Lecture 8

STR403 - Metallic Bridges "BEARINGS"

Sherif A. Mourad

M. Hassanien

Professors of Steel Structures and Bridges

Faculty of Engineering, Cairo University

Lecture 8: BEARINGS

<u>Topics</u>

- Why are bearings needed?
- Types of Bearings.
- Design Requirements.
- Steel Bearings.
- Design of Steel Bearings.
- Elastomeric Bearing.
- Design of Elastomeric Bearings.

WHY BEARINGS?

1- Transfer forces from one part of the bridge to another, usually from the superstructure to the substructure.

2- Allow movement (translation along and/or rotation about any set of axes) of one part of the bridge in relation to another.

WHY BEARINGS?

- Movement is mainly from temperature changes.
- Axial and rotational strains arise from applied loads.
- It is not recommended to fully restrain a bridge against temperature movements. Why?

WHY BEARINGS?

If we consider a steel plate girder of cross sectional area 500 cm^2. If this girder is subjected to a 30ºC rise in temperature and is restrained from expanding axially, an axial stress of

$$\mathbf{E\ \alpha\ \Delta T = 2100x(1.2x10^{-5})x30 = 0.756\ t/cm^2}$$

is induced in the girder. The corresponding restraining force required is 0.756*500 = 378 ton. Neither the girder nor its supporting structure can carry such a force.

Lecture 8: BEARINGS

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- Why are bearings needed?
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TYPES OF BEARINGS

Bearings may be classified according to their **Deformation Behavior** into three basic types:

a) Fixed Bearings.

b) Hinged Bearings

c) Expansion/Roller Bearings.

TYPES OF BEARINGS

FIXED BEARINGS

A *fixed-end bearing* completely restrains the member end from translation and rotation. It is capable of supplying a vertical and a horizontal reaction plus a restraining moment. Considering the expense of fixing a heavy steel member at the ends, the use of such a bearing is usually **limited to sites having very strong rocky soils.**


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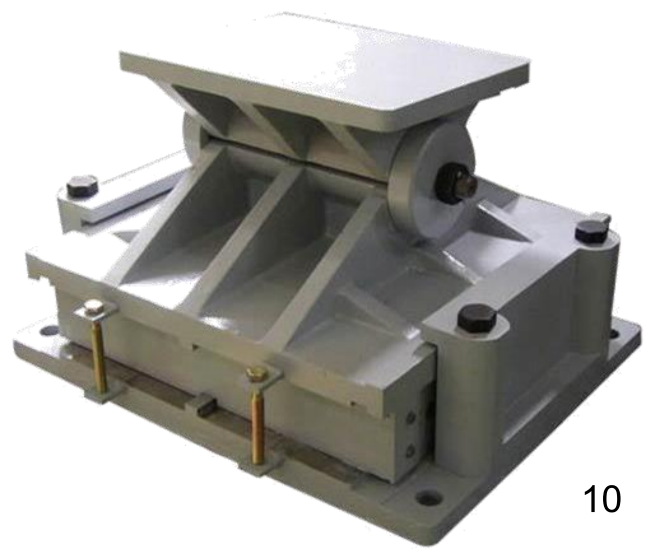
TYPES OF BEARINGS

HINGED BEARINGS

A *hinged bearing* will permit rotation of the member ends, and this is usually accomplished by a pin. Hinges carrying heavy vertical loads are normally provided

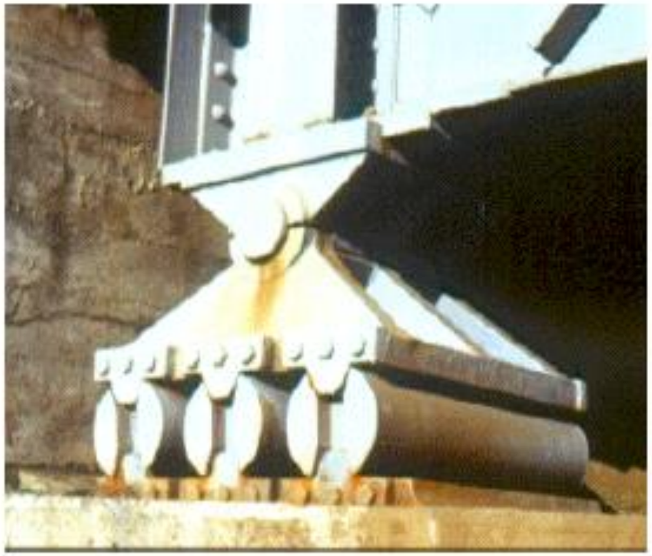
With lubrication systems to reduce friction and ensure free rotation without excessive wearing.



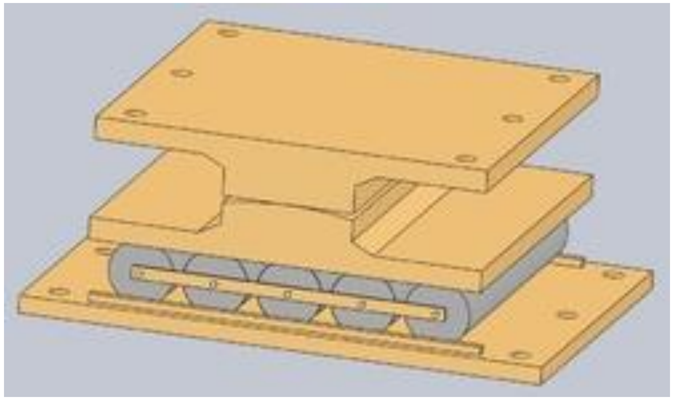
TYPES OF BEARINGS

EXPANSION/ROLLER BEARINGS

Expansion bearings permit movement as well as rotation of the superstructure, in two forms: sliding type and rolling type.



Sliding type bearings are used only for short spans and small loads since they cause high friction forces between the sliding plates.



Rolling-type bearings achieve their translational movement by using cylindrical rollers.

Lecture 8: BEARINGS

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DESIGN REQUIREMENTS

1. Movement.
2. Design Life.
3. Durability.
4. Limit states.
5. Materials.

DESIGN REQUIREMENTS

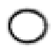
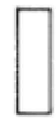
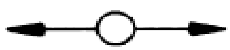
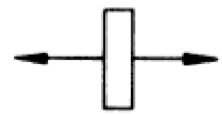
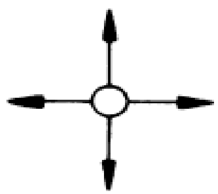
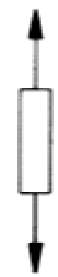
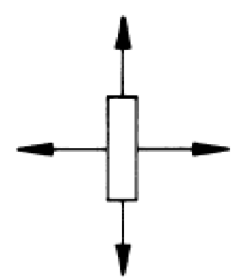
1. MOVEMENT

The sources of movement include:

- Bridge skew and curvature effects,
- Initial camber,
- Misalignment or construction tolerance,
- Settlement of support,
- Thermal effects,
- Construction loads, and traffic loading.

DESIGN REQUIREMENTS

SYMBOLIC REPRESENTATION

Symbol	Function	Symbol	Function
	All translation fixed Rotation all round		All translation fixed Rotation about one axis only
	Horizontal movement constrained in one direction only Rotation all round		Horizontal movements constrained perpendicular to rotational axis Rotation about one axis only
	Horizontal movement in all directions Rotation all round		Horizontal movement constrained parallel to rotational axis Rotation about one axis only
	Movement constrained in one direction only No vertical load		Horizontal movement in all directions Rotation about one axis only

NOTE All bearings can support a vertical load unless otherwise indicated. Symbols represent plan view on bearing.

DESIGN REQUIREMENTS

2. DESIGN LIFE

Bearings should be designed to last as long as the bridge itself. However, with some non-metallic materials in use today, it is difficult to ascertain this requirement. **Inadequate maintenance of metallic parts of bearings may reduce their service life**. It is thus important to allow for inspection and replacement of bridge bearings, in whole or in part.

DESIGN REQUIREMENTS

2. DESIGN LIFE

Provisions should be made for **installation of jacks necessary** for the removal of bearings, insertion of shims, or any other operations requiring lifting the bridge deck from the bearings.

Adequate space should be provided around bearings to facilitate inspection and replacement. If there is a possibility of differential settlement, provisions should be made for jacking up the bridge deck and inserting metal shims.

DESIGN REQUIREMENTS

3. DURABILITY

Bearings should be **detailed without recesses and enclosures that may trap moisture and dirt**. The materials used in their manufacture and the method adopted for protection against corrosion should ensure that the bearings function properly throughout their life.

DESIGN REQUIREMENTS

4. LIMIT STATES

The **strength** and **stability** of the bearings should be adequate to resist the ultimate design loads and movements of the structure.

DESIGN REQUIREMENTS

5. MATERIALS

Bearings may also be classified according to the **Material** used in their fabrication into:

a) Steel Bearings.

b) Elastomeric Bearings.

Lecture 8: BEARINGS

Topics

- Why are bearings needed?
- Types of Bearings.
- Design Requirements.
- **Steel Bearings.**
- Design of Steel Bearings.
- Elastomeric Bearing.
- Design of Elastomeric Bearings.

STEEL BEARINGS

Steel Bearings may also be classified into:

a) Roller Bearing.

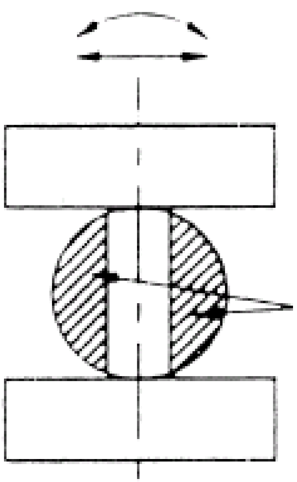
b) Rocker Bearing.

c) Knuckle Pin Bearing.

d) Leaf pin bearing.

