Bearing of Bridges
What is Bearing?

• Mechanical arrangements provided in the superstructure to transmit the load to the substructure.

• Function of bearings:
  – To transmit vertical loads to the substructure. Ex: to the pier or abutment.
  – To facilitate movement caused by thermal changes. (expansion & contraction)
  – To provide rotational movement of the girders
Forces on Bearings

- Bearing intended to transmit the forces and sustain the translational and rotational movement of the bridge structure.
- 4 major forces are considered
- The reactions generated at the end of the structural members create reactive forces on the bearings.
- The longitudinal & transverse forces may be caused due to earthquake, thermal expansion and contraction, braking effect, etc.
Types of Bearings

Types of bearings

1. Fixed Bearings
2. Expansion Bearings
Types of Bearings

- Fixed bearing only allowed rotation
- Expansion bearing allowed both rotation and translation
- Cause of movement in bearing due to:
  1. Creep in concrete
  2. Shrinkage
  3. Settlement
  4. Uplift forces
  5. Thermal forces
  6. Sudden application of brakes initiate some movements
Types of Bearings

• Generally, for each span, one end of the bridge is provided with fixed bearings and the other end with the expansion bearings.
• The free ends allows for movement and the fixed end hold bridge
• If both end provided with fixed bearings, internal stress are sure to develop in the bridge components.
Type of Bearings

1. Pin bearing
2. Roller bearing
3. Rocker bearing
4. Sliding bearing
5. Knuckle pinned bearing
6. Pot bearing
7. Elastomeric bearing
1. Pin Bearing

- Type of fixed bearings that accommodates rotations through the use of a steel.
- Translational movements are not allowed.
- The pin at the top is composed of upper and lower semi-circularly recessed surfaces with a solid circular pin placed between.
- Usually, there are caps at both ends of the pin to keep the pin from sliding off the seats and to resist uplift loads if required.
- The upper plate is connected to the sole plate by either bolting or welding. The lower curved plate sits on the masonry plate.
1. Pin Bearing

- Rotational Movement is allowed
- Lateral and Translational Movements are restricted
2. Roller Bearing

- A general drawback to this type of bearing is its tendency to collect dust and debris.
2. Roller Bearing

- Longitudinal movements are allowed
- Lateral Movements and Rotations are Restricted
3. Rocker Bearing

• A rocker bearing is a type of expansion bearing that comes in a great variety.
• It typically consists of a pin at the top that facilitates rotations, and a curved surface at the bottom that accommodates the translational movements.
• Rocker and pin bearings are primarily used in steel bridges.
4. Sliding Bearing

- A sliding bearing utilizes one plane metal plate sliding against another to accommodate translations.
- The sliding bearing surface produces a frictional force that is applied to the superstructure, substructure, and the bearing itself.
- To reduce this friction force, PTFE (polytetrafluoroethylene) is often used as a sliding lubricating material. PTFE is sometimes referred to as Teflon, named after a widely used brand of PTFE.
4. Sliding Bearing

- Sliding Bearings be used alone or more often used as a component in other types of bearings
- Pure sliding bearings can only be used when the rotations caused by the deflection at the supports are negligible. They are therefore limited to a span length of 15 m or less by ASHTTO [10.29.1.1]
5. Knuckle Pinned Bearing

- It is a special form of Roller Bearing in which the Knuckle pin is provided for easy rocking.
- A knuckle pin is inserted between the top and bottom casting. The top casting is attached to the Bridge superstructure, while the bottom casting rests on a series of rollers.
- Knuckle pin bearing can accommodate large movements and can accommodate sliding as well as rotational movement.
6. Pot Bearing

- A POT BEARING consists of a shallow steel cylinder, or pot, on a vertical axis with a neoprene disk which is slightly thinner than the cylinder and fitted tightly inside.
- A steel piston fits inside the cylinder and bears on the neoprene.
- Flat brass rings are used to seal the rubber between the piston and the pot.
- The rubber behaves like a viscous fluid flowing as rotation may occur.
- Since the bearing will not resist bending moments, it must be provided with an even bridge seat.
6. Pot Bearing

