Outline of Presentation
1. Bridge Bearing Types and Functional Properties
2. Possible arrangement of Bearing Layouts
3. Introduction to the New set of Limit State Codes
4. Installation Requirements for Bearings
5. Testing and Acceptance Criteria

Function of Bridge Bearings
1. Bearings are elements transferring vertical loads from Superstructure to Substructure, but allowing unrestrained rotation & displacement of superstructure, thus avoiding large forces to be transferred to substructure & foundation.

2. Bearings are critical elements within overall bridge systems. They can potentially cause significant problems if they do not function properly. Malfunction in bearing can cause distress / failure of the bridge

Functions of Bridge Bearings .... Contd
- Allows rotation between superstructure and substructure
- Functions as per design requirements: It prevents displacements (Fixed Bearings), or allow displacements in only one direction (Guided Bearings) or allows displacements in all directions (Free Bearings).
- Enables unrestrained movement of the deck, ensuring that large forces are not transferred to the substructure and foundation due to restraints in movement.
- Recent Bridge bearings are also designed to act as seismic protectors, that arrests and dissipate energy during earthquakes and other seismic activities.

Primary Function & Operating Principles of Bridge Bearings
- Sliding
- Rolling/Rocking
- Deforming

In addition to above application of Bearings, the modern bearing system combines the routine function of bearing with other functions (such as seismic isolators / LUD)
Primary Function & Operating Principles of Bridge Bearings

Continuous Bridges with Lock Up Devices

Seismic Isolators

Isolator resulting from the combination of a LRB and Crescent Moon Steel Hysteretic Devices

Lead Rubber Bearings and Steel Hysteretic Dampers (SHD)

Isolation and Energy Dissipation

Combined effect of period shift and damping
**Brief History of Bridge Bearings**

1. Until the middle of this 20th century, the bridge bearings used consist of following types only:
   - Pin
   - Roller & Rocker
   - Metal sliding bearings

2. Increased demands and improvements in engineering materials, particularly plastics & elastomers have led to innovative designs and led to use of following types:
   - Elastomeric Bearings
   - Flexible Bearing
   - High Load Multi Rotational Bearings (Pot, Spherical, Disc)
   - Rigid Bearing

**Types of Modern Bridge Bearings**

1. The most widely used structural bearings are reinforced elastomeric bearings and pot bearings (90%).

2. Spherical bearings are the best solution for large rotations.

3. Elastomeric, pot and spherical bearings can be fixed, guided or free depending on design requirements.

**Some very important general principles in bearing design:**

1. Bearings are to be designed such that their components can be inspected, maintained and replaced if necessary. Lifting of the superstructure for maintenance / replacement of Bearings shall be foreseen in design.

2. Bearings shall be designed to permit the specific movements & rotations with the minimum possible reacting force & couple.

3. ‘Pre-setting’ shall be avoided as far as possible. This principle reflects negative past experience caused by wrong pre-setting or installation that cancelled the very small economical saving that could be achieved by reducing the movement capacity of the bearings.

4. For dynamically stressed structures like railway bridges or structures subject to the earthquake, the horizontal forces cannot be transferred by friction.
**Reinforced Elastomeric Bearings**

The trend in USA is to avoid using an alternative bearing system where a conventional reinforced elastomeric pad can provide the required characteristics through shear deformation.

Only when the practical limits of elastomeric bearing pads are exceeded, designers should consider using Pot, Spherical, Disc or other types of Bearings.

**Steel Roller and Rocker Bearings**

These types of bearings are used only very seldom in new constructions due to the rotation capacity around one axis only and to the fact that roller bearings can provide the movement only in the direction perpendicular to the rotation axis. However they still exist in a large number of old bridges.

**Steel Roller-cum-Rocker and Rocker Bearings**

**Steel Roller Bearings**

Brittle Fracture
Pot Bearings

1. Pot bearings represent the largest portion of the bearings market in the world.
2. First used in Germany in 1958. Suitable for design load between 1MN to 50MN and more.
3. Elastomer inside a steel pot is confined & functions like a viscous fluid.
4. Flat brass sealing rings are used to contain the elastomer inside the pot.

Composition of a Pot bearing

The most important detail of the pot bearings is the seal, preventing the leakage of the elastomer through the gap between pot and piston and governing the durability under repeated rotations.

(PTFE Sliding) Pot Bearings

- Long life span
- High loading capacity
- Free of wear
- Small reaction forces
- Impressive damping service
- Vertical stiffness
- Horizontal play
- Horizontal load transfer
- Passed in general
- Failed for some applications like high speed railway bridges.