STEEL BEARINGS

ROLLER BEARINGS

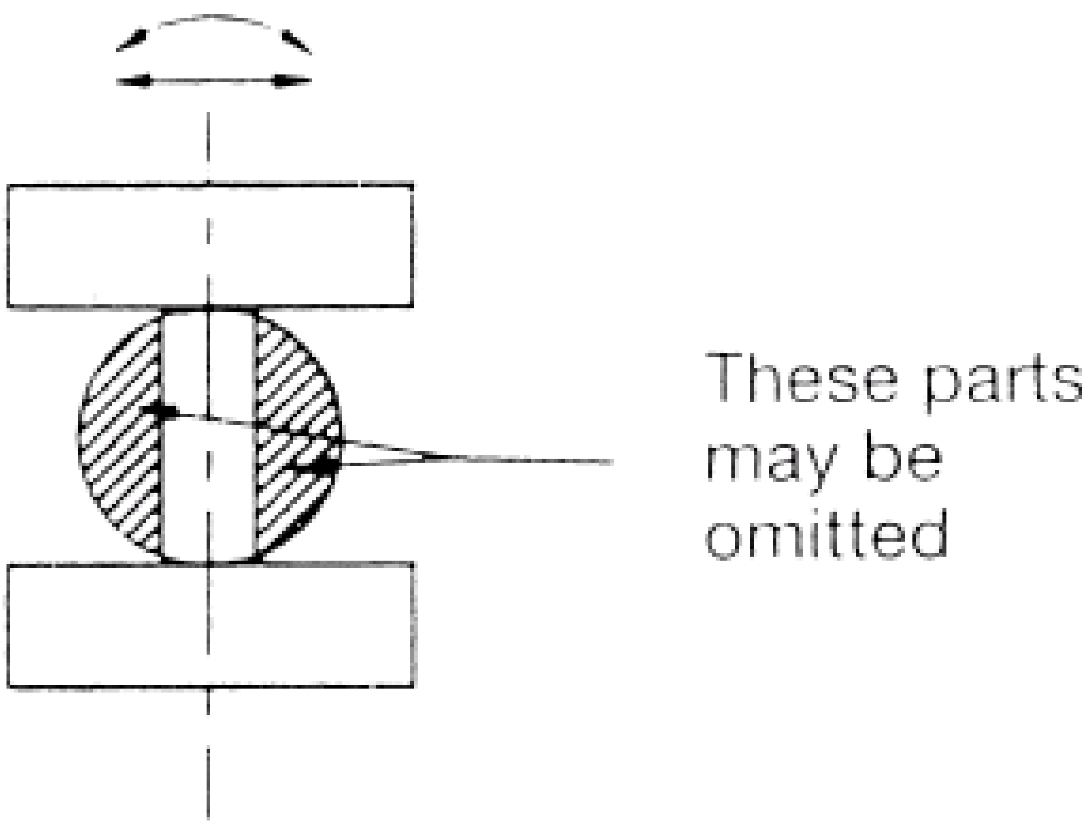


Consist of one or more steel cylinders between parallel upper and lower plates. Gearing or some other form of guidance should be provided to ensure that the axis of the roller is maintained in the desired orientation during the life of the bearing.

Roller bearings with a single cylinder can permit translation parallel to the longitudinal bridge axis and rotation about a horizontal axis in the transversal direction. Multiple cylinders on the other hand require another element such as a rocker or a knuckle bearing to permit rotation.

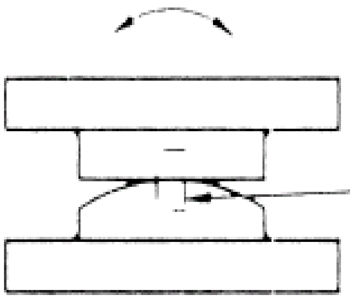
STEEL BEARINGS

ROLLER BEARINGS



STEEL BEARINGS

ROCKER BEARINGS

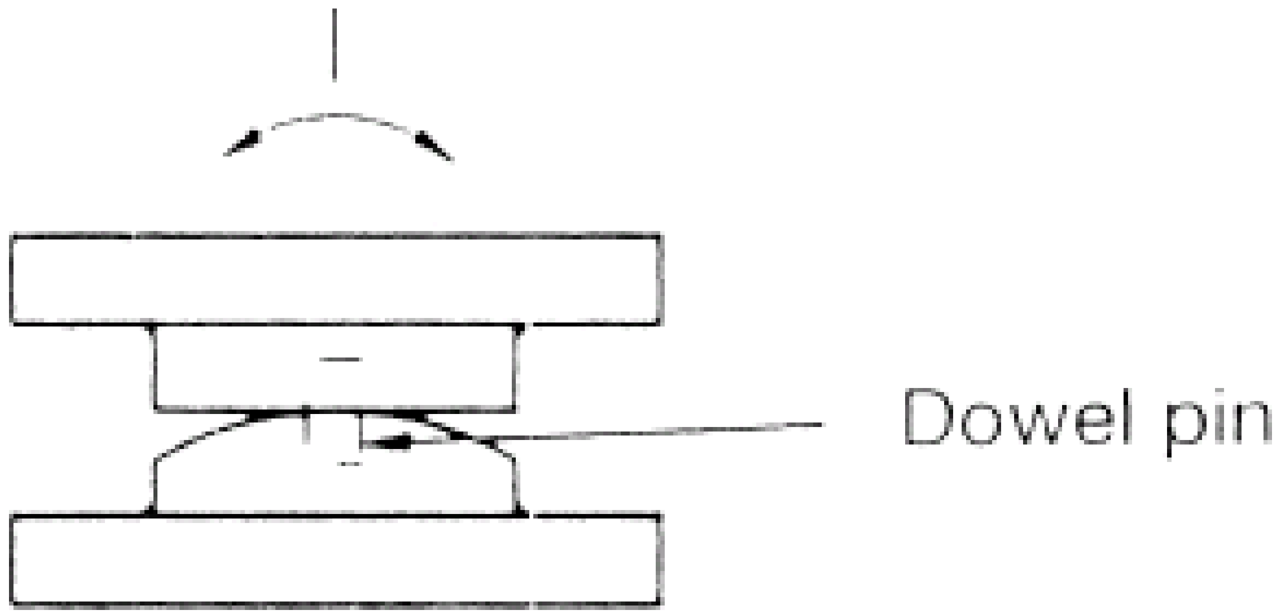


Consist primarily of a curved surface in contact with a flat or curved surface and constrained to prevent relative horizontal movement. The curved surface may be cylindrical or spherical to permit rotation about one or more axes.

Rocker bearings on their own do not permit translation and are usually used at the fixed end of a bridge to complement roller bearings. They can also permit rotation by the rolling of one part over another.

STEEL BEARINGS

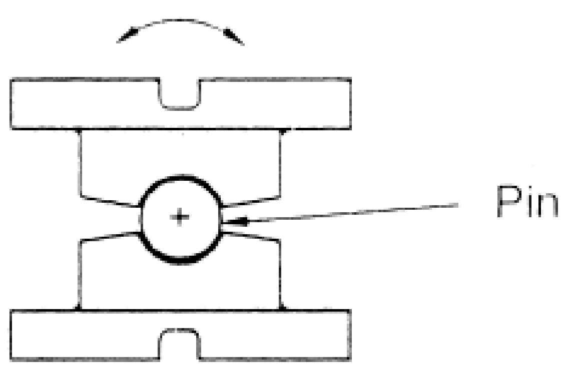
ROCKER BEARINGS

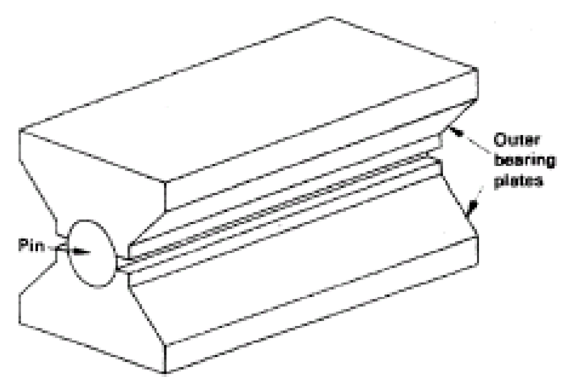


STEEL BEARINGS

KNUCKLE PIN BEARINGS

Consist of a steel pin housed between an upper and a lower support each having a curved surface which mates with the pin. This type of bearing permits rotation by the sliding of one part on the other.

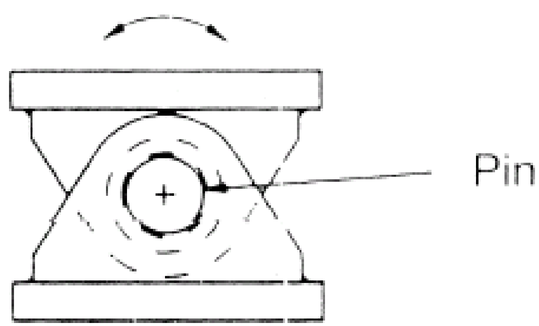


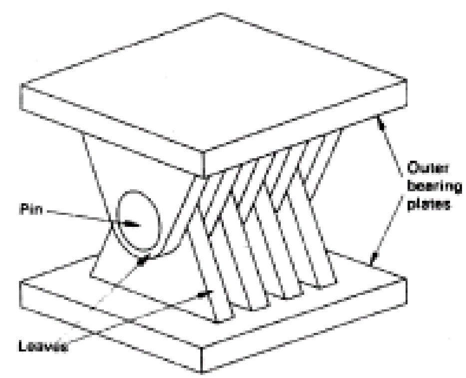


STEEL BEARINGS

LEAF PIN BEARINGS

Consist of a pin passing through a number of interleaved plates fixed alternatively to the upper and lower bearing plates. They permit only rotational movements, but can be used in conjunction with roller bearings to provide rotation and translation.





