IRC:83-2018 (Part-II)

STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES

(SECTION: IX)

BEARINGS

(Elastomeric Bearings)

Part-II

(Second Revision)

INDIAN ROADS CONGRESS

2018

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AND
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Published by:

INDIAN ROADS CONGRESS

Kama Koti Marg,
Sector-6, R.K. Puram,
New Delhi-110 022

MAY, 2018

Price : ₹ 600/-
(Plus Packing & Postage)

First Published	:	June, 1987
Reprinted	:	March, 1991
Reprinted	:	January, 1996
Reprinted	:	September, 2000 (with Amendments)
Reprinted	:	June, 2003
Reprinted	:	January, 2007
Reprinted	:	September, 2008
First Revision	:	January, 2015
Second Revision	:	May, 2018

Printed by India Offset Press, Delhi - 110 064

500 Copies

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STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES

SECTION: IX BEARINGS
PART- II (ELASTOMERIC BEARINGS)

INTRODUCTION

The Standard Specifications and Code of Practice for Road Bridges, Section IX–Elastomeric Bearings, Part-II based on working stress method was first published in June, 1987. Thereafter, unprecedented growth of knowledge in the field of Bridge Bearing Design, Manufacturing & Workmanship, Acceptance Specifications, Certification & Marketing and Development of high strength materials took place in the past two decades. Prelude to this, the first revision of this Code based on Ultimate Limit State (ULS) condition was brought-out in January, 2015 and is widely being adopted across the country. Meanwhile, feedbacks/inputs have been received from Industries, Users, etc on usage of this code and seeking more clarifications. Thereafter, the newly constituted B-6 Committee for the tenure 2015-17 also felt the necessity to include Seismic provisions, Compound properties of Natural Rubber & Raw materials, Manufacturing Tolerances, Compression Stiffness Test Parameters, etc in line with the best global practices. For this purpose, a Sub-Group comprising of Shri Alok Bhowmick and Shri S. Majumdar prepared the list of Errata and Amendments pertaining to the published Code IRC:83-2015 (Part-II), ‘Standard Specifications and Code of Practice for Road Bridges; Section: IX Bearings (Elastomeric Bearings) Part-II. The suggestive list of Errata and Amendments was circulated among the members of B-6 Committee and comments were received from the members. The B-6 Committee constituted a Sub-Committee comprising of the following members to address the received comments in the revised draft document appropriately.

(i) Shri G. Sharan, Convener, (ii) Shri A.K. Benerjee, (iii) Shri Alok Bhowmick, (iv) Shri S.S. Gaharwar.

The Sub-committee held its meetings on 4th February 2017 to finalize the Errata and Amendments. The recommendations of the Sub-Committee were discussed in the meeting of B-6 Committee held on 15th September 2017. After deliberations, B-6 Committee approved the recommendations of the Sub-Committee with the opinion that the modified draft document incorporating the Errata and Amendments may be submitted for the approval of BSS Committee as the revised draft document. Thereafter, the revised draft document was approved by the Bridges Specifications and Standards (BSS) Committee in its meeting held on 23.10.2017. The Executive Committee in its meeting held on 2nd November, 2017 considered and approved the same for placing it before the IRC Council. Finally, the document was considered by the IRC Council in its 213th meeting held on 03.11.2017 during the Annual Session held at Bengaluru (Karnataka) and was approved for publication.

The Bearings, Joints and Appurtenances Committee (B-6) of the Indian Roads Congress was constituted in 2015 with the following personnel:

Puri, S.K.	……	Convenor
Arora, H.C.	……	Co-Convenor
Gaharwar, Dr. S.S.	……	Member-Secretary

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1 SCOPE

This part of the Specification (referred to as 'Code' hereinafter) applies to elastomeric bearings with or without complementary bearing devices to extend their field of use such as flat sliding elements covered by relevant Part, as used in bridge structures or any other structure with comparable support conditions.

This part of Code applies to laminated bearings, laminated sliding bearings, plain pad and strip bearings and does not cover elastomeric bearings made with other elastomer materials than those specified in Clause 4.0. This part of Code applies to elastomeric bearings with dimensions in plan up to 1200 x 1200 mm for laminated bearings, plain pad bearing and width in plan up to 1200 mm for strip bearing. The elastomeric bearings covered in this code can be used in conjunction with other bearing elements, as appropriate, as per other relevant parts of IRC: 83.

Elastomeric Bearings can be used with following possible arrangements:

a) Elastomeric Bearings provided on individual supports to transfer vertical loads and non-seismic lateral loads and to accommodate imposed deformations and translations. Seismic actions in this case are transferred to substructure by separate structural connections (either monolithic or through pin/guide bearings) of the deck to other supporting members (piers or abutments).
b) On all or individual supports, with the same function as in a) above, combined with seismic links/seismic stoppers which are designed to resist seismic actions.
c) On all supports to resist both seismic as well as non-seismic actions. Refer **Annexure D** for design considerations when elastomeric bearings are used to resist seismic actions.

This part of Code applies to normal (low damping with an equivalent viscous damping ratio < 0.06) elastomeric bearings only. Use of special (high damping) elastomeric bearings are not covered in this code, for which specialist literature or international code may be consulted.

This part deals with bearings for use in operating temperatures ranging from -10 °C to + 50 °C. For locations where the minimum atmospheric temperature drops below -10 °C for continuous periods of 24 hours or more, the provision of this Code shall not apply.

2 TERMINOLOGY

2.1 Batch

Individual mix or blend of mixes of elastomer, when used for bearing production or a number of identical components produced at the same machine setting.

2.2 Chloroprene Rubber (CR)

Also known as polychloroprene is a polymerised form of the monomer chloroprene.

2.3 Crystallisation

A phase change in elastomer (arrangement of previously disordered polymer segments of repeating patterns into geometric symmetry) promoted by very low temperature and marked by large and quick changes in hardness, stiffness, shear modulus, etc. which are reversible.

2.4 Elastomeric Bearing

Bearing comprising a block of vulcanised elastomer that may be reinforced with one or more steel plates

2.5 Engineer/Engineer-in-Charge

The Engineer-in-Charge, responsible for the execution of the bridge project and so designated in the contract or his authorized representative.

