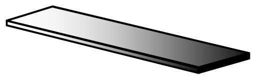
Elastomeric Bearings

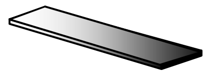
LT Rubber Manufacturing Sdn Bhd

Introduction

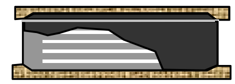
Recommendations and symbols given are taken from BS5400 : Sections 9.1 and 9.2 : 183. For further information, please refer to the original text.



Plain Rubber Strip Bearing



Plain Rubber Pad



Laminated Rubber Bearing

Symbols

Symbols used in this brochure are as follows:

A	overall plan area of elastomeric bearing
A_e	effective plan area of elastomeric bearing
A_1	reduced effective plan area of elastomeric bearing
b	overall width of bearing (the shorter dimension of a rectangular bearing)
b_e	effective width of elastomeric bearing (= width of reinforcing plates)
E_b	bulk modulus of elastomer
G	shear modulus of elastomer
H	horizontal force
k	a factor
l	overall length of bearing (the longer dimension of a rectangular bearing)
l_e	effective length of elastomeric bearing (= length of reinforcing plates)
l_p	force-free perimeter of elastomeric bearing
S	shape factor
S'	shape factor of thickest elastomer layer
T	minimum shade air temperature
t_1, t_2	thickness of adjacent elastomer layers
t_e	effective thickness of elastomer in compression
t_i	thickness of an individual elastomer layer in a laminated bearing
t_q	total thickness of elastomer in shear
V	vertical design load effect
α_b	angular rotation across width b of bearing
α_l	angular rotation across length l of bearing
Δ	total vertical deflection
δ	vertical deflection of individual elastomer layer
δ_b	maximum horizontal relative displacement of parts of bearing in the direction of dimension b of the bearing
δ_l	maximum horizontal relative displacement of parts of bearing in the direction of dimension l of the bearing
δ_r	maximum resultant horizontal relative displacement of parts of bearing obtained by vectorial addition of d_b and d_l.
ε_c	nominal strain in elastomer slab due to compressive loads
ε_q	shear strain in elastomer slab due to translational movement
ε_t	total nominal strain in elastomer slab
ε_a	nominal strain in elastomer due to angular rotation a
σ_s	stress in steel

Units

It is essential that the units used for these in the formula are compatible with each other. The following units are utilized.

- forces and loads : N or kN (1 kN = 10^3N)
- moduli : N/mm^2 (1 N/mm^2 = 1 Map)
- dimension : mm
- angles : radians

Recommendations for Laminated Elastomeric Bearings

1. General

1.1 Function

Elastomeric bearings can accommodate translational movements in any direction direction and rotational movements about any axis by elastic deformation. They should not be used in tension.

1.2 Basis of design

The basis of the design is that the elastomer is an elastic material, the deflection of which under a compressive load is influenced by its shape.
Reinforcing plates included in the bearing should be bonded to the elastomer to prevent any relative movement at the steel/elastomer interface.
Elastomeric bearing should be designed at the serviceability limit state only.

1.3 Shape Factor

The shape factor S is a means of taking account of the shape of the elastomer in in strength and deflection calculations. For laminated bearings, the shape factor S for each individual elastomer layer is given by the expression.

$$S = A_e / l_p t_e$$

where

A_e is the effective plan area of the bearing, i.e. the plan area common to elastomer and steel plate, excluding the area of any holes if these are not later effectively plugged;

l_p is the force-free perimeter of the bearing, including that of any holes if these are not later effectively plugged;

t_e is the effective thickness of an individual elastomer lamination in compression; it is taken as the actual thickness t_i for inner layers, and 1.4 t_i for outer layers;

t_i is the thickness of an individual elastomer layer.

NOTE : For a rectangular bearing without holes,

$$A_e = l_e b_e \quad \text{and} \quad l_p = 2\,(l_e + b_e)$$

1.4 Moduli of elastomer

Typical values of the shear modulus G and also an appropriate value for the bulk modulus E_b are given below :

Nominal hardness (IRHD)	Shear modulus, G (N/mm^2)	Bulk modulus, Eb (N/mm^2)
50	0.7	2000
60	**0.9**	
70	1.2	

For temperatures below 0^{o}C, the values of G may, in the absence of test data, be taken as equal to the values in table multiplied by

$$1 - \frac{T}{25}$$

where T is the minimum shade air temperature (in ^{o}C).