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- **Design of Steel Bearings.**
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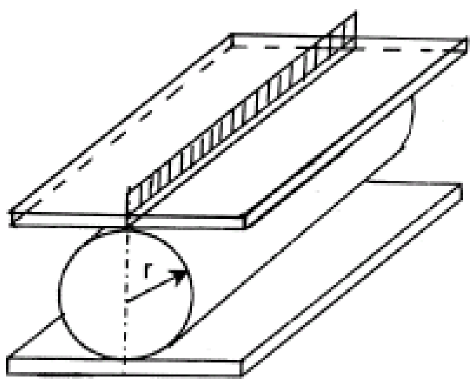
DESIGN OF STEEL BEARINGS

STEEL ROLLER BEARING

The maximum contact stress (*f* in t/cm^2) between a roller and a flat surface is given by the following *Hertz formula:*



$$f = \sqrt{\frac{EV}{2\pi r(1-\upsilon^2)L}} = 0.423\sqrt{\frac{EV}{L\,r}}$$

V = reaction in tons

r = radius of roller, cm

E = Young's modulus of steel (t/cm^2)

υ = Poisson's ratio of steel

L = roller length, cm

f =19.4 SQRT(V/Lr)

r =375.75 (V / L f ^{2})

DESIGN OF STEEL BEARINGS

STEEL ROLLER BEARING

Since the contact stress is confined and limited to a small area, it is permissible to use a high allowable stress, even exceeding the ultimate tensile strength of the material. For fixed, sliding and movable bearings with one or more rollers, the allowable contact stresses shall be as given below when the surface of contact between the different parts of a steel bearing is a line:

Material	Allowable Contact Stress (t/cm^2)
Cast Iron Cl 14	5.00
Rolled Steel St 44	6.50
Cast Steel CST 55	8.50
Forged Steel FST 56	9.50

DESIGN OF STEEL BEARINGS

STEEL ROLLER BEARING

For Steel Roller Bearing, resting on flat plates, using $E = 2100\ t/cm^2$, and $\upsilon = 0.30$:

Material		Allowable Reaction (ton)
Rolled steel	**St 37**	**0.040 d.ℓ**
Rolled steel	**St 44**	**0.055 d.ℓ**
Cast steel	**CST 55**	**0.095 d.ℓ**
Forged steel	**FST 56**	**0.117 d.ℓ**

Where:

d = Diameter of roller (cm).

ℓ = Length of roller (cm).

Note: For bearings employing more than two rollers, the maximum permitted design loads given above for single rollers should be reduced by 20% to allow for uneven loading of the rollers caused by dimensional differences.

DESIGN OF STEEL BEARINGS

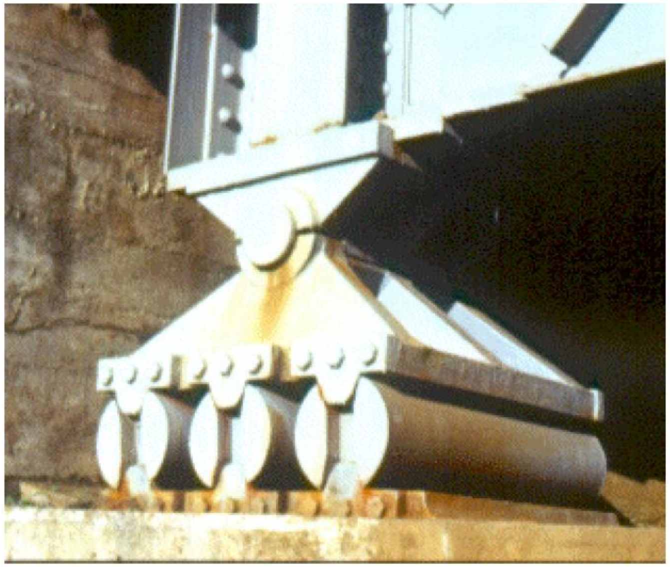
STEEL MULTIPLE ROLLER BEARING

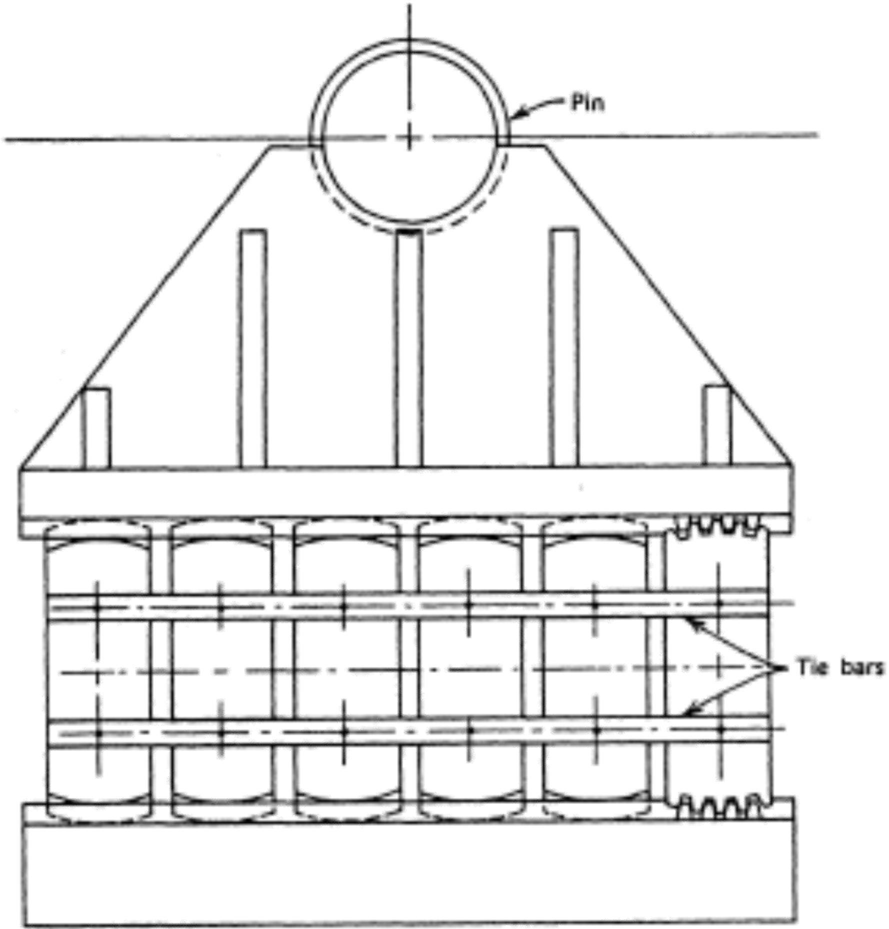
With two or more rollers, an independent pin must be provided to allow end rotation of the bridge due to bending deflection.

To save space between rollers, they can be **flat sided**. Such rollers should be symmetrical about the vertical plane passing through the center and the width should not be less than **(1/3)d** or such that the bearing contact doesn't move outside the middle third of the rolling surfaces when the roller is at the extreme of its movement.

DESIGN OF STEEL BEARINGS

STEEL MUILTIPLE ROLLER BEARING





DESIGN OF STEEL BEARINGS

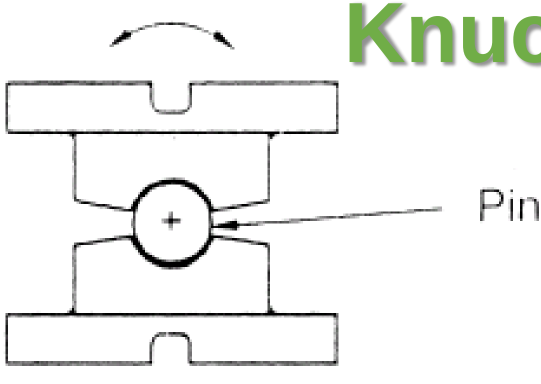
BASE PLATE

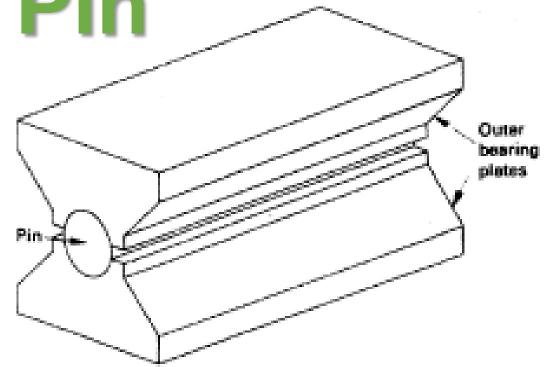
The rollers are seated on a base plate which distributes the vertical load to the concrete abutment or pier. The area of this plate is computed from the allowable bearing stress on the concrete which is **70kg/cm^2** for concrete C250 and **110kg/cm^2** for C350.

Anchor bolts connecting the base plate to concrete are designed to transmit transversal or longitudinal frictional forces resulting from movements. If the bearing is subjected to negative reactions, they are designed to carry tension.

DESIGN OF STEEL BEARINGS

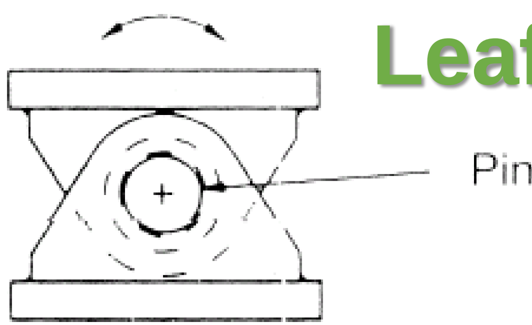
Knuckle Pin

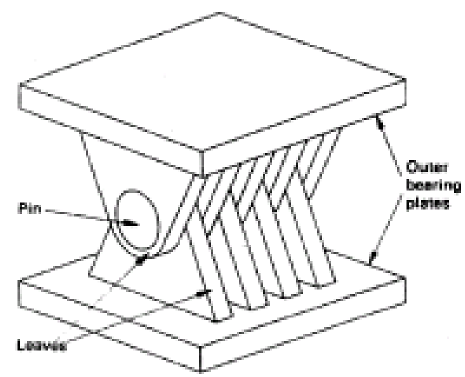




DESIGN OF
STEEL HINGED BEARINGS

Leaf Pin





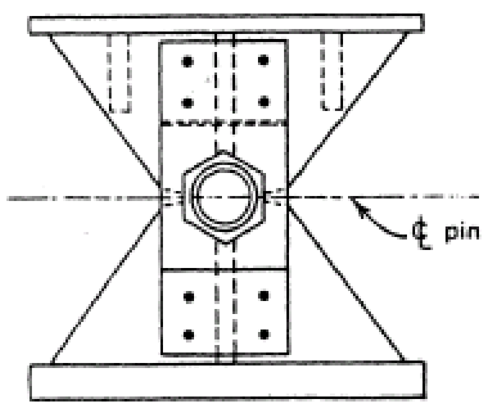
DESIGN OF STEEL BEARINGS

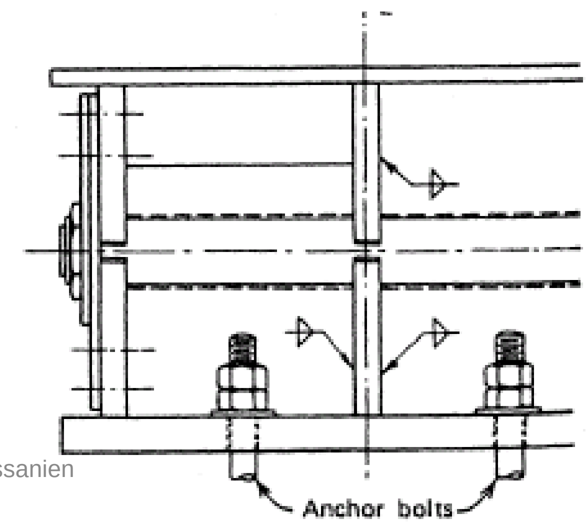
STEEL HINGED BEARINGS

- The design of hinged bearings is based on cylindrical cast steel knuckle pin, where the pin diameter is given by:
  <u>**d = 4/3 V/L**</u>