2.6 Ethyl Propylene Dimonomer (EPDM), Isobutane Isoprene Copolymer (IIR), Chloro-Isoprene Copolymer (CIIR)

Synthetic rubber like materials capable of being used in bridge bearings by the process of vulcanisation (not permitted by this Code) but have enjoyed limited use in various parts of the world.

2.7 Inspector

Authorised representative of the engineer for acceptance testing of given lots of bearings at the manufacturers'plant.

2.8 Laminate

A layer of reinforcing material integrally bonded to elastomer during vulcanisation process, to restrain the lateral expansion of the elastomer.

2.9 Laminated Bearing

Elastomeric bearing reinforced internally with one or more steel plates, chemically bonded during vulcanisation.

2.10 Natural Rubber (NR) (Polyisoprene)

A polymer occurring naturally in the sap of certain plants, particularly Havea Brasiliensis.

2.11 Plain Pad Bearing

Elastomeric bearing consisting of a solid block of vulcanised elastomer without internal laminates or cavities.

2.12 Raw Elastomer

Any member of a class of Virgin Polychloroprene (CR) capable of being vulcanised with compounds, that possesses rubber like-properties after vulcanisation, especially the ability to regain shape almost completely after large deformation.

2.13 Shore Hardness

Mechanical property of a material which describes its resistance to indentation of a standard device (i.e. durometer) and measured in degrees on several scales (I.R.H. Shore A, Shore B, etc.)

2.14 Sliding Plate

Component which bears on and is immediately adjacent to the top sliding surface of a bearing. It can be:

- a single piece of austenitic steel.
- a thin plate of austenitic steel fixed to a mild steel supporting plate.

2.15 Sliding Elastomeric Bearing

Laminated bearing with a PTFE sheet, at top surface, which may be vulcanised directly onto the outer layer of elastomer or fixed to a steel plate, and will remain in contact with a sliding plate.

2.16 Strip Bearing

Plain pad bearing for which the length is at least ten times the width.

3 NOTATIONS

3.1 Latin Upper Case Letters

A = Overall plan area of elastomeric bearing in mm²

A_1 = Effective plan area of laminated bearing (area of the steel reinforcing plates) in mm²

A_r = Reduced effective plan area of elastomeric bearing in mm²

E_a = Apparent Compression stiffness of a bearing in N/mm

D = Overall diameter of circular bearing in mm

D' = Effective diameter of circular laminated bearing (Diameter of steel reinforcing plate) in mm

E = Modulus of elasticity in MPa

E_b = Bulk modulus in MPa

F_x,F_y = Horizontal forces in N: kN
F_{xd}, F_{yd} = Horizontal design forces in N: kN
$F_{xy,\,d}$ = Maximum resultant horizontal force obtained by vector addition of F_{xd} and F_{yd} in N: kN
$F_{z,d}$ = Vertical design force in N: kN
G = Nominal value of conventional shear modulus of elastomeric bearing in MPa
K_f = Friction factor
K_h = Factor for induced tensile stresses in reinforcing plate
K_L = Type loading factor
K_p = Stress correction factor for the steel reinforcing plates
$K_{r,d}$ = Rotation factor
K_s = Factor for restoring moment
M = Restoring moment due to rotation in N-mm
R_d = Design value of resistance in N: kN
R_{xy} = Resultant of the forces resisting translatory movement in N: kN
S = Shape factor
S_1 = Shape factor for the thickest layer
T_b = Total nominal thickness of bearing in mm
T_e = Total nominal thickness of elastomer in mm
T_q = The average total initial thickness of elastomer in shear, including the top and bottom covers when these are not restrained for shearing in mm
V_x = Maximum horizontal relative displacement in direction of dimension a in mm
V_y = Maximum horizontal relative displacement in direction of dimension b in mm
$V_{z,d}$ = Vertical movement/deflection in mm
V_{xy} = Maximum resultant horizontal relative displacement obtained by vectorial addition of V_x and V_y in mm

3.2 Latin Lower Case Letters

a = Overall width of bearing (shorter dimension of rectangular bearing) in mm
a' = Effective width of laminated bearing (width of the steel reinforcing plates) in mm
b = Overall length of a bearing (longer dimension of a rectangular bearing) in mm

b'	=	Effective length of a laminated bearing (length of the steel reinforcing plates) in mm
f_y	=	Yield stress of steel in MPa
l_p	=	Force free perimeter of elastomeric bearing
n	=	Number of elastomer layers
t	=	Thickness of plain pad or strip bearing in mm
t_e	=	Effective thickness of elastomer in compression in mm
t_i	=	Thickness of an individual elastomer layer in a laminated bearing in mm
t_p	=	Thickness of PTFE sheet in mm
t_s	=	Thickness of steel reinforcing plate in mm
t_{so}	=	Thickness of outer steel reinforcing plate in mm

3.3 Greek Letters

α	=	Angular rotation of a bearing in rad
α_a	=	Angular rotation across width a of a rectangular bearing in rad
α_b	=	Angular rotation across length b of a rectangular bearing in rad
α_{ab}	=	Resultant angular rotation across width a and length b of a rectangular bearing in rad
α_d	=	Angular rotation across the diameter D of a circular bearing in rad
γ_m	=	Partial safety factor for the resistance
δ	=	Vertical deflection of individual elastomer layer in mm
Σ	=	Sum of values
$\varepsilon_{\alpha,d}$	=	Design strain in elastomeric bearing due to angular rotation
$\varepsilon_{c,d}$	=	Design strain in elastomeric bearing due to compressive loads
$\varepsilon_{q,d}$	=	Design shear strain in elastomeric bearing due to translatory movements
$\varepsilon_{t,d}$	=	Total nominal design strain in elastomeric bearing
ε_z	=	Compressive strain of a bearing
μ_e	=	Friction coefficient for elastomer
σ_c	=	Compressive stress in MPa
σ_m	=	Average of the compressive stress in MPa
τ	=	Shear stress in MPa

3.4 Subscripts

d	Design
dyn	Dynamic
k	Characteristic
max	Maximum

min	Minimum
t	Total
u	At ultimate limit state
test	Test values

3.5 Abbreviations

For the purposes of this Standard, the following abbreviations apply.