2. Design recommendations

The design of elastomeric bearings should be such that they satisfy the following conditions :

2.1 Shear strain

The shear strain ε_q, of the elastomer due to translational movement should not exceed 0.7, as given by the expression

$$\varepsilon_q = \delta_r / t_q$$

2.2 Cover of elastomer

The cover of elastomer to the steel interleaving plates should be a minimum of 4.5 mm to all edges that would otherwise be exposed and a minimum of 2 mm to the contact surfaces.

2.3 Maximum design strain

At any point in the bearing the sum of the nominal strains due to all load effects, ε_t, as given by the expression

$$\varepsilon_t = k\,(\varepsilon_c + \varepsilon_q + \varepsilon_a)$$

should not exceed 5.0, where

k is a factor equal to
1.5, for live load effects;
1.0, for all other effects (including wind and temperature);

ε_c is the nominal strain due to compressive loads, where ec is given by the expression

$$\varepsilon_c = 1.5V / GA_1S$$

A_1 is the reduced effective plan area due to the loading effects, where A_1 is given by the expression

$$A_1 = A_e \left(1 - \frac{\delta_b}{b_e} - \frac{d_l}{l_e} \right)$$

ε_q is the shear strain due to translational movements, where ε_q is given by the expression

$$\varepsilon_q = \delta_r / t_q$$

ε_α is the nominal strain due to angular rotation, where ε_α is given by the expression

$$\varepsilon_\alpha = (b_e^2\alpha_b + l_e^2\alpha_l) / 2t_i\Sigma t_i$$

t_i is the thickness of the individual layer of elastomer being checked;

Σt_i is the total thickness of elastomer in the bearing.

2.4 Reinforcing plate thickness

To resist induced tensile stresses under load, the minimum thickness of the steel plates should be

$$1.3V(t_1 + t_2)/A_1\sigma_s \text{ but not less than 2 mm}$$

where

t_1 and t_2 are the thicknesses of elastomer on either side of the plate;

σ_s is the stress in the steel, which should be taken as not greater than the yield stress, nor greater than
120 N/mm^2, for plates with holes;
290 N/mm^2, for plates without holes.

2.5 Stability

The mean pressure, V/A_1, should satisfy the expression

$$V/A_1 < 2b_eGS' / 3\Sigma t_i$$

The above criterion will be satisfied automatically if

$$\Sigma t_1 < b_e/4$$

2.6 Vertical deflection

The total vertical deflection of a laminated bearing, Δ, does not exceed the value specified by the Engineer.

This deflection given by the expression

$$\Delta = \Sigma\delta \text{ where}$$

$$\delta = \frac{Vt_i}{5A_eGS^2} + \frac{Vt_i}{A_eE_b}$$

δ is the vertical deflection of an individual layer of elastomer.

This expression may be used to estimate the change in deflection between one-third of the total load and full load, with an accuracy of the order of $\mp$ 25%.

2.7 Rotational limitation

The rotation of the bearing does not allow separation at the contact surfaces between the bearing and the structure; this recommendation is met if the total vertical deflection, D, satisfies the expression

$$\Delta > (b_e\alpha_b + l_e\alpha_l) / 3$$

2.8 Shear resistance

The force exerted on the structure by the bearing resisting translational movement does not exceed the value specified by the Engineer. For elastomeric bearings where horizontal movement is accommodated by shear in the elastomer, the nominal horizontal force H due to expansion or contraction is given by the expression

$$H = AG\delta_r/t_q$$

Typical values of G are given in 1.4. An allowance of $\mp$ 20% should be made in the calculated values of H to give the most adverse effect.

For movements due to live load effects on railway bridges, the value of G should be doubled. Due allowance should be made in the value of G for temperature variation.

2.9 Fixing and Installation of bearings

When the requirements for bearing installation are being specified, the following should considered :

a) Flatness of contact surfaces.

As laminated bearings are stiff, the contact surfaces should be flat and irregularities should be kept small. A tolerance of $\mp$ 1 mm over the contact surfaces is normally adequate.

b) Out-of-parallel between contact surfaces.

Where bearings are to be installed between performed surfaces, the out-of-parallel tolerance between these surfaces should be specified to ensure that the combination of out-of-parallel of the bearings themselves added to the out-of-parallel of the contact surfaces will leave sufficient rotation capacity in the bearing for working conditions. For thin bearings having small rotation capacity, it may be advisable to form one contact surface after placing the bearings.

c) Texture of contact surfaces.
The best contact surfaces are those that have a uniform texture and a high coefficient of friction. Smooth or slippery surfaces should be avoided.