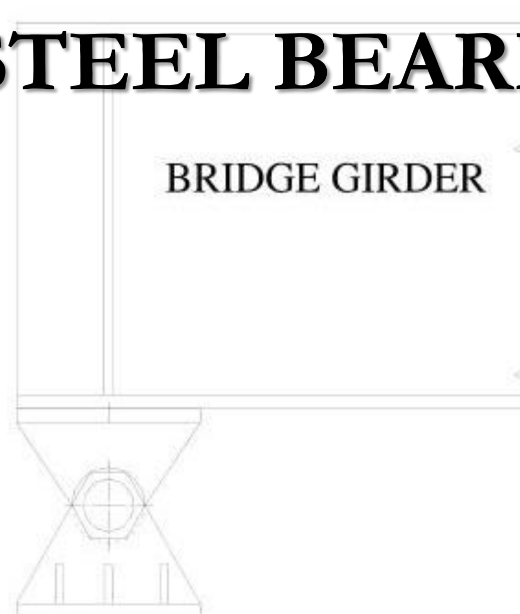
d=pin diameter, cm, **V**=vertical load, ton, **L**= pin length, cm.

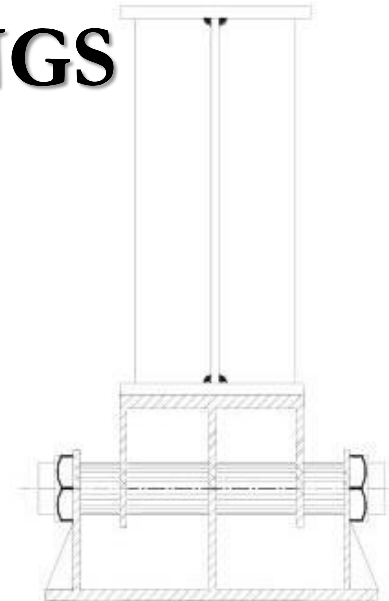
- The bearing pressure between pin made of cast or forged steel and the gusset plates shall not exceed **2.40** t/cm**2**.