CR	Polychloroprene Rubber
NR	Natural Rubber
pphm	Parts per hundred million by volume
PTFE	Polytetrafluoroethylene
SLS	Serviceability Limit State
ULS	Ultimate Limit State

4 MATERIALS

4.1 Raw Material

The elastomer used in the manufacture of Elastomeric Bearing should be specified in the project documentation as either Natural Rubber (NR) or Chloroprene Rubber (CR) as the raw polymer. Blending with up to 5% of another polymer, which may be added to aid processing, is permitted. No reclaimed or ground vulcanised rubber shall be used.

4.1.1 For CR compound, grades of raw elastomer of proven use in elastomeric bearings, with low crystallization rates and adequate shelf life (e.g. Neoprene WRT, Bayprene 110, Skyprene B-5, Denka S-40V) shall be used.

4.1.2 For NR compound, grade of raw elastomer shall be RSS 1X conforming to IS: 15361

4.1.3 Bearings made of NR compounds may be fully made of NR compounds (i.e., including cover layers). Bearings made of NR compounds may also be protected by cover layer (top, bottom and side) made of CR compound with both parts (NR compound in internal layers and CR compounds in cover layers) being vulcanized simultaneously.

4.1.4 The polymer content of the bearing shall not be lower than 50 percent and the ash content shall not exceed 5 percent. Polymer content shall be determined in accordance with ASTM-D297 and ash content as per IS: 3400-Part XXII

4.1.5 EPDM and other similar candidate elastomers for bridge bearing use shall not be permitted.

4.1.6 Tests for polymer identification through Pyrolysis test and confirmation about percentage of polymer content shall be carried out as per IS: 3400 (Part XXII).

4.2 Properties

4.2.1 The elastomer shall conform to all the properties specified in **Table 1** depending upon the raw polymer used (CR/NR).

Table 1: Properties of Elastomer

Characteristics	**Requirements**			**Test Method**
G Modulus (MPa)	0.7	**0.9**	1.15	
Tensile Strength (MPa) Moulded Test Piece Test Piece from Bearing	 ≥ 16 ≥ 14	 **≥ 16** **≥ 14**	 ≥ 16 ≥ 14	 ISO 37 type 2
Minimum Elongation at Break (%) Moulded Test Piece Test Piece from Bearing	 450 400	 **425** **375**	 300 250	
Minimum Tear Resistance (kN/m) CR NR	 ≥ 7 ≥ 5	 **≥ 10** **≥ 8**	 ≥ 12 ≥ 10	ISO 34-1 Trouser (Method A)
Compression Set (%) 24h ; 70 °C	CR ≤ 15 NR ≤ 30			ISO 815 φ 29 x 12.5 mm Spacer : 9.38 – 25%
Accelerated Ageing (maximum change from unaged value) - Hardness (IRHD) NR 7d, 70 °C CR 3d, 100 °C - Tensile strength (%) NR 7d, 70 °C CR 3d, 100 °C - Elongation at break (%) NR 7d, 70 °C CR 3d, 100 °C	 -5, +10 ± 5 ± 15 ± 15 ± 25 ± 25			ISO 48 ISO 188
Ozone Resistance Elongation : 30% - 96h 40 °C ± 2 °C NR 25 pphm CR 100 pphm	No cracks			ISO 1431-1

Note: Generally, elastomer of G value 0.9 MPa are used for standard elastomeric bearings. Elastomer of G value 0.7MPa or 1.15 MPa may be used depending upon the requirement of stiffness and application.

4.2.2 Shear modulus (G) is the apparent "conventional shear modulus" of the elastomer bearing determined by testing. At nominal temperature of 23 ºC ± 2 ºC the value of G shall comply the values given in **Table 2**.

Table 2: Shear Modulus at Nominal Temperature

Hardness (IRHD)	G (MPa)	Tolerances of G (MPa)
(1)	(2)	(3)
50 ± 5	0.7	± 0.10
60 ± 5	0.9	± 0.15
70 ± 5	1.15	± 0.20

Note: The correlation between shear modulus and hardness is not precise and the values of hardness as in **Table 2** are given as guide only. Shear modulus will form the basis of design

4.2.3 The adhesion strength of elastomer to steel plate, determined according to IS: 3400 Part XIV method A, shall not be lesser than 7kN/m.

4.2.4 Ozone resistance test shall be conducted in all cases of use of elastomeric bearings. In case of a Natural Rubber (NR), bearing having a chloroprene (CR) cover, the natural rubber (NR) does not have to be tested for ozone resistance. The chloroprene Compound (CR) for the cover shall meet all the requirement for chloroprene (CR) and the core shall meet the requirement of Natural Rubber (NR) except for ozone resistance

Note: For use of elastomer in extreme cold climates (at atmosphere temperature below -10°C), special grade of low temperature resistant elastomer shall be used in conformity with operating ambient temperature conditions. The specifications of such special grade elastomer including the tests for low temperature resistance shall be mutually agreed to between the buyer and the manufacturer and are outside the purview of this Code.

4.2.5 Laminates of mild steel conforming to IS: 2062/ IS: 1079 or equivalent international grade shall be used. The yield stress of the material shall not be lesser than 250 MPa. Uses of any other materials like fibreglass or similar fabric as laminates are not permitted for the purpose of this Code.

4.2.6 The raw material for PTFE sheet shall be pure polytetrafluoroethylene free sintered without regenerated materials or fillers. The PTFE sheet may be with or without dimples depending upon the application. PTFE sheet shall conform to the requirement of relevant part covering sliding element. For design of sliding elements, relevant part of IRC:83 shall be referred.

4.2.7 Corrosion protection of exposed steel surfaces, if any, shall conform to the requirement of relevant part covering corrosion protection of bearing plates.

5 DESIGN

Elastomeric bearings shall be designed to meet the relevant provisions of this section at the Ultimate Limit State. At the ultimate limit state, the strength and stability of bearings shall be adequate to withstand the ultimate design loads and movements of the structure. Performance and durability of bearings designed according to this Code are based on the assumption that tolerances given in **Clause 6** are complied with. A typical bridge bearing schedule giving the information normally required for design of the bearings for a particular structure is given in **Annexure A**.