SLIDING SURFACE OF BEARINGS:

<table>
<thead>
<tr>
<th>Pure Surface</th>
<th>Curved Surface</th>
<th>Guides</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTFE/CHROMITE (single)</td>
<td>Stainless Steel</td>
<td>PTFE/CHROMITE (single)</td>
</tr>
</tbody>
</table>

Use of aluminium alloy is permitted as mating surface for curved sliding interface only. The alloy shall be AlMg3M or AlSi7Mg TF in accordance with the requirements of ISO 1022 or as covered in the special approval documents like ETA, FWA, or similar.

Pure PTFE has a low compressive strength and a high coefficient of thermal expansion. To make it suitable for use in bridge bearings, PTFE must be combined with suitable fillers. These fillers are typically glass fiber and bronze.

SLIDING MATERIAL IN BEARINGS

| Fixed | Free Sliding | Guided Sliding | Polished Stainless Steel Sheets | Special silicon grease | Pure, virgin PTFE |
Pot Bearings

Internal seal failure = elastomeric disc extrusion: Special attention shall be paid to very flexible structures and to large sized bearings.

1. This is a very robust bearing system that is traditionally considered to be the most reliable HLMR type.
2. It can be designed to accommodate large loads (1 MN to 100 MN) and rotations.
3. It requires high degree of manufacturing quality control.

PTFE Spherical Bearings

- Long life span
- High loading capacity
- Free of wear
- Small reaction forces
- Unacceptable during service
- Vertical stiffness
- Horizontal play
- Horizontal load transfer

Passed in general, failed for some applications like high speed railway bridges.

Spherical Bearings

The latest invention & developments in the field of Bridge support & protection system "Spherical Bearing" have longer durability, enhanced service & performance life when compared with conventional Steel, Elastomeric & even Pot Bearings.

In Signature Bridge, Wazirabad, Delhi. Spherical Bearings has been used with a ULS load capacity of 23,000 MT, these bridge bearings will be one of the biggest ever manufactured & used in a bridge structure.

Spherical Bearings:

Adantages:
- Multirotational Bearings. Can accommodate higher rotations
- Relatively high vertical load capacity
- Low height
- Negligible vertical deflection under load.

Disadvantages:
- Require high degree of quality control and careful attention when installing – especially to ensure no dis-assemble.
- Requires periodic maintenance.
VARIOUS Spherical Bearings

1. For the curved surfaces, aluminium or chromium plated mating surfaces are allowed.
2. For the guides of sliding guided bearings the use of un-dimpled PTFE or composite materials based on PTFE are allowed.
3. These materials allow a considerably higher pressure but have also a much higher friction.

Disc Bearings

Disc Bearings, introduced in 1970, offers lower profiles over other multi-rotational bearings such as Pot Bearings. This is due to the use of an elastomeric unconfined polyurethane disc to accommodate rotation instead of a confined elastomer, a pot and a piston in case of Pot Bearing.

DISC BEARINGS: REASONS FOR IT'S LIMITED USE IN BRIDGES

1. They have not been extensively used because of proprietary status until recent years.
2. Service life experience and fatigue testing experience is limited.
3. There is concern that rotational stiffness can cause high stresses on sliding surfaces.

SELECTION OF APPROPRIATE BEARING TYPE FOR A GIVEN SITUATION

5. The choice of bearing depends on a wide variety of factors, including:
   - Type of Structure (Rail / Highway, Span length)
   - Vertical load (max. and min.)
   - Max. rotation,
   - Horizontal displacement,
   - Environment (Climate, Seismicity, Wind),
   - Economics
   - Structural arrangements.
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### FOR SIMPLY SUPPORTED SPANS:

**BEARING LAYOUT WITH ELASTOMERIC BEARINGS**

- Elastomeric bearings with PTFE sliding surface to take vertical loads & a separate mechanism to take lateral loads

**BEARING LAYOUT WITH ELASTOMERIC BEARINGS**

- Elastomeric bearings with PTFE sliding surface to take vertical loads & a separate elastic restraint to take lateral loads

**FOR SIMPLY SUPPORTED SPANS - HLMR BEARINGS:**

Structural bearings are fixed, guided or moveable in all directions

**Plan View of Span**

**FOR HLMR BEARINGS:**

- Fixity in longitudinal direction

**Plan View of Span**
Possible arrangement of Bearing Layouts

**FOR HLMR BEARINGS:**

Plan View of Span

Wind or other impacts

Fixity in transverse direction

Possible arrangement of Bearing Layouts

**FOR SIMPLY SUPPORTED SPANS:**

Structural bearings are fixed, guided or moveable in all directions

Possible arrangement of Bearing Layouts

**FOR CONTINUOUS SPANS (WITH HLMR BEARINGS):**

Guided in direction of Expansion

Line joining ZMP with the guide

Guided in constant direction from direction of Expansion

Guided in direction tangential to curve

Structural bearings allow movements – several layout patterns are possible.
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### Changes in the Code —Contd....:

**b. Size:**

<table>
<thead>
<tr>
<th>Previous Code</th>
<th>Plan Dimension should be as per series</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. ( b / l ) or ( l / b ) ≤ 2</td>
</tr>
<tr>
<td></td>
<td>2. ( t ) to ( t_p ) ≤ 2.5 mm</td>
</tr>
<tr>
<td></td>
<td>3. ( t ) to ( t_p ) ≤ 4 mm</td>
</tr>
<tr>
<td></td>
<td>4. ( t ) to ( t_p ) ≤ 8 mm</td>
</tr>
<tr>
<td></td>
<td>5. ( t ) to ( t_p ) ≤ 10 mm</td>
</tr>
</tbody>
</table>

### Technical Lecture Series — Indian Association of Structural Engineers

**Introduction to new set of Limit State Codes**

**Changes in the Code —Contd....:**

**c. Transfer of Seismic Forces through EB’s:**

New Code: Elastomeric Bearings, in its conventional form shall generally be used to transmit vertical loads, rotations and horizontal forces other than the forces due to Seismic. As a consequence of this requirement, conventional non-anchored elastomeric bearings can rarely be used for taking Seismic Forces.

In case they are used for taking Seismic forces, the bearings shall be:

1. Suitably Anchored to Substructure & Superstructure
2. Suitable devices for dislodgement of Superstructure need to be incorporated and
3. Bearings shall be tested for cyclic loadings, for which specialist literature shall be referred.

**d. Wider Choice in Material Properties:**

Code permits Structural Designer to specify the design material properties as per the requirement.

This is a positive development as it opens a dialogue between structural designer and rubber technologist, which was hitherto absent.
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**Installation Requirements for Bearings**

Specification, workmanship and installation of the grout or mortar are extremely important to control shrinkage / expansion and compressibility, to ensure that voids do not remain between the bearing and the structure, and to ensure sufficient strength.

**Collapsed Ultadanga Flyover**

Kolkata - March 2013

 DISTRESS IN DELHI METRO LINE- AIRPORT LINK

1. ELASTOMERIC BEARINGS OF SIZE - 95MM X 95MM X 50MM
2. ON RCC PEDISTALS OF 500 MM X 500 MM X 500 MM PROVIDED
3. VIBRATIONS ON RAILWAY TRACK CAUSED FURTHER DETERIORATION.
4. BEARINGS FOUND LOOSENED AND DAMAGED.
5. ADJOINING CONCRETE FOUND DISINTEGRATED.
6. SPEED REDUCTION AND SHIMMING UNDER RAILS DID NOT HELP.
7. RAIL TRAFFIC SUSPENDED JULY 2012.
8. IN ALL 216.0 BEARINGS RECTIFIED.

**Changes in the Code …Contd…..:**

e. Maximum and Minimum axial compressive stress in Bearing

**Previous code:**
Restricted the average compressive stress in bearing, 10 Mpa > σu > 2 Mpa

**In the New Code:**
There is no limitation for the maximum pressure on the bearings. Minimum pressure under ULS, for permanent load is restricted to 3 Mpa.

f. Maximum Strains

**Previous code:**
Limits of permissible total design strain was 5.0 and maximum shear strain was 0.7 under serviceability limit state (SLS).

**New Code:**
The limits of total strain and shear strain is taken as 7.0 and 1.0 respectively under ultimate limit state (ULS). The partial safety factor on action is taken as 1.4.

**Installation Requirements for Bearings**

1. Inappropriate handling, storage and installation will have an adverse effect on the bearing life.
2. The best bearing in the world will not perform satisfactorily, if it is damaged during transport and handling or if it is not correctly installed.
3. There are several examples of bridge failure / distress due to improper installation of Bearings.
Installation Requirements for Bearings

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Testing of Elastomeric Bearings

1. Short-term behaviour tests:
   - Shear Modulus test for G
   - Shear strength tests for shear bond
   - Compression test for stiffness

2. Long-term behaviour tests
   - Compression Set test (Creep test)

3. Environmental Influence Tests
   - Accelerated Ageing test
   - Ozone resistance test

Testing of HLMR Bearings

1. Tests on Raw Materials:
   - On Cast Steel, Mild Steel, Forged Steel, Mating Surface, Stainless Steel, Elastomer, PTFE, Bolts and Nuts.

2. Inspection of Finished Bearings
   - Visual Inspection for all Bearings
   - Testing of One pair of Bearings (Vertical Load Test, Friction Test and Rotation Test)

2. Process Inspection
   - Tests on Welding
   - Surface Hardness
   - Corrosion Protection

For any query, contact bsec.ab@gmail.com