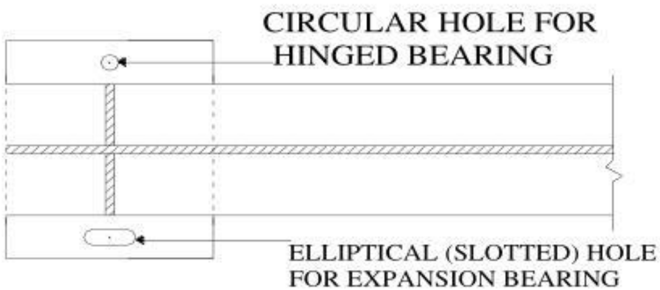


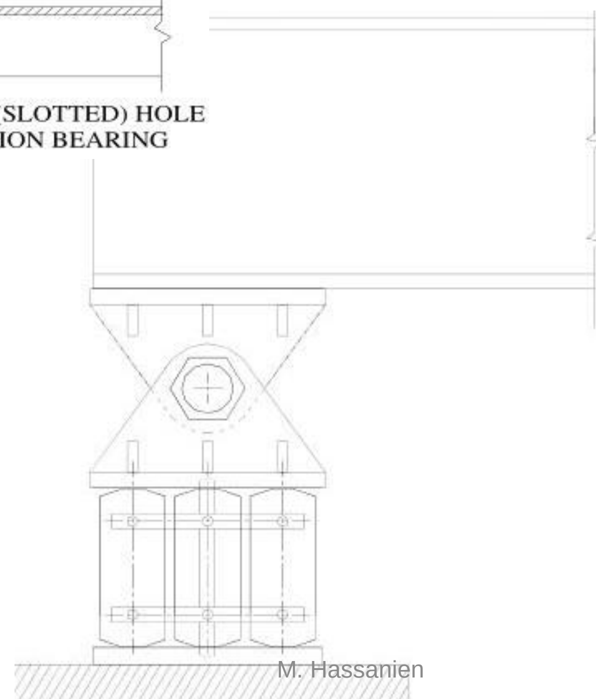


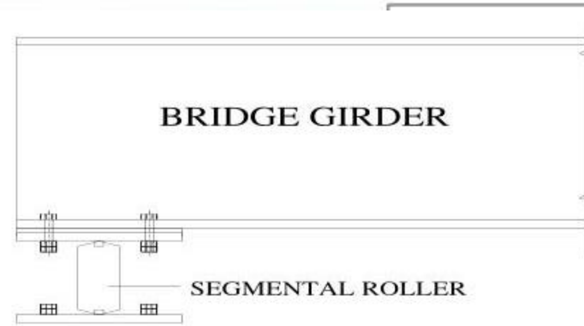
DESIGN OF STEEL BEARINGS

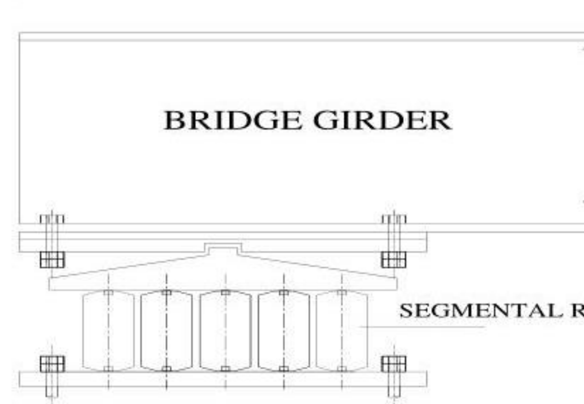










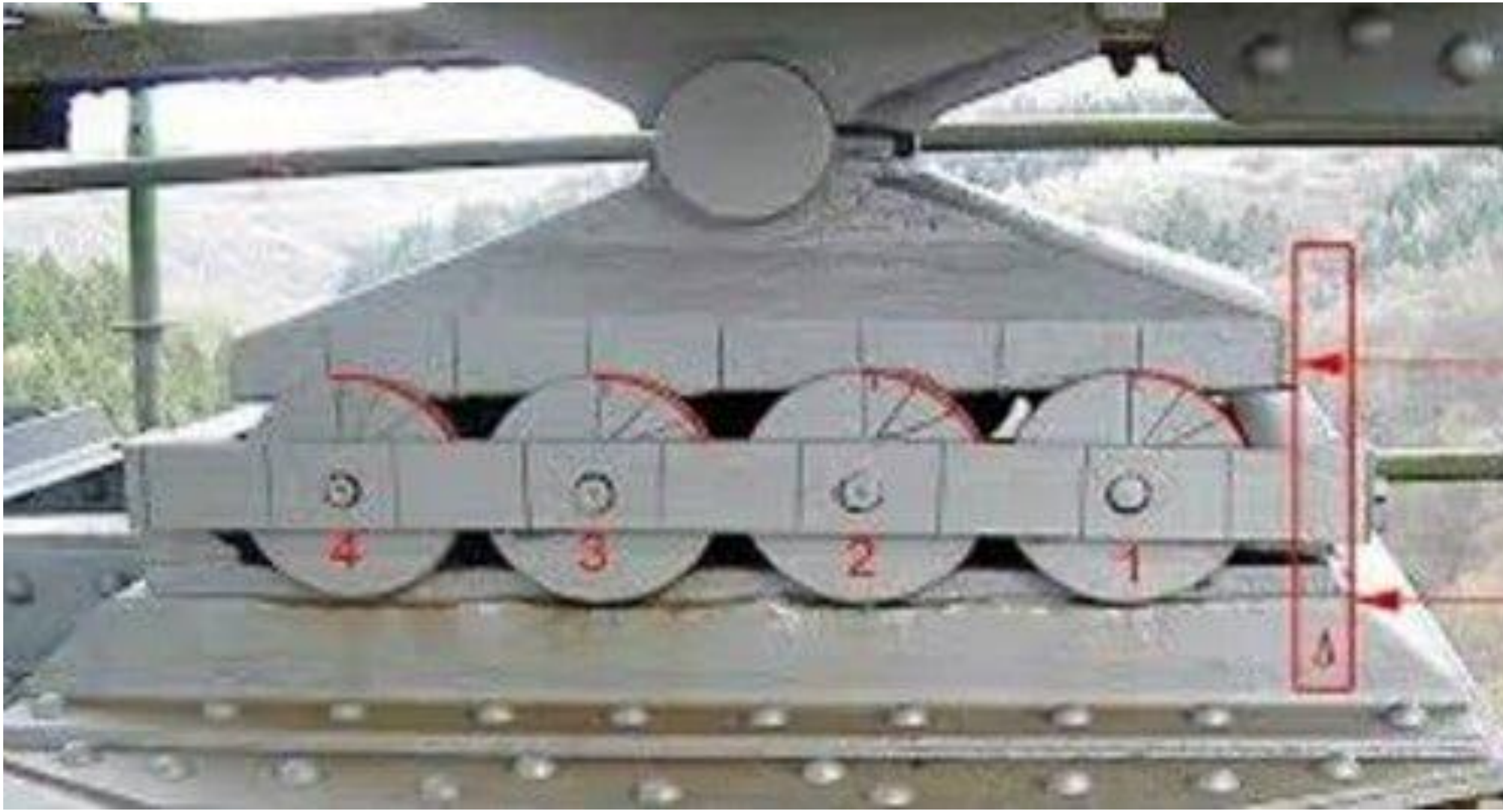


DESIGN OF STEEL BEARINGS

PHOTO

DESIGN OF STEEL BEARINGS

PHOTO



Lecture 8: BEARINGS

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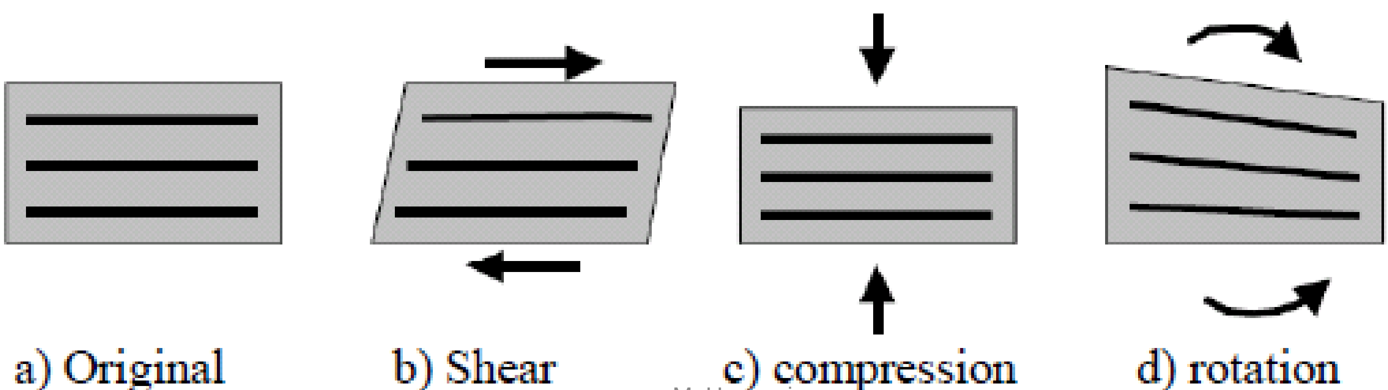
- **Elastomeric Bearing.**
- Design of Elastomeric Bearings.

ELASTOMERIC BEARING

The main component of elastomeric bearings is the rubber pad that distributes the loads from the superstructure to the substructure.

Translational Movement is accommodated by shear in the elastomer, one surface of which moves relative to the other.

Rotational Movement is accommodated by the variation in compressive strain across the elastomer.



ELASTOMERIC BEARING

Either natural rubber or synthetic rubber (neoprene) are now widely used in new bridges. Elastomeric bearings are available in two forms:

- **Plain Elastomeric Pads***:* Unreinforced elastomer pads of relatively thin section;
- **Reinforced Elastomeric Pads***:* Layers of elastomer pads bonded to reinforcing plates in sandwich form. Two types of reinforcements:

i) Steel.

ii) Polytetraflouroethylene (PTFE) known as Teflon.