5.1 Laminated Bearings

5.1.1 *Types of laminated bearings*

Bearing design shall be in accordance with one of the types or a combination of the types classified as in **Table 3**.

5.1.2 *Sizes and shapes of laminated bearings*

Bearing types shall be rectangular, square or circular. A particular bearing shall be designed with internal rubber layers of the same thickness between 8 mm and 20 mm each. Usage of internal layer thickness up to 25 mm is permissible under special situations.

Bearings shall preferably be designed and sizes determined by the bearing manufacturer as it is important that the design and detail is compatible with the manufacturing facility available with the manufacturer. Typical standard sizes for bearing type B are given in **Annexure B** as per international standard as well as R'20 series of IS: 1076.

For laminated bearings, it is permissible to reduce the loaded area, without changing the plan dimensions, by including holes of uniform section in the loaded area.

Minimum thickness of inner reinforcing plates shall be 3 mm (provision of Clause 5.1.3.5 shall apply). Minimum thickness of thicker outer reinforcing plates, if provided, (**Table 3, Type C, D, E, F, H & I**) shall be 12 mm for bearings having internal elastomer layer thickness less than equal to 8 mm and minimum plate thickness shall be 16 mm for thicker internal layer of elastomer.

Minimum thickness of top and bottom cover layer shall be 2.5 mm and minimum thickness of side cover shall be 4 mm.

The symbols used in design rules are shown in **Fig. 1**

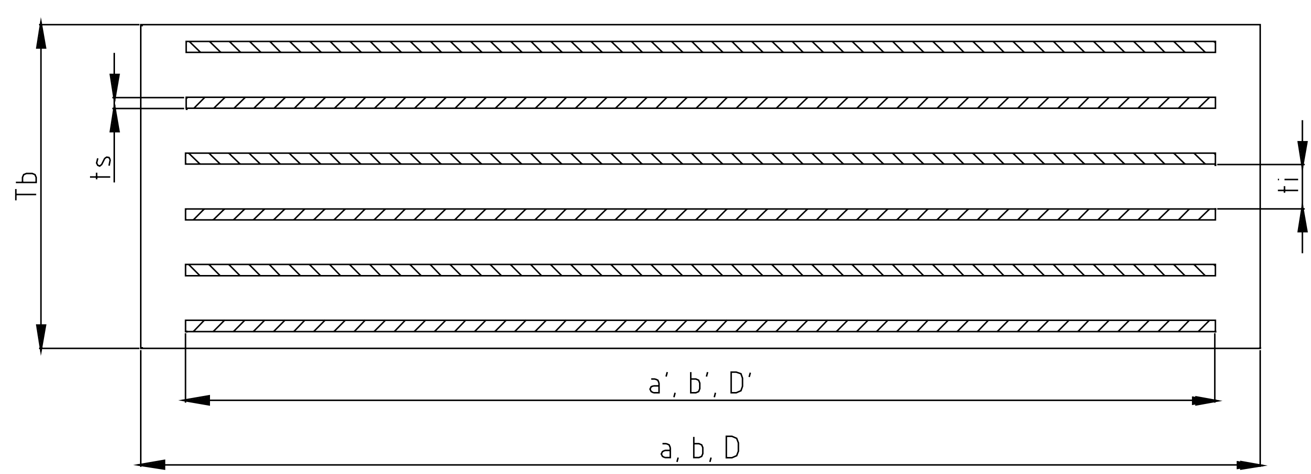
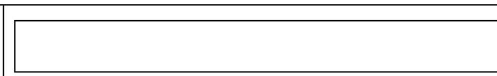
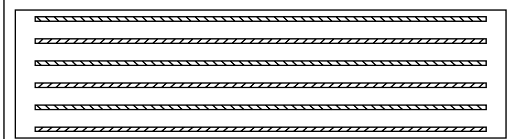
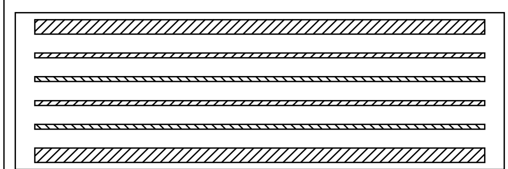
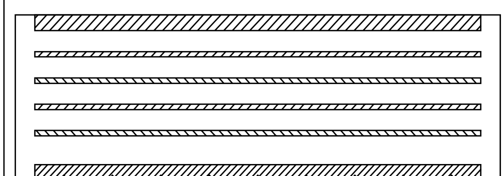
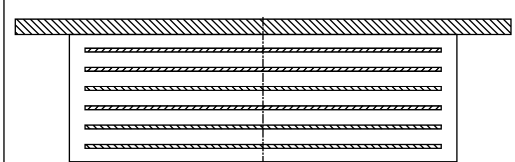
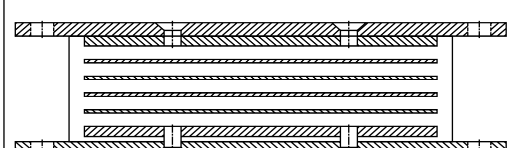
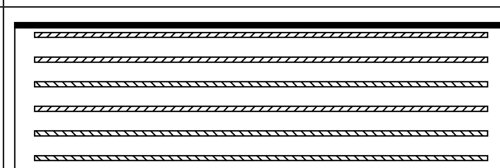
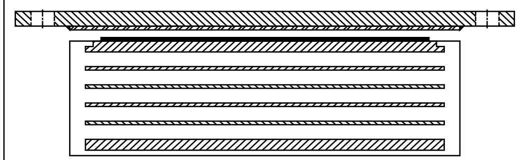
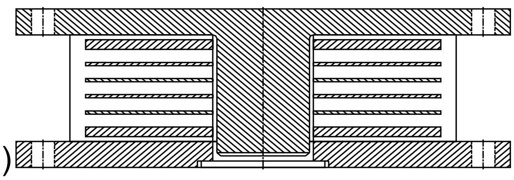
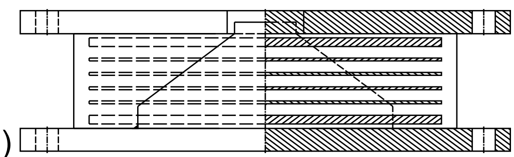