(b) Pot Bearing

- Sole plate
- Keeper plate
- PTFE sliding surface
- Sealing ring
- Steel piston
- Elastomeric pad

Components:
- Steel Slide Plate
- Stainless Steel
- Steel Piston
- Brass Sealing Rings
- Elastomeric Disc
- Steel Pot Plate
7. Elastomeric Bearing

• The problem providing bearings that will accommodate comparatively small movement (~ 6 to 125 mm), with or without rotation has been solved by using roller bearing or sliding plate bearing.
• However, the price of both bearings were expansive and required long term maintenance.
• Bridge designer has turned to use elastomeric bearings because it has a life expectancy comparable when properly design and manufactured.
7. Elastomeric Bearing

- Elastomeric bearing accommodate horizontal movements by shearing and have enough shearing flexibility to avoid transmitting high loads to the bridge supports.
- Advantages:
  - Easy installation
  - No maintenance
  - Low cost
  - Extremely versatile
7. Elastomeric Bearing

- Types of rubber:
  - Volcanized natural rubber
  - Synthetic rubber

- Special properties of rubber that required for bearing:
  - Good resistance to the action of oils, weather, atmospheric ozone and the extreme temperature
7. Elastomeric Bearing

Type of rubber bearings

Plain rubber pad/unreinforced bearing

Laminated/reinforced bearing

Elastomeric material interspersed with steel plates
7. Elastomeric Bearing

1. Plain rubber pad/unreinforced bearing consisting solely rubber.
   - Use to accommodate rotations in location with little or zero horizontal movement.
2. Laminated/reinforced bearing
   - Design to accommodate most combination of load and shear movement, by reinforcing the rubber with one or more steel plates.
8. Laminated Elastomeric Bearing

- consist of a laminated elastomeric bearing equipped with a lead cylinder at the center of the bearing.
- The function of the rubber-steel laminated portion of the bearing is to carry the weight of the structure and provide post-yield elasticity.
- The lead core is designed to deform plastically, thereby providing damping energy dissipation.
- Lead rubber bearings are used in seismically active areas because of their performance under earthquake loads.
Design of Bearings

The basic principles for the design of rubber bearing are as follows:

1. The plan area of the bearing depends on the allowable pressure on the bearing support.
2. The total thickness of rubber is dependent on the total shear movement and the stability of the bearing.
3. The thickness of individual layers of rubber in reinforced bearings is dependent on the need to limit shear stresses or strains to prohibit tensile strains and to limit the vertical deflection.
4. The thickness of the steel reinforcement plates is governed by the need to limit the tensile stress in them.
5. The protection of the bearing is most satisfactorily achieved by totally encasing the bearing in rubber.
6. The method of attaching bearings must be considered so that slip cannot occur.
Design of Unreinforced Elastomer Bearing

1. Plan dimensions of elastomeric bearing

<table>
<thead>
<tr>
<th>Size (Index no.)</th>
<th>Width, a (mm)</th>
<th>Length, b (mm)</th>
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</table>
2. The vertical (axial) stiffness of the elastomer is represented by its shape factor. The shape factor $S$ of the elastomer is given by the ratio

$$\frac{\text{loaded surface area}}{\text{surface area free to bulge}} = \frac{ab}{2t(a+b)}$$

Where $a$ and $b$ are plan dimensions of the pad, and $t$ is the thickness of the pad.
3. Thickness

the thickness of a bearing is governed by its shear movement. If $u$ is the translational shear deformation (Figure), then

$$u = t \tan \phi$$

$$\tan \phi = \frac{H_c + H_s}{GA}$$

Where $G =$ modulus of rigidity in N/mm$^2$

$H_c =$ sustained horizontal load in newton

$H_s =$ sustained dynamic horizontal load in newton

The value of $u$ should be less than 0.7$t$, such that $t > 1.43u$
Design of Unreinforced Elastomer Bearing