ELASTOMERIC BEARING

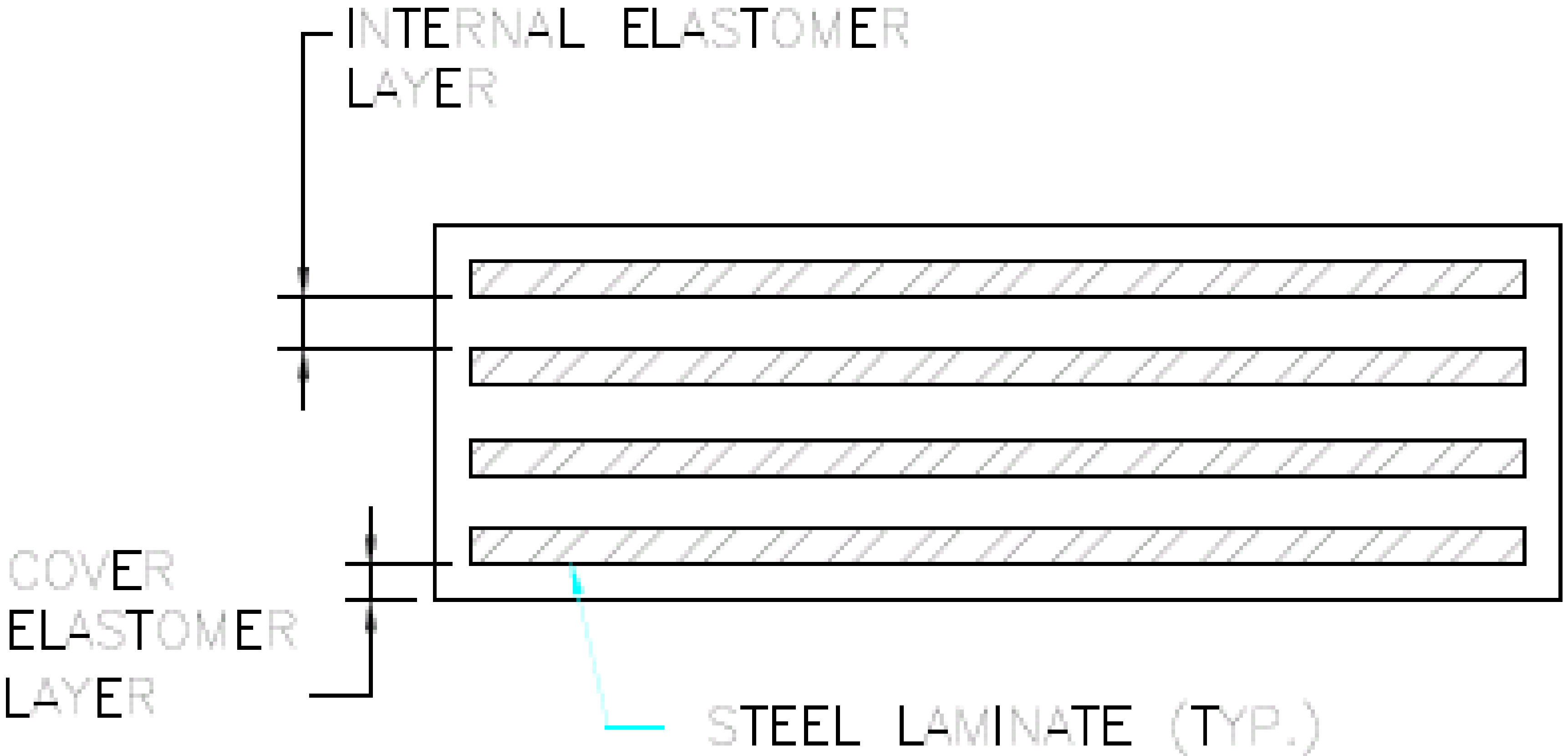
Synthesized from Petroleum byproducts

Neoprene rubber resists degradation more than natural or synthetic rubber

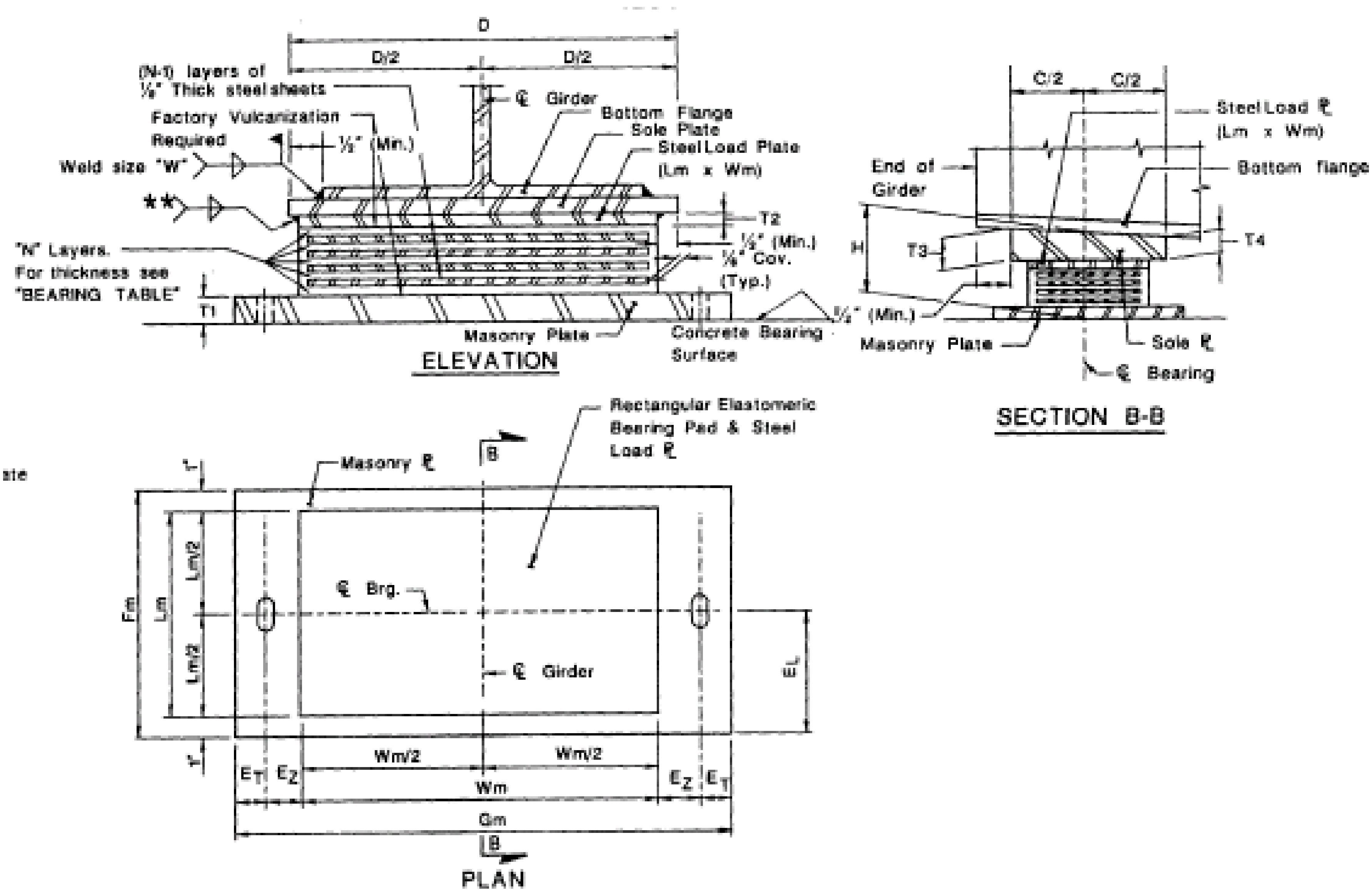
ELASTOMERIC BEARING

A **steel reinforced elastomeric** bearing consists of discrete steel thin plates strongly bonded between adjacent layers of elastomer. The design of this type of bearings consists of finding the plan dimensions, number of elastomeric layers and their corresponding thicknesses, and steel plate thicknesses. Because these calculations depend largely on the properties of the rubber used, the design of these bearing types is usually taken from their manufacturer's certified design tables.

ELASTOMERIC BEARING



ELASTOMERIC BEARING



ELASTOMERIC BEARING

The steel reinforcement within elastomeric pads makes their behavior quite different from plain elastomeric pads. The bearing accommodates translation and rotation by deformation of the elastomer. Under uniaxial compression, the flexible elastomer would shorten significantly and sustain large increases in its plan dimension, but the stiff steel layers restrain this lateral expansion. This restraint induces a bulging pattern and provides a large increase in stiffness under compressive loads.

ELASTOMERIC BEARING

A steel reinforced elastomeric bearing may support relatively high compressive loads while accommodating large translations and rotations. The stress in the steel plates and the strain in the elastomer are controlled by the elastomer thickness and the shape factor (Plan Area / Perimeter Area) of the bearing. Translations and rotations may occur about either horizontal axes, thus these bearings are suitable for bridges where the direction of movement is not precisely defined.

ELASTOMERIC BEARING

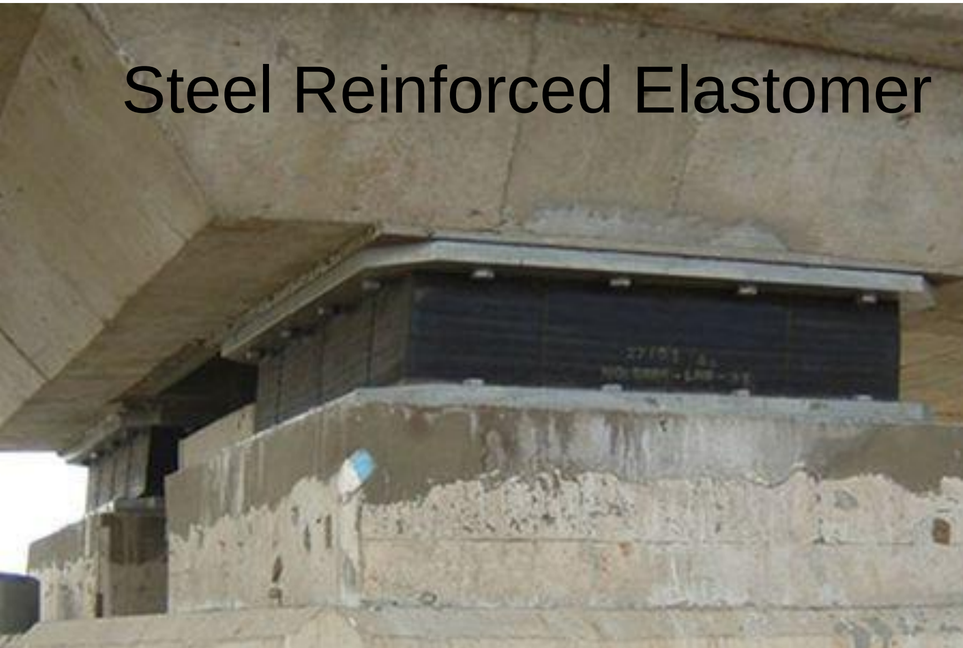
Elastomeric bearing pads and steel reinforced elastomeric bearings have several advantages. They have a low cost and require minimal maintenance. Further, the components can sustain higher values than the design loads, which is useful in case of extreme events that have a low probability of occurrence (earthquakes, for example). Natural rubber or neoprene may be used in the bearings.

ELASTOMERIC BEARING

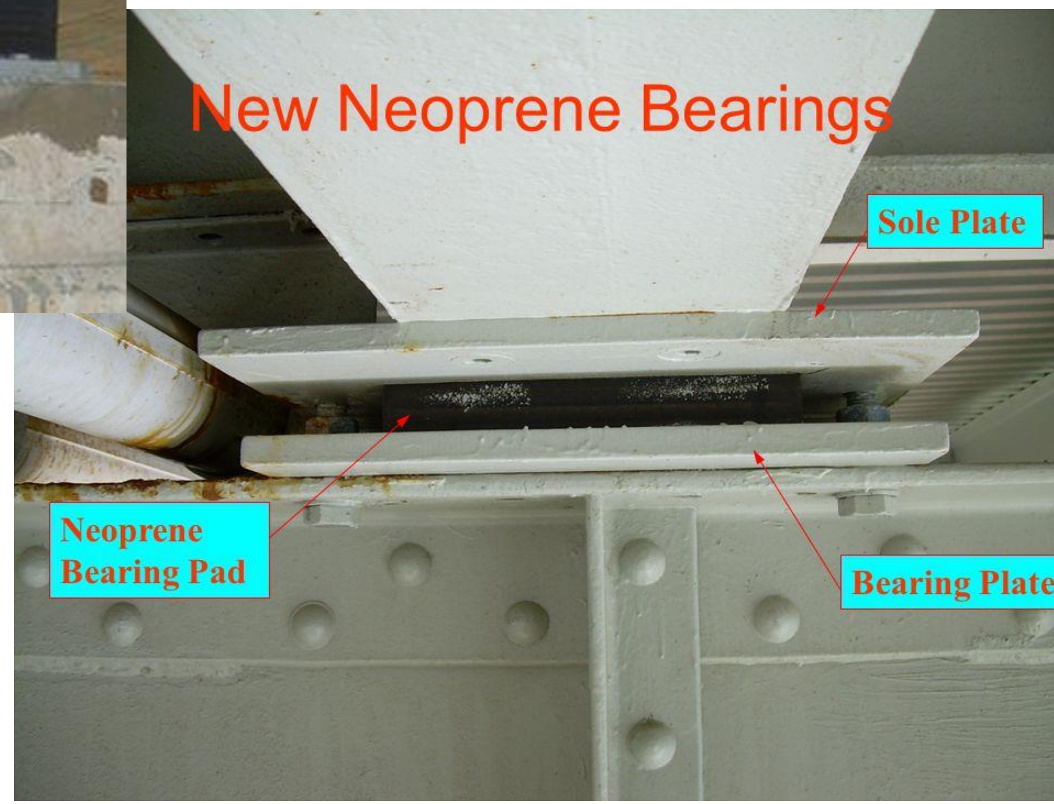
Four Basic Categories:

1. Elastomeric pads.
2. Pot bearings.
3. Sliding surfaces.
4. Curved sliding surfaces.

ELASTOMERIC BEARING

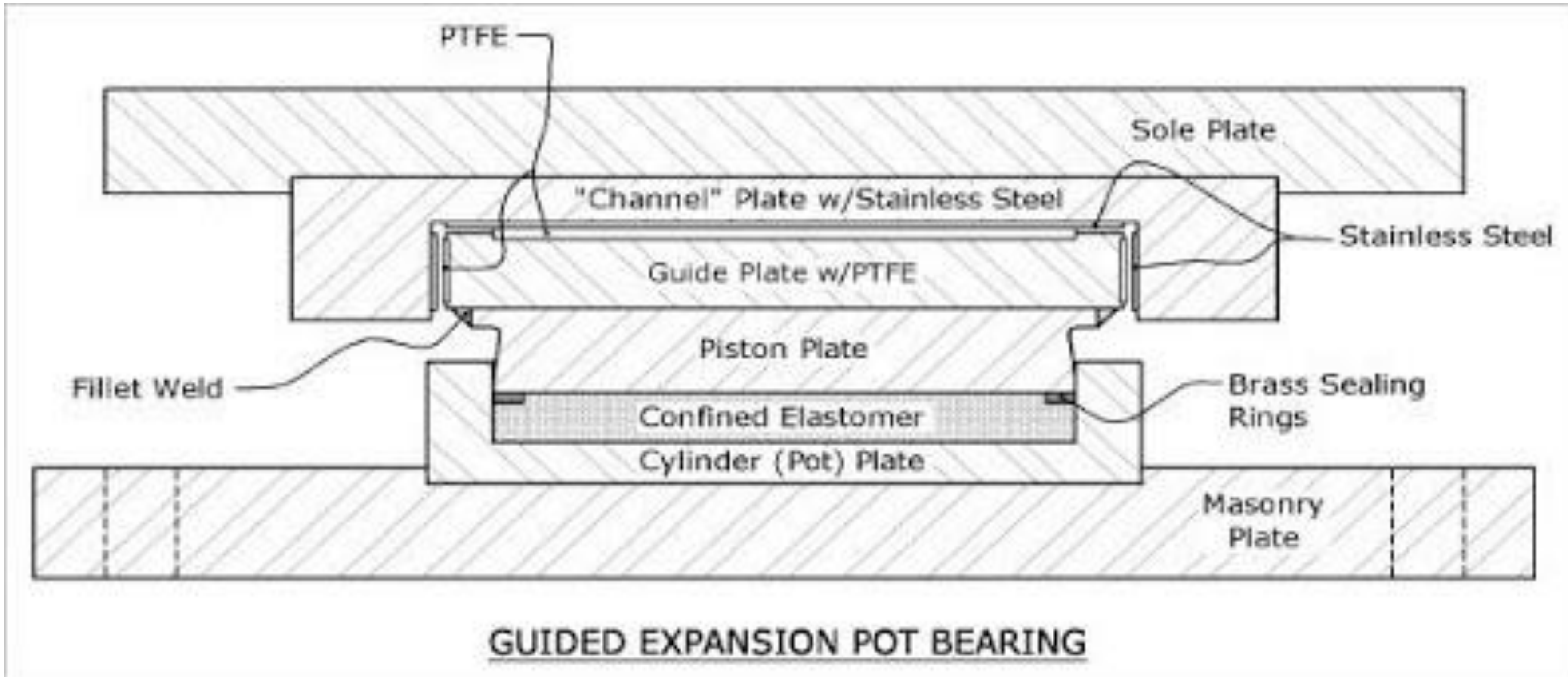


ELASTOMERIC PADS



ELASTOMERIC BEARING

Pot Bearing

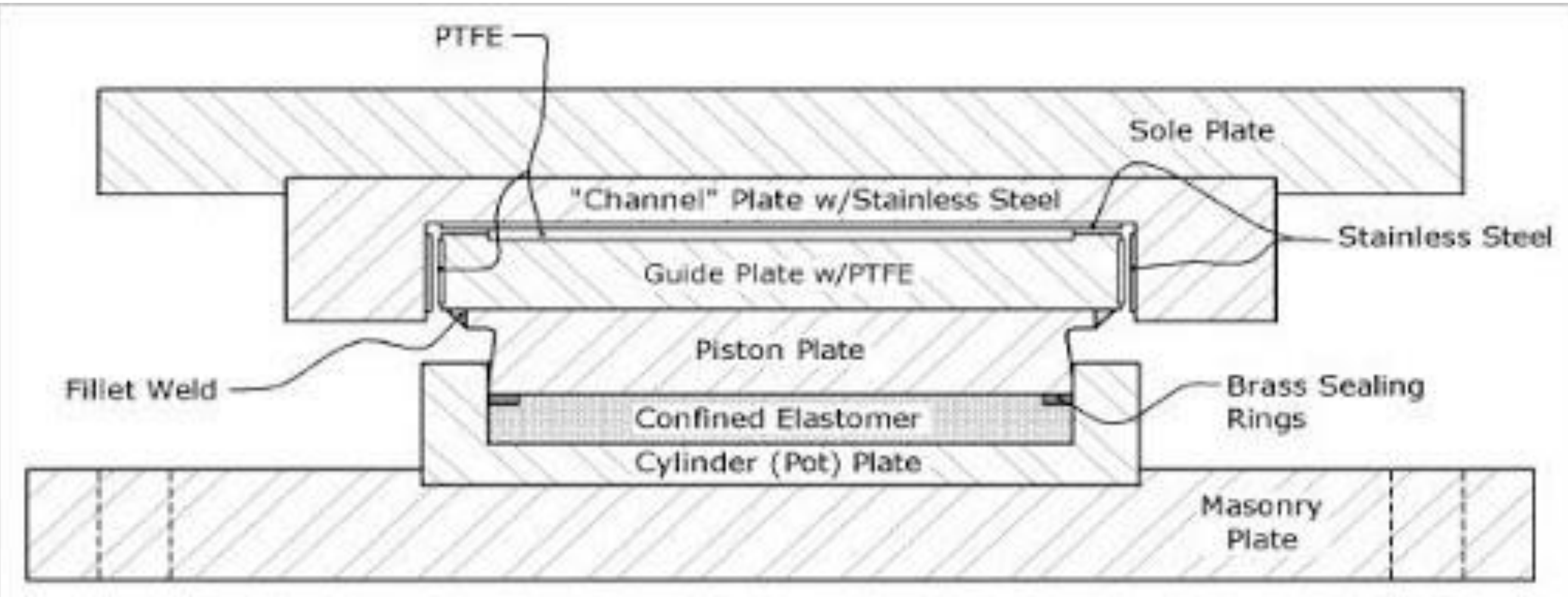


Pot bearings are fixed against all translation unless they are used with a PTFE sliding surface

ELASTOMERIC BEARING

Pot Bearing

Vertical load is carried through the piston and the elastomeric pad. **Rotation** about any axis is accommodated by elastomeric pad deformation. To achieve 0.02 radians, the ratio D/t must not exceed 15. Increasing pad thickness accommodates larger rotations

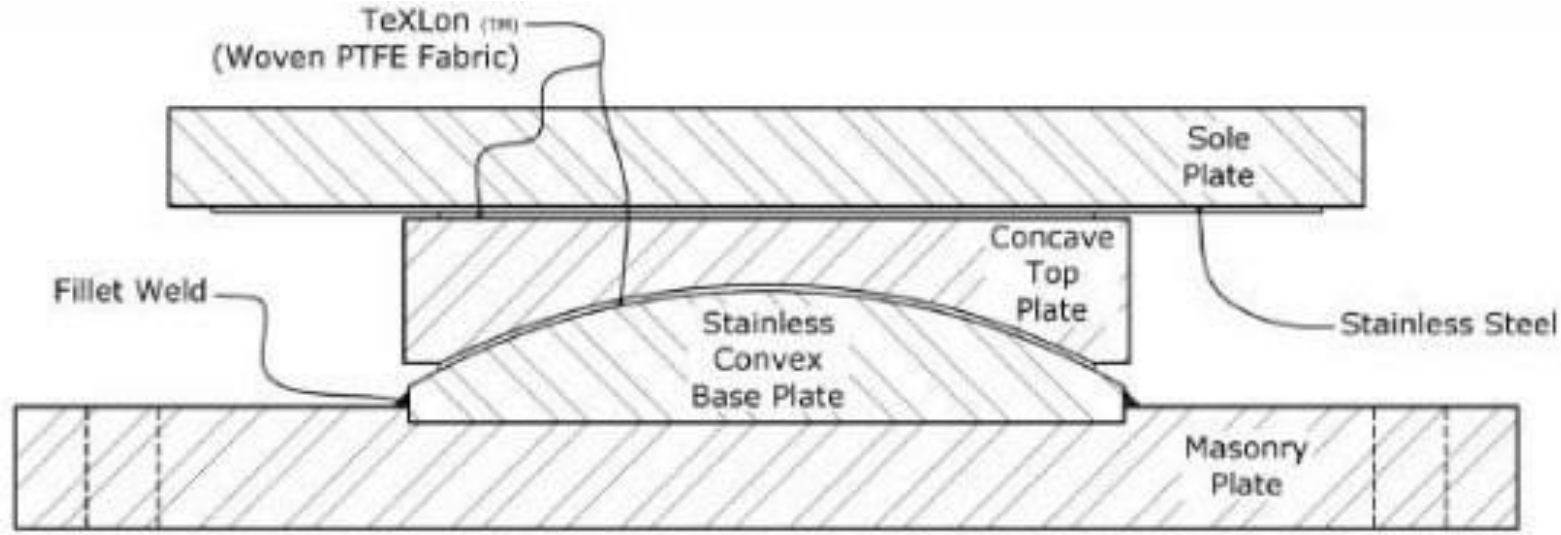


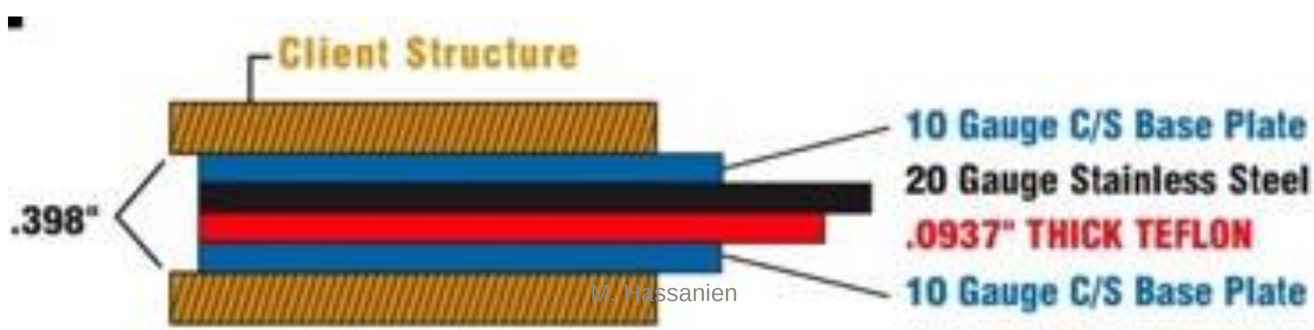
GUIDED EXPANSION POT BEARING

ELASTOMERIC BEARING

Sliding/Curved Sliding Surfaces

Lubricated bronze and PTFE (Teflon) are commonly used for bridge sliding bearings.





ELASTOMERIC BEARING

Sliding/Curved Sliding Surfaces

Lubricated Bronze:

Coefficient of friction is typically 0.07 to 0.1 as the surface dissipates with time and movement.

PTFE w/ Stainless Steel:

Coefficient of friction is typically 0.06 to 0.16 for bearing stress range 5 to over 30 N/mm2. The stainless steel plate (or anodized aluminum) is typically placed on top of the PTFE to prevent contamination with dust or dirt. PTFE wears under service conditions and may require replacement after a period of time.

ELASTOMERIC BEARING

Selection of Bearing Type

1- Define the design requirements (forces, translation, and rotation limits).

2- Identify the bearing types that satisfy the design requirements.

3- Identify the initial and maintenance cost of the bearings.

4- Choose the bearing type that meets the design requirement at lowest overall cost.

5- Consider ease of access for inspection, maintenance and possible replacement.