Fig. 1 Typical Cross Section of an Elastomeric Bearing Type B

Table 3: Types of Elastomeric Bearings

1)	**Type A:** Plain pad/Strip bearings	
2)	**Type B:** Laminated bearings	
3)	**Type C:** Laminated bearings with thicker end laminates: - laminate may be on either side or on both side - ensures better load distribution - ensures better rotation - back lifting of bearing under shear may be avoided	
4)	**Type D:** Laminated bearings with thicker end laminates exposed: - Corrosion protection is required on exposed steel surface - May be useful for better frictional resistance at bearing structure interface - Friction, if taken into account, should be based on tested and certified value - Useful for contact with steel structure	
5)	**Type E:** Bearings with separate steel plate directly vulcanised with the bearing - lifting/separation of bearing elastomer at edges from exposed steel plate should be avoided under all loading	
6)	**Type F:** Bearings with positive anchorage: - Separate plates provide ease of replacement and fool-proof positive anchorage - Plates may be connected to covered/exposed end laminates - internal fastening and positive means of location to be adequately designed	
7)	**Type G:** Bearings with PTFE bonded to the elastomer: - bond of elastomer to PTFE is critical and vulnerable	

8)	**Type H:** Bearings with sliding interface: - Refer relevant Part covering sliding element for design of sliding interface - Other end may be of any other option as above	
9)	**Type I:** Bearings with restraint against translation to simulate support condition - a) Typical detail of restraint in form of central pin - b) Typical detail of side restraint. - Restraints shall be designed based on relevant Part or other relevant IRC code.	a)  b) 

5.1.3 *Basis of design*

The design rules are based on the assumption that the elastomer is a viscoelastic material, the deflection of which under a compressive load is influenced by its shape. Reinforcing plates in the bearing shall be chemically bonded to the elastomer during vulcanisation to prevent any relative movement at the steel/elastomer interface. Unless otherwise specified design values stated in this code means values in ULS and are represented with subscript 'd' (**Clause 3.4**) in respective notation. For loads, load factors and load combinations, IRC: 6 shall be referred. For the strength analysis of the elastomeric bearings, the resultant rotational movement shall be taken as not less than ±0,003 radians and the resultant translational movement as not less than ±10 mm.

Effect of top and bottom cover layer shall not be considered in design when their thickness is less or equal to 2.5 mm.

All designed bearings shall meet the requirements given hereafter:

a) Maximum design strain

At any point in the bearing the sum of the strains ($\varepsilon_{t,d}$) due to the design load effects is given by the expression:

$$\varepsilon_{t,d} = K_L\,(\varepsilon_{c,d} + \varepsilon_{q,d} + \varepsilon_{\alpha,d})$$

where:

$\varepsilon_{c,d}$ = design strain due to compressive design loads as defined in Clause 5.1.3.2.

$\varepsilon_{q,d}$ = design shear strain due to design translatory movements as defined in Clause 5.1.3.3.

$\varepsilon_{\alpha,d}$ = design strain due to the design angular rotation as defined in Clause 5.1.3.4.

K_L is a type-loading factor. The value of K_L is normally considered as equal to 1.0. In case of applications with specific requirement of limiting the strain under live load effects, K_L may be considered as 1.5 only for live load effects. For all other load effects, K_L may be considered as 1.0.

$\varepsilon_{t,d}$ shall not exceed the maximum value $\varepsilon_{u,d}$ given by the expression:

$$\varepsilon_{u,d} = \frac{\varepsilon_{u,k}}{\gamma_m}$$

where:

$\varepsilon_{u,k}$ = maximum permissible value of 7 for ULS (See **Note 1**)

γ_m = partial safety factor. Unless otherwise specified, the recommended value is γ_m = 1.00

b) Maximum tensile stresses in reinforcing plates

Reinforcing plates shall be designed for ULS as defined in Clause 5.1.3.5.

c) Stability criteria (see Clause 5.1.3.6)

Stability criteria shall be evaluated taking into account the following:

Stability regarding rotation

Stability regarding buckling

Stability regarding sliding

d) Forces, moments, and deformations exerted on the structure (see Clause 5.1.3.7)

Forces, moments and deformations shall be evaluated taking into account the following:

- The pressure at the contact surfaces between the bearing and the structure.
- The force exerted on the structure by the bearing resisting translatory movement.
- The restoring moment due to the bearing resisting rotational movement
- Vertical deflection due to the vertical load

Note 1: The maximum permissible value for $\varepsilon_{u,d}$ defined as 7 for ULS has been derived from $\varepsilon_{s,d}$ the empirical value of 5 for a serviceability check by multiplying both side of the equation by γ_m = 1.40. It should not be taken to reflect the ultimate strain of the material. Elastomeric bearings are designed to operate well below the ultimate strength of the materials from which they are made, to allow for fatigue effects in the rubber. Consequently bearings can sustain accidental overloads and deformations considerably greater than the design values, without failure. Experiment shows that even when the compressive loads are sufficient to fracture the steel reinforcing plates the bearing still supports the load.

Note 2: The nominal shear modulus can be modified for dynamic load effects (railway loading in Rail-Road bridges, earthquake), depending on the exciting frequencies (generally frequencies > 6Hz) and movement amplitudes: the factor, which may vary for different elastomer compounds, can be obtained experimentally.

Note 3: User can have an extra bearing to be tested at ULS in order to verify the satisfactory performance if they so wish. A bearing tested to ULS cannot be used in the structure since its performance at SLS cannot be guaranteed after such treatment.

5.1.3.1 Shape factor

The shape factor is a means of taking account of the shape of the elastomer in strength and deflection calculations. It is the ratio of the effective plan area of an elastomeric slab to its force-free surface area, including holes.

For laminated bearings the shape factor *S* for each individual elastomer layer is given by the expression:

$$S = \frac{A_1}{l_p \times t_e}$$

For plain pad bearings the shape factor *S* is given by the expression:

$$S = \frac{A}{l_p \times t_e}$$

For strip bearings the shape factor *S* is given by the expression:

$$S = \frac{a}{2 \times t_e}$$

where:

A_1 = 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.