4. Average compressive stress

\[ \sigma_m = \frac{P}{A_e} \]

Where \( P \) = total vertical load in newton

\( A_e = \text{effective plan area excluding shear deformation in mm}^2 \)

\[ A_e = \frac{a - u}{b} < 2GS \]
Design of Unreinforced Elastomer Bearing

5. To prevent slip
The slip of bearing is due to high horizontal force and low vertical force. To avoid slip the following conditions need to be met with

\[ \sigma_m = \frac{P_c}{A_e} > \left(1 + \frac{a}{b}\right) \text{Mpa} \]

\[ (H_c + H_s) < f (P_c + P_f) \]

Where \( P_c \) and \( P_s = \) sustained & dynamic vertical load (N)
\( H_c \) and \( H_s = \) sustained & dynamic horizontal load (N)
\( f = \) coefficient of friction (average value = 0.3)
Example

• Design an elastomeric unreinforced neoprene pad bearing to suit the following data:

  vertical load (sustained) = 200 kN
  vertical load (dynamic) = 40 kN
  horizontal force = 60 kN
  modulus of rigidity of elastomer = 1 N/mm²
  friction coefficient = 0.3
  dimension of elastomeric bearing:
  a = 250 mm, b = 500 mm, t = 30 mm
Example

• Solution
Exercise

• Question
Design an elastomeric unreinforced neoprene pad bearing to suit the following data:
  - vertical load (sustained) = 345 kN
  - vertical load (dynamic) = 51 kN
  - horizontal force = 45 kN
  - modulus of rigidity of elastomer = 1 N/mm²
  - friction coefficient = 0.3
Expansion Joints
Expansion Joints

• An integral part of any bridge structure & should be considered at an early stage in design
• With proper design and installment, it can reduce the maintenance in service and can give trouble-free performance for many years.
• Important to appreciate the expansion joints in the most vulnerable position on any bridges situated at surface level.
• Exposed to impact and vibration of the traffic, dust, silt, water, salt solution, cement alkalis and petroleum derivative.
Requirement for Expansion Joints

- Accommodate all movements of structure and withstand all loadings
- Not impart stress to the structure unless the structure has been designed accordingly
- Have good riding characteristics
- Not present a skid hazard
- Not present a danger to traffic such as cyclist, animals, etc
- Be silent and vibration-free in operation
- Give reliable operation throughout the expected temperature range
- Be sealed against water & foreign matter or make provision for their proposal
- Resists corrosion & withstand attack from grit, chemical, etc
- Facilitate easy inspection, maintenance & repair
Expansion Joints

Deck Joints

Open joint

• Open joint - an opening between the concrete deck and adjacent structural elements.
• Prone to leakage, deterioration & can handle small longitudinal movement only.
• Only found in old bridge

Closed joint

• Closed joint – the gap between adjacent elements of the deck is covered by a sealant.
• Widely adopted for bridges.
Expansion Joints

- Closed joint – consists of a sealant, which is either inserted or hot poured into the joint.
- Suitable for rehabilitation work, when upgradation of existing joints (damaged) is required.
Compression Seal Joint

- Made by squeezing a sealant material into an open joint.
- An adhesive lubricant is provided along the sealant.
- Common material used is extruded neoprene.
- This material takes up movement of the bridge by getting itself compressed.
- Compression seal are combined with steel angles at the deck slab edge to formed an armored joint (durability).
- Problem: - loosening of bond between the seal & concrete surface
- cause loss of compression: lead to seal popping out of joint.
Strip Seal Joint

• Consists of an elastomeric material which is placed between the dual rails that are anchored to the face of the joint opening.
• Common material used – neoprene rubber
• Material is mechanically fitted into the steel rails assemblies
• Can accommodate a larger movement than that by compressive seals (up to 100mm)
Modular Joint

- Uses multiple strip seals to accommodate very large deck movement
- Seals are fitted between rolled beams, which run along the length of the joint
- Accommodate movements ranging from 900mm to 1200mm
- Used for skewed and curved decks