If there is insufficient friction to prevent relative movement between the bearing and the structure under the most adverse loading conditions, positive means of location should be provided. Friction may be considered adequate if under all loading conditions,

numerically, $H < 0.1(V + 2A_1)$

and under permanent loads,

$V/A1 > 2$

NOTE : Positive means of location may limit the depth available for shear. This should be considered in the design of the bearing.

Where steel plates are used and corrosion protection is required, zinc spraying has been shown to be the most satisfactory.

d) Edge clearance.
Contact surfaces should extend beyond the edge of the bearings to allow for tolerances on placing and ensure adequate edge support. A distance of 20mm is generally adequate.

More information in installation of bearings refer Technical Data No 30.

Notes on Design of LTR Plain or Laminated Rubber Bearings

Maximum capacity of a rubber bearing is controlled by a combination of direct load, shear movement and rotation. Where high shear movement and/or rotation is required, the maximum direct load which a bearing can carry is reduced from that when no shear movement and/or rotation is required. Intermediate combinations may be interpolated for a rough capacity estimation.

The loads shown for bearings do not make allowance for dowel holes. If these are specified, allowable loads are required to be reduced. Dowel holes can be provided as required for pads and strips.

Bearings should normally be placed so that rotation occurs about the longer axis. Strips bearings must have length five times the width and not less than one metre. LTR Rubber Bearings are designed, manufactured in Malaysia in accordance with BS5400 : Section 9.1: 1983 and structures Design Manual for Highways and Railways. Bearing are tested in Malaysia in accordance with the requirements stipulated in BS5400:Section 9.2:1983.

55^o - 65^o IRHD Hardness Natural Rubber to BS1154 Group Z60 is used throughout. The main design parameters adopted are :

- shear modulus G 0.9 N/mm^2
- bulk modulus E_b 2000 N/mm^2

However, bearings can be designed and manufactured with Group Z50 or Z70 rubber for different loading capacities. Chloroprene rubber (Neoprene) can also be used to meet specific needs of protection against chemical attack from corrosive environment.

New bearing types can be designed on request to meet any particular bearing requirements.

When sending in enquiries please provide the following information :

1. Maximum serviceability limit state (SLS) permanent load;
2. Maximum and minimum SLS live loads including either HA or HB loads;
3. Irreversible and reversible movements in longitudinal and transverse direction;
4. Irreversible and reversible rotations about longitudinal and transverse axes;
5. Available plan dimensions;
6. Longitudinal and transverse horizontal loads, if any

Material Specification

Elastomer

Property	Standard	Specified Value				
Natural rubber (NR)	BS1154	NR				
		Z50	Z60	Z70		
Chloroprene rubber (CR)	BS2752				CR	
					C60	C70
Hardness (IRHD)	BS903:Part A26 (method N)	50	60	70	60	70
Shear Modulus, G (N/mm^2)	BS903:Part A14 (Shear Strain=0.25)	0.7 +/-0.09	0.9 +/-0.14	1.2 +/-0.18	0.9 +/-0.14	1.2 +/-0.18
Tensile Strength, (N/mm^2)	BS903:Part A2	Min15.5		Min14.0	Min13.0	
Elongation at break (%)	BS903:Part A2	Min 500	Min 400	Min 300	Min 250	Min 200
Compression set (%)	BS903:Part A6	(24 hours at70°C)				
		Max 30			Max 25	
Ageing resistance	BS903:Part A19	(7 days at 70°C)				
change in hardness (IRHD)		Max +10			Max +7	
change in tensile strength (%)		Max -15			Max -12	
change in elongation at break (%)		Max - 20			Max -20	
Ozone resistance	BS903:Part A43	(25pphm/20% strain 96 hrs at 30°C) No cracks				
Bond of elastomer to metal	BS903:Part A21	Min 7 N/mm				

Interleaving Plates

Property	Standard	Specified Value
Rolled mild steel sheet	BS1149 : Part 1 JIS : G03131	-
Tensile Strength (N/mm2)		Min 360
Yield strength (N/mm2)		Min 290
Elongation at break (%)		Min 20

Methods of Installing LTR Rubber Bearings
Technical Data No 30

1. Introduction

Rubber bridge bearings can be conveniently divided into two types - "Fixed", where the deck is permitted only to rotate and horizontal movements of the deck are restrained, and "Free", where the deck can rotate and move horizontally.