A = overall plan area of the elastomeric bearing.

a = overall width of the strip bearing.

l_p = force-free perimeter of the bearing including that of any holes if these are not later effectively plugged.

t_e = effective thickness of an individual elastomer layer in compression; in laminated bearings it is taken as the actual thickness t_i for inner layers, and $1.4t_i$ for outer layers with a thickness ≥ 3 mm (if the thickness of outer layer is less than 3mm, effect of outer layers shall not be considered in calculation); in plain pad and strip bearings, it is taken as $1.8t_i$ (t_i is the thickness of an individual elastomer layer).

Note: For a rectangular bearing without holes:

$A_1 = a' \times b'$

$l_p = 2 \times (a' \times b')$

where

a' = effective width of the bearing (i.e. the width of reinforcing plates).

b' = effective length of the bearing (i.e. the length of reinforcing plates).

5.1.3.2 Design strain due to compressive load

For calculation purpose *G* shall be one of the values defined in **Table 2**

$\varepsilon_{c,d}$ = design strain due to compressive loads, and is given by the expression:

$$\varepsilon_{c,d} = \frac{1.5 \times F_{z,d}}{G \times A_r \times S}$$

A_r = reduced effective plan area due to the loading effects, where A_r is given by the expression:

$$A_r = A_1 \times \left(1 - \frac{V_{x,d}}{a'} - \frac{V_{y,d}}{b'}\right)$$

where

$V_{x,d}$ = maximum horizontal relative displacement of parts of the bearing in the direction of dimension a of the bearing due to all design load effects;

$V_{y,d}$ = maximum horizontal relative displacement of parts of the bearing in the direction of dimension b of the bearing due to all design load effects.

5.1.3.3 Shear strain

The shear strain $\varepsilon_{q,d}$ of the elastomer due to translatory movement shall not exceed 1.00, and is given by the expression.

$$\varepsilon_{q,d} = \frac{V_{xy,d}}{T_q}$$

where

$V_{xy,d}$ = maximum resultant horizontal relative displacement of parts of the bearing obtained by vectorial addition of coexisting values of $V_{x,d}$ and $V_{y,d}$;

($V_{x,d}$, and $V_{y,d}$ are defined in Clause 5.1.3.2)

T_q = total thickness of the elastomer in shear including the top and bottom cover, unless relative movement between the outer plates of the bearing and the structure is restrained by dowelling or other means.

Note: The maximum permissible value for $\varepsilon_{q,d}$ defined as 1.00 for ULS has been derived by multiplying the SLS value of 0.7 by 1.40.

5.1.3.4 Design strain due to angular rotation

The nominal strain due to angular rotation is given by the expression:

$$\varepsilon_{\alpha,d} = \frac{\left(a'^2 \times \alpha_{a,d} + b'^2 \times \alpha_{b,d}\right) \times t_i}{2 \sum t_i^3}$$

$\alpha_{a,d}$ = angle of rotation across the width, *a,* of the bearing;

$\alpha_{b,d}$ = angle of rotation (if any) across the length, *b,* of the bearing;

t_1 = thickness of an individual layer of elastomer.

5.1.3.5 Reinforcing plate thickness

To resist induced tensile stresses under load, the minimum thickness of the steel plates in a laminated bearing is given by the expression:

$$t_s = \frac{K_p \times F_{z,d} \times (t_1 + t_2) \times K_h \times \gamma_m}{A_r \times f_y} \text{ and } t_s \geq 3mm$$

where

$F_{z,d}$ and A_r are as defined in Clause 3.1

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

f_y = yield stress of the steel;

K_h = factor for induced tensile stresses in reinforcing plate which value is given hereunder

without holes : $K_h = 1$

with holes : $K_h = 2$

γ_m = partial safety factor. Unless otherwise specified the recommended value is $\gamma_m = 1.00$

K_p= stress correction factor, the value of which may be considered as 1.3

5.1.3.6 Limiting conditions

a) Rotational limitation condition

For laminated bearings, the rotational limitation shall be satisfied when the total vertical deflection $\Sigma v_{z,d}$ (see Clause 5.1.3.7) complies with:

For rectangular bearings

$$\sum V_{z,d} - \frac{a'^2 \times \alpha_{a,d} + b'^2 \times \alpha_{b,d}}{K_{r,d}} \geq 0$$

For circular bearings

$$\sum V_{z,d} - \frac{D' \times \alpha_d}{K_{r,d}} \geq 0$$

where,

D' = effective diameter of the bearing.

$K_{r,d}$ = a rotation factor, the value of which may be considered as 3.

$\Sigma V_{z,d}$ = total vertical deflection

b) Buckling Stability (ULS)

For laminated bearings, the pressure, $\frac{F_{z,d}}{A_r}$ shall satisfy the expression:

$\frac{F_{z,d}}{A_r} < \frac{2 \times a' \times G \times S_1}{3 \times T_e}$ - For rectangular bearings

For circular bearings *a'* shall be deemed to be the diameter.

c) Non sliding condition (ULS)

For non-anchored bearings the following formulae shall be satisfied:

$$F_{xy,d} \leq \mu_e \times F_{z,d\,min}$$

and under permanent loads:

$$\sigma_{cd\,min} = \frac{F_{z,d\,min}}{A_r} \geq 3\ MPa$$

where,

$F_{xy,d}$ = resultant of all the horizontal forces

$F_{z,d\,min}$ = minimum vertical design force coexisting with $F_{xy,d}$

μ_e = friction coefficient given by the expression hereafter:

$\mu_e = 0.1 + 1.5 \times \frac{K_f}{\sigma_m}$ at ULS

where,

K_f = 0.6 for concrete

= 0.2 for all other surfaces including bedding resin mortars and steel.

σ_m = average of the compressive stress from $F_{z,d\,min}$

Note: The design values of the friction coefficients for the sliding condition are relatively low to allow for long term effects. Nevertheless more stringent values of μ_e than those mentioned above can be specified for structures with high dynamic conditions, such as railway bridges, or with smooth plinth surfaces.

Where a bearing fails to satisfy the requirements for stability against sliding, positive means of location i.e., anchors may be provided to resist the whole of the horizontal forces. For design of anchors, relevant part of IRC:83 may be referred.

