relative to the inside dia of base POT, the sealing rings have difficulty in containing the elastomer, which acts like a fluid under pressure.

15.3 **Improper Design:** The design issues are sometimes responsible for distress in bearings in service. A few instances are listed below:

15.3.1 **Inadequate vertical load on POT:** The elastomeric pad provided in POT bearings requires minimum 5 MPa pressure in order to be able to perform properly. If this minimum load is not available, the pad will not behave properly and chances of elastomer oozing out from sides of the piston increase.

15.3.2 **Inadequate rotation capacity of bearing:** Under loads, the girders rotate. Under this rotation, the upper part of bearing rotates with respect to the lower part. The design of bearing involves check that under maximum rotation, the upper and lower parts of bearings will have clearance more than 5 mm. If the rotation of girder is more than that computed, then the two parts of the bearing will touch and the load transfer can start taking place through this contact bye-passing the bearing mechanism and this can cause wear and tear as well as cracks/ other failure of components.



Clearance requirement for a POT-PTFE bearing

15.3.3 **Inadequate thickness/ edge distances in components:** This can lead to cracks in components or deformation/gaps. Inadequate edge distances can also lead to cracks in surrounding concrete or steel members also.

15.3.4 **Incorrect assumption in Design:** In rare cases, such errors are seen. For example, in a case, the bending effect on top plate of POT-PTFE bearing due to the distance between the webs of bottom chord of steel open web girder was not considered in a particular case due to communication gap between different designers which resulted in bending of this plate, as seen in photograph below:

Top Plate of bearing developed upward convexity due to bending

15.4 **Normal wear and tear and Ageing:** Bearings suffer wear and tear in service, which can accumulate and problems might appear with age. More problems are likely to appear in bearing subject to relatively larger horizontal loads and those subject to more cyclical loadings.

15.5 **Problems in Cold Weather:** During extreme cold temperatures, coupled with high-design pressures, the rubber has been known to crystallize, which in turn eliminates the rotational capacity of the device. Most parts of India, though, don't experience these cold weathers and this might not be a big issue for Indian railways.

16. **MAINTENANCE OF POT CUM PTFE AND SPHERICAL/ CYLINDRICAL BEARINGS:** The normal maintenance activities given in para 7 above are adequate for POT cum PTFE and Spherical/ Cylindrical bearings. For any other defects, special coordinated efforts are required on part of design engineers and field engineers to identify reasons for the same, based on which further action shall be decided.

17. **LIFE OF BEARINGS:** The replacement of bearings is another important decision to be taken by the maintenance engineers. Normally Indian Railways follows the practice of condition based renewals for bridges and for bearings also, no design life is specified. The decision regarding life of different type of bearings shall be taken as follows:

17.1 **Steel Bearings:** The steel sliding/ roller-rocker bearings generally have same life as the structure and very rarely replacement is required. The replacement shall be done if so warranted by the condition of bearing as seen during inspections.

17.2 **Life of elastomeric Bearing:** Life of elastomeric bearings is less than that of the structure and it is expected that rubber will deteriorate and require replacement before the typical design life of bridge (more than 80 years) is over. These bearings, therefore, might be required to be replaced. In practical applications on Indian Railways, it has been seen that some bearings have had to be replaced in as less as three-four years after installation whereas others have had uneventful performance over more than 20 years. Therefore, it is not possible to lay down a definite life of elastomeric bearings. Similar experience has been had in world railways also where it

has not been possible to specify the life of elastomeric bearings. The decision on replacement shall be taken on the basis of pattern of problems being detected in the bearings. If no visible signs of problems are visible but doubt arises about the condition of bearing, **it is suggested that whenever, doubt arises about the life of bearings, two typical bearings shall be replaced from a bridge and sent for laboratory testing.** The destructive tests specified for complete bearings in IRC 83 part II shall be conducted and values obtained shall be compared with the initial/design values to take decision regarding replacement of bearings. However, for elastomeric bearings and other types of bearings, replacement shall be required within the normal design life of girders (60-80 years or even higher).

17.3 **POT-PTFE/ Spherical/ Cylindrical Bearings:** Indian Railways' experience with these bearings is as yet limited and so the design life of these bearings can't be laid down as yet. The decision regarding replacement shall be taken based on results of inspection. One factor that needs to be considered, however, is that the materials like PTFE/ UHMWPE have limited design life when expressed in terms of total sliding distance travelled. Most of this sliding takes place under the thermal variations while a smaller part takes place under the effect of traffic loads. The sliding travel of PTFE is of the order of 10 KMs whereas that of UHMWPE is higher, which can go even upto 50 KMs depending on type of material. The approximate daily travel based on thermal variations in different seasons can be computed to determine approximate life of the sliding material and when the life thus computed nears completion, a few sample bearings can be inspected to determine if the wear and tear of the sliding surface is within limits or not.

Condition of UHMWPE sliding surface after testing in laboratory

18. **RESULTS AND ACTIONS:** The results of every inspection shall be recorded in inspection report for which appropriate performa shall be used. Various defects shall be critically analyzed and following types of action shall be recommended by the inspecting engineer:

18.1 No action required.

18.2 Further measures/long-term monitoring or design analysis needed (e.g., considering extreme temperatures/exposures, variation of loads, etc.).

18.3 Minor repair works e.g. cleaning, repainting etc.

18.4 Repair or replacement of entire bearing or parts of the bearing.

Important Note: *Bearings are a difficult subject and in many cases, the cause of defects can't be easily determined especially if there are more than one reasons contributing to the problem. It is quite possible that the further necessary actions cannot be determined by the inspecting person or the field bridge engineer. In such cases, the design engineers/ manufacturer should be consulted. Joint inspection of site shall be arranged, if required.*

19. Bibliography

a. Indian Railways Bridge Manual, 1998. Upto A & C Slip no 32.
b. IRC 83 Part I, Part II, Part III and Part IV.
c. UIC 772-2R, 1989.
d. RDSO drawings on RAILNET site 10.100.2.19.
e. Inspection of bridge bearings, Chapter 9 by Mark Rossow, Continuing Education and Development, Inc. New York.
f. AREMA Bridge Inspector's handbook, 2008.
g. Appraisal and restoration of surface defects and damages to elastomeric bearings, Die Bahn, German Railways.
h. RDSO report no BS-48, September 2002.
i. RDSO report no BS-113, November 2014.
j. M & C Dte, RDSO's letter no M&C/Lub/VI/4/A Dated 17/18.03.2005.
k. Poster on "Neoprene bearing replacement in Rio-Niterio bridge, Rio De Janeiro, Brazil – Technical and Economical view", by Marcus Werneck Carvalho and others presented in Fifth World congress of Joints, Bearings and Seismic systems for concrete structures, Rome, October 2001.

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