1.1 Fixed Ends

Fixity is usually provided by dowels passing from the deck to the abutment. One end of each of these dowels should be fitted with a LTR's rubber dowel cap, which permits the deck to expand and contract laterally and to rotate. For convenience, dowels are best placed between the bearings, but where space is restricted they can pass through dowel holes provided in specially designed LTR LTR laminated bearings. It is possible to cut holes in thin pads and continuous strip on site, thus removing the necessity of accurate dowel positioning. But for laminated bearings, locations and dimensions of the holes are predetermined cannot be changed on site.

1.2 Free Ends

Bearings will locate satisfactorily by friction alone, provided that the requirement in Clause 10.11, Section 9.1, BS5400 is satisfied.
Standard LTR bearings can be stuck to the structure above and below, using and appropriate epoxy mortal in accordance with the manufacturer's instruction.

2. Design

2.1 General

All bearings are to be set horizontally. Some additional considerations are required where the superstructure is inclined or has a cross-fall. Normally, the solution is to make steps at the abutment and soffit in the form of plinths and downstands so that horizontal seatings for the bearings can be provided.

2.2 Plinths

The contact stresses under rubber bearings are low and seldom require special attention However, if a raised concrete plinth is of approximately the same size as the bearing, then depending on its thickness, it sometimes may need to be reinforced. To ensure that the bearing is adequately restrained, and to guard against spalling at concrete edge, it is recommended that any plinth should extend at least 50mm beyond the edge of the bearing, assuming a 45^{o} dispersion of stress from the bearing.

3. Handling and Storage on Site

Bearing should be carefully stored under cover, away from sunlight, heat, oil and chemicals. They should always be handled carefully and stacked neatly. Damaged bearings, for example with bend steel interleaving plates or partially debonded rubber layers, should never be installed.

Bearings with differing internal arrangements of steel and rubber can have the same external dimensions. It is essential that all bearings are clearly and permanently identified, to avoid installation in the wrong location.

4. Installation

4.1 Seating

Where the support is concrete, the cast surface is usually irregular. The bearing is therefore normally placed accurately to line and level on a bedding plinth. The plinth can be made of high strength non-shrink cement grout or epoxy mortal with fine dry quartz sand. In either case, the cube crushing strength of the mortal should be at least the same as that of concrete.

Where the support is steel, a rolled surface may be suitable for use directly, provided that it is reasonably smooth and true to level. Otherwise a bedding should be used. Trowelling often seems to produce a bedding that is slightly rounded on the top surface, and it is preferable to screed off or cast against a flat plate.

Pockets or box-outs for dowels are prepared at the supports during concreting The void is then filled with non-shrink cement grout or similar after installing the dowels. The arrangement of dowels between bearings is preferred because it presents fewer installation problems and the replacement of bearing is possible.

Stainless steel dowels are normally required because they are no longer protected by the bearing from corrosion.

The dowels must penetrate to sufficient depth to resist the design horizontal load, without inducing excessive stresses in concrete.

4.2 In-situ Superstructures

When the superstructure is to be concrete cast in-situ, the spaces around and between the bearings can be filled with expanded polystyrene, or well rammed damp sand covered with an impervious membrane such as polythene sheet. Extreme care must be taken not to disturb the bearing during casting. After curing the superstructure, the sand infill can be washed away from the bearings, or the polystyrene can be broken up and blown out with compressed air. (Note : it should not be dissolved by any chemical solvent, as it may attack the rubber of the bearings.)

4.3 Precast, Preflex and steel Superstructures

Where precast concrete beams are used they should be lowered onto a 2-3mm thick wet mortar skim on the top of the bearings, to eliminate soffit irregularities and twist in the beams. The bearings should be selected to accommodate the possible rotation due to precamber of beams at this very low level of vertical loading. Otherwise the beams should be propped with wedges so that the bearings do not rotate until the mortar skim has hardened Special treatment is needed at fixed end. Pockets can be left in the precast beams at approprate points to receive the dowel caps and bars. The pockets are then grouted after after the landing of the beams.

Steel beams will have to be jig-drilled to accommodate any fixing devices. Taper plates can be attached to the beams during fabrication to provide horizontal seatings for the bearing, although care must be taken to avoid difficulties due to lateral inaccuracies in level.

Particular care should be taken with precast tensioned and preflex beams, where the maximum rotation, due to precamber, occurs during erection and is coupled with very light loading. Subsequent loading tends to straighten these beams and so reduce the rotation.

It is worth sounding at final cautionary note. Failures have occurred in bearings during installation, due to the imposition of eccentric loads, perhaps coupled with rotations, for which the bearings are not designed for.