5.1.3.7 Forces, moments, and deformations exerted on the structure

a) Pressure on the contact surfaces

Elastomeric bearing exert a non-uniform pressure on the contact surface with the structure. It is sufficient to ensure that mean pressure does not exceed the strength of the supporting material.

Force exerted on the structure by the bearing resisting translatory movement.

The force R_{xy} exerted on the structure by the bearing resisting translatory movement is given by:

$$R_{xy} = A \times G \times \frac{V_{xy}}{T_e}$$

where,

R_{xy} = resultant of the forces resisting to translatory movement,

A = total plan area of the bearing,

G = shear modulus of the bearing,

T_e = total thickness of elastomer in shear

The force R_{xy} shall not exceed the value specified.

b) Resistance to rotation

The design value of the restoring moment due to rotation about an axis through the centre of the bearing, parallel to the length (b direction), is given by the following expressions:

for rectangular bearing:

$$M = \frac{G \times \alpha \times a'^5 \times b'}{n \times t_i^3 \times K_s}$$

for circular bearing:

$$M = \frac{G \times \alpha \times \pi \times D'^6}{512 \times n \times t_i^3}$$

To determine the factor K_s see **Table 4** hereafter

Table 4: Restoring Moment Factor

b/a	0.5	0.75	1	1.2	1.25	1.3	1.4	1.5
K_s	137	100	86.2	80.4	79.3	78.4	76.7	75.3
b/a	1.6	1.7	1.8	1,9	2	2.5	10	∞
K_s	74.1	73.1	72.2	71.5	70.8	68.3	61.9	60

Note 1: If $b < a$, the formula is still applicable for rotation about the axis parallel to *b,* but in this case *b* is the shorter dimension and *a* is the longer dimension, in contrast with the definitions given in Clause 3.2.

Note 2: The calculated value of the restoring moment is sufficient for most purposes but if a precise knowledge of its value is necessary then the value should be determined experimentally.

c) Vertical Deflection

The total vertical deflection $\Sigma V_{z,d}$ of a laminated bearing is the sum of the vertical deflection of the individual layers given by the expression:

$$\Sigma V_{z,d} = \Sigma \left[\frac{F_{zd} \times t_i}{A_1} \times \frac{1}{5 \times G \times S_1^2 + (1/E_b)} \right]$$

The theoretical vertical deflection of elastomeric bearings shall be estimated from the expressions given above for use in conjunction with Clause 5.1.3.6. Where a precise value is required it shall be checked by testing sample bearings without any correlation or comparison with the expression given.

Note 1: The value of the bulk modulus E_b generally used is the following:

E_b = 2000 MPa

Note 2: The actual deflection of a bearing includes an initial bedding down phase that can produce deflections of approximately 2 mm. Thereafter, the stiffness of the bearing increases with increasing load. Where the vertical deflection under load is critical to the design of the structure, the stiffness of the bearing should be ascertained by tests. However, a variation of as much as ± 20 percent from the observed mean value may still occur. When a number of similar bearings are used at a support and the differential stiffness between the bearings is critical for the structure, a variation of compressive stiffness should be allowed in the design, equal to either ± 15 percent of the value estimated from the above equation, or ± 15 percent of the mean value observed in tests.

Note 3: The calculation for the deflection of a bearing is likely to underestimate the deflection under permanent loads and overestimate the deflection under transient loads.

5.2 Type A: Plain Pad Bearings

This type of bearing consists of a solid block of elastomer without reinforcing plates. These bearings are only suitable for low pressure and predominantly static actions as indicated below.

5.2.1 *Geometry*

Plain pad bearings are generally of square, rectangular or circular plan area. The thickness shall not be less than 8 mm.

5.2.2 *Loads*

The mean design pressure, σ_{cd} on a plain pad bearing is defined by the expression:

$$\sigma_{cd} = \frac{F_{z,d}}{A}$$

where,

$F_{z,d}$ = vertical design load effect

A = overall plan area of the plain pad bearing

The mean design pressure σ_{cd} shall not exceed 1.4 *GS* or *7G*, whichever is the lesser, where *G* is the shear modulus of the elastomer and *S* is the shape factor of the elastomer slab.

Note: The maximum permissible value for σ_{cd} for ULS has been derived from *GS* or *5G* for SLS by multiplying with 1.40

5.2.3 *Shear strain*

The provisions of Clause 5.1.3.3 shall apply.

5.2.4 *Stability criteria*

Rotation: The provisions of Clause 5.1.3.6 shall apply.

Buckling: Thickness < 1/4 minimum lateral dimension.

Sliding: The provisions of Clause 5.1.3.6 for all loads shall be applied and

$\frac{F_{z,d}}{A_r} > 1 + a/b$ for permanent loads.

5.2.5 *Deformations and forces exerted on the structure*

Vertical deflection: The deflection is given by the equation for a single layer in Clause 5.1.3.7. (Ignoring term involving the bulk modulus).

Mean Pressure: $\frac{F_{z,d}}{A}$

Translatory: The force arising from the shear strain is given in Clause 5.1.3.7.

5.3 **Type A: Strip Bearings**

This type of bearing consists of a solid strip of elastomer without reinforcing plates.

5.3.1 *Geometry*

The thickness of strip bearings shall not be less than 8 mm.

5.3.2 *Loads*

The mean design pressure, σ_{cd} on a strip bearing as defined by the expression:

$$\sigma_{cd} = \frac{F_{z,d}}{A}$$

shall not exceed the maximum limit value σ_{cd} = 1.4 x G x S or 7 x G, whichever is the lesser, where,

$F_{z,d}$ = vertical design load effect

A = overall plan area of the strip bearing

G = nominal shear modulus of the elastomer

S = shape factor of the elastomer slab

5.3.3 *Shear Strain*

The calculation for determining $\varepsilon_{q,d}$ described in Clause 5.1.3.3 shall apply. The shear strain shall be limited to the following value:

$\varepsilon_{q,d} \leq 0.3$

5.3.4 *Stability Criteria*

Rotation: $\sum \delta > a \times \alpha_a / 3$

Buckling: Thickness < 1/4 of width

Sliding: The provisions in Clause 5.1.3.6 for all loads shall be applied and

$\frac{F_{z,d}}{A_r} > 1 + a/b$ for permanent loads

5.3.5 *Deformations and maximum forces exerted on the structure*

Vertical deflection: The deflection is given by the equation for a single layer in Clause 5.1.3.7 (Ignoring term involving the bulk modulus).