Lecture 8: BEARINGS

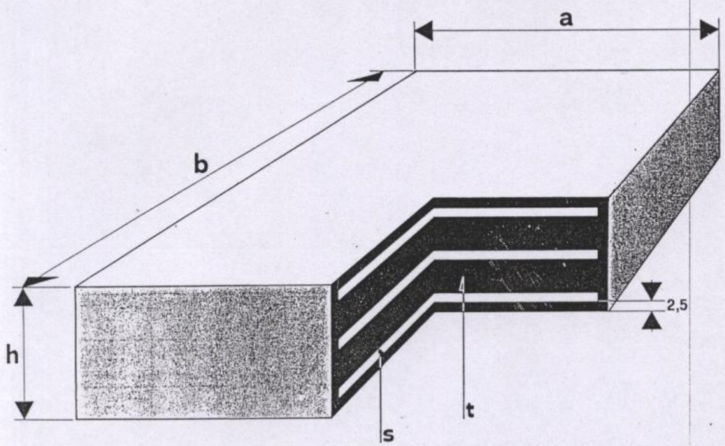
Topics

- Why are bearings needed?
- Types of Bearings.
- Design Requirements.
- Steel Bearings.
- Design of Steel Bearings.
- Elastomeric Bearing.
- **Design of Elastomeric Bearings.**

DESIGN OF ELASTOMERIC BEARINGS

ALGABLOC — NB

ALGABLOC
Elastomeric bearings



ALGABLOC elastomeric bearings consist of individual layers of rubber with steel plates inserted between them. The steel plates and rubber layers are vulcanized together giving a bond on their connecting faces.
Additionally, the plates are completely surrounded by the rubber to prevent any corrosion.
All bearings are individually molded. Formulation of the rubber is based on polychloroprene synthetic rubber which assures a very long life of the bearings and a very high resistance to oils, solvents, ozone and to the chemical products contained in the concrete.
ALGABLOC bearings are suitable for application within a range of temperature of –22 F +122 F (until 158 F for short periods).
For special applications natural rubber or different kinds of synthetic rubber may be used.

Materials properties

Our standard production utilizes the following materials:
- Rolled mild steel plates Fe 42 UNI 7070/72
- Synthetic rubber

Shore A hardness 60 ± 5
Tensile strength 175 kg/cm^2
Ultimate elongation 450%
the sole polymer employed is polychloroprene.

Technical modifications reserved.

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ALGABLOC — NB

ALGABLOC Bearings
Dimensions table

Dimensions	Total thickness	Total rubber thickness	Number of internal rubber layers	Tickness of internal rubber layers	Number of steel plates	Thickness of steel plates	Bearing capacity	Movement tan γ = 0.5 (1)	Movement tan γ = 0.7 (2)	Rotation
a x b	h	hg	nt	t	ns	s	P	el = ±	el = ±	α
mm	mm	mm	n	mm	n	mm	ton	mm	mm	‰
100 x 100	21 28	15 20	2 3	5	3 4	2	10	7,5 10,0	10.5 14.0	8 12
100 x 150	21 28 35	15 20 25	2 3 4	5	3 4 5	2	15	7,5 10,0 12,5	10.5 14.0 17,5	8 12 16
100 x 200	21 28 35	15 20 25	2 3 4	5	3 4 5	2	20	7,5 10,0 12,5	10.5 14.0 17.5	8 12 16
150 x 200	28 35 42	20 25 30	3 4 5	5	4 5 6	2	30	10,0 12,5 15,0	14.0 17.5 21.0	9 12 15
150 x 300	28 35 42	20 25 30	3 4 5	5	4 5 6	2	55	10,0 12,5 15,0	14.0 17.5 21.0	9 12 15
200 x 300	41 52 63	29 37 45	3 4 5	8	4 5 6	3	75	14,5 18,5 22,5	20.3 25.9 31.5	9 12 15
200 x 400	41 52 63	29 37 45	3 4 5	8	4 5 6	3	100	14,5 18,5 22,5	20.3 25.9 31.5	9 12 15
250 x 400	41 52 63	29 37 45	3 4 5	8	4 5 6	3	125	14,5 18,5 22,5	20.3 25.9 31.5	7.5 10.0 12.5
300 x 400	52 63 74 85	37 45 53 61	4 5 6 7	8	5 6 7 8	3	180	18,5 22,5 26,5 30,5	25.9 31.5 37.1 42.7	8 10 12 14
300 x 500	52 63 74 85	37 45 53 61	4 5 6 7	8	5 6 7 8	3	225	18.5 22,5 26,5 30,5	25.9 31.5 37.1 42.7	8 10 12 14
300 x 600	52 63 74 85	37 45 53 61	4 5 6 7	8	5 6 7 8	3	270	18,5 22,5 26,5 30,5	25.9 31.5 37.1 42.7	8 10 12 14
400 x 600	69 84 99 114	49 60 71 82	4 5 6 7	11	5 6 7 8	4	360	24,5 30,0 35,5 41,0	34.3 42.0 49.7 57.4	8 10 12 14
400 x 700	69 84 99 114 129	49 60 71 82 93	4 5 6 7 8	11	5 6 7 8 9	4	420	24,5 30,0 35,5 41,0 46,5	34.3 42.0 49.7 57.4 65.1	8 10 12 14 16
400 x 800	69 84 99 114 129	49 60 71 82 93	4 5 6 7 8	11	5 6 7 8 9	4	480	24,5 30,0 35,5 41,0 46,5	34.3 42.0 49.7 57.4 65.1	8 10 12 14 16

1) Deformation allowed by Italian code CNR 10018/85.
2) Deformation allowed by many International codes among which the German one.

Technical modifications reserved.

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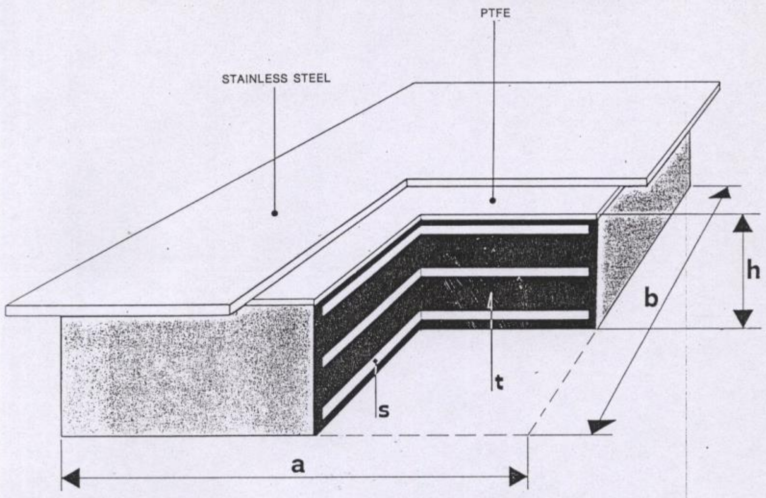
DESIGN OF ELASTOMERIC BEARINGS

ALGAFLON — NT

Sliding Bearings ALGAFLON made of rubber and PTFE



Materials properties

Our standard production utilizes the following materials:
- Rolled mild steel plates Fe 42 UNI 7070/72
- Synthetic rubber
  Shore A hardness 60 ± 5
  Tensile strength 175 kg/cm^2
  Ultimate elongation 450%
  the sole polymer employed is polychloroprene.
- PTFE freely sintered and not subsequently compressed. Only virgin PTFE without additives of regained material or filler.
- Stainless steel. Austenitic steel sheet plates according to UNI X 5CrNiMo 1712 (AISI 316) with surface finish not exceeding 1 μm.

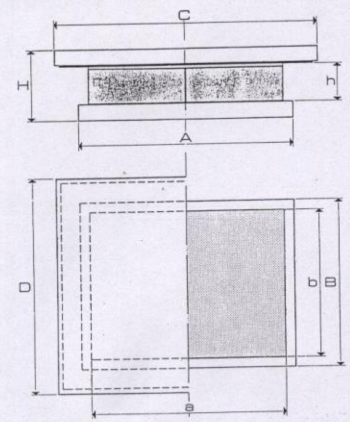
The dimensions of ALGAFLON bearing pads are the same of ALGABLOC ones.

Technical modifications reserved.

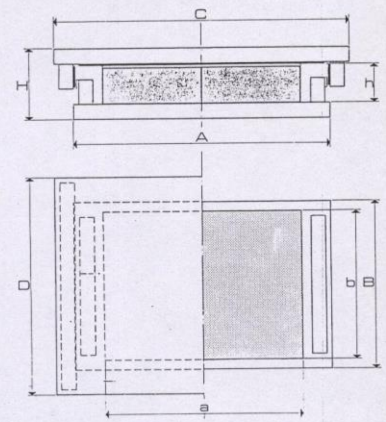
ALGAFLON — NTm - NTu

ALGAFLON elastomeric and PTFE bearings

NTm
Sliding bearing



NTu
Sliding guided bearing



Transversal force = 5% of the capacity

Dimensions table

Capacity ton	H mm	Rubber			Rot.	NTm				NTu			
		a mm	b mm	h mm	α ‰	A mm	B mm	C mm	D mm	A mm	B mm	C mm	D mm
15	55	150	100	35	16	170	120	220	220	210	120	260	220
20	65	200	100	35	16	220	120	270	220	260	120	310	220
30	72	200	150	42	15	220	170	270	270	260	170	310	270
55	72	300	150	42	15	320	170	370	270	370	170	430	270
75	71	300	200	41	9	320	220	370	320	370	220	430	320
100	103	400	200	63	15	420	220	470	320	490	220	570	320
125	103	400	250	63	12.5	420	270	470	370	490	270	570	370
180	103	400	300	63	10	420	320	470	420	490	320	570	420
225	113	500	300	63	10	520	320	570	420	600	320	690	420

Top plates dimensions must be referred to bearings with longitudinal movement ± 5 cm and transversal movement ± 2,5 cm (only NTm type).

Technical modifications reserved.

Lecture 8: BEARINGS

Summary of Today’s Topics

- Why are bearings needed?
- Types of Bearings.
- Design Requirements.
- Steel Bearings.
- Design of Steel Bearings.
- Elastomeric Bearing.
- Design of Elastomeric Bearings.