Mean Pressure: $\frac{F_{z,d}}{A}$

Translatory: The force arising from the shear strain is given in Clause 5.1.3.7.

5.4 Type G&H: Sliding Elastomeric Bearings

Bearings of type G & H in **Table 3** shall conform to the design rules and manufacturing tolerances for laminated bearings, see Clause 5.1.3.

The maximum frictional force $F_{xy,d}$ when calculated in accordance with relevant Part covering sliding element shall comply with:

$F_{xy,d} \leq R_d$

$R_d = A \times G$

5.5 Internal Fastening Connections and Positive Means of Location

Internal fastening connections for (Bearing type F: Bearing with positive anchorage in **Table 3**) and positive means of location shall be designed for a minimum $F_{xy,d}$. For designing of positive means of location/anchorage, refer relevant Part

$F_{xy,d} = A \times G$

6 MANUFACTURING & WORKMANSHIP

6.1 Plain pad and strip bearing shall be moulded in one piece, or comprise single pieces cut from previously moulded strips or slabs. Cutting shall produce a smooth surface without injurious heating of the elastomer.

6.2 Bearing with steel laminates shall be moulded as single unit in a mould and vulcanised under heat and pressure. Moulding of elements in separate units and subsequent bonding is not permitted, nor shall cutting from large size cast be permitted.

6.3 The moulds used shall have standard surface finish adequate to produce bearings free from any surface blemishes.

6.4 Internal steel laminates shall be free from sharp edges.

6.5 Steel plates for laminates shall be sand/ grit blasted to clean all mill scales and shall be free from all contaminants prior to bonding by vulcanisation. Rusted plates with pitting shall not be used.

6.6 Bonding shall be carried out during vulcanisation using suitable bonding agent for bonding of elastomer to steel such that the bond peel strength is at least 7 N/mm width when tested in accordance with IS:3400 Part XIV Method A.

6.7 Spacers used in mould to ensure cover and location of laminates shall be of minimum size and number practicable. Any hole at surface or in edge cover shall be filled in subsequently.

6.8 Care shall be taken to ensure uniform vulcanisation conditions and homogeneity of elastomer through the surface and body of the bearing.

6.9 The bearings shall be manufactured with the tolerances specified in **Table 5**. Tolerances of thickness of individual layer of elastomer, dimension of laminates, and flatness of laminates are primarily meant for quality control during production. In order to measure thickness of individual layer of elastomer, dimension of laminates and flatness of laminates of a finished bearing it is essential to cut the bearing, which may be done if agreed upon between the manufacturer and the buyer.

Table 5: Manufacturing Tolerances

<table>
<tr><th>Sl. No.</th><th>Items</th><th colspan="2">Tolerances</th></tr>
<tr><td>1</td><td>Overall Linear Plan Dimensions</td><td colspan="2">−2 mm,+4 mm</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Total Mean Bearing Thickness
(The mean thickness is the arithmetic average of the thickness measured at five points on the major surface as indicated for various shaped bearings:
Rectangular: corners and centre
Circular: corners of inscribed square and centre)</td><td>$T_b \leq 100mm$</td><td>± 2mm</td></tr>
<tr><td>$100mm < T_b \leq 150mm$</td><td>± 3mm</td></tr>
<tr><td>$150mm < T_b$</td><td>± 4mm</td></tr>
</table>

3	**Parallelism**		
a)	Of top surface of bearing with respect to the bottom surface as datum	*1 in 300*	
b)	Of one side surface with respect to the other as datum	*1 in 100*	
4	**Thickness of Individual Layer of Elastomer**		
a)	Inner layer of elastomer	$5mm \le t_i < 10mm$	*± 15%*
		$10mm \le t_i < 15mm$	*± 12%*
		$15mm \le t_i < 25mm$	*± 10%*
b)	Outer layer of elastomer	*0 mm,+2 mm*	
c)	Side cover	*0 mm,+3 mm*	
5	**Dimension of Laminates**		
a)	Plan dimensions of laminates	*+2 mm,+1mm*	
b)	Thickness of laminate	$t_s \le 4mm$	*+0.8mm,−0.4mm*
		$t_s > 4mm$	*+1.1mm,−0.4mm*
c)	Parallelism of laminate with respect to bearing base as datum (with respect to diameter for plates circular in plan and shorter side for plates rectangular in plan)	*1 in 100*	
6	**Flatness**		
a)	Load bearing surface of the bearing Flatness of load bearing surface of a bearing shall be assessed by placing a straightedge along the diagonal or diameter. The gap between the straightedge and the surface shall not exceed 0.3% of the diagonal or diameter or the values specified in the next column against Tb whichever is greater	$T_b \le 50mm$	*± 1mm*
		$50mm < T_b \le 100mm$	*± 1.5mm*
		$100mm < T_b \le 150mm$	*± 2mm*
		$150mm < T_b$	*± 2.5mm*
b)	Steel laminate	*1% of diameter or diagonal (max of 1.5 mm)*	

6.10 The vulcanising equipment/press should be such that between the platens of the press the pressure and temperature are uniform and capable of being maintained at constant values as required for effecting uniform vulcanisation of the bearing.

6.11 The moulding dies utilized for manufacturing the bearings should be so set inside the platen of the press so that the pressure developed during vulcanisation of the product is evenly distributed and the thickness maintained at all places are within acceptable tolerance limits taking into consideration, the shrinkage allowance of vulcanisate.

6.12 The raw compound which has been introduced inside the metal dies for vulcanisation, should be accurately weighed each time and it must be ensured that sufficient quantity has been put inside the die for proper flow of material at every place so that a homogeneous and compact bearing is produced without any sign of sponginess or deficiency of material at any place.

6.13 Before any vulcanisate of any batch of production is used for producing vulcanised bearings, test pieces in the form of standard slab and buttons should be prepared in accordance with prescribed standards and salient properties tested and recorded regularly against each batch of production to monitor the quality of the products.

7 ACCEPTANCE SPECIFICATION

7.1 The manufacturer shall have all test facilities required for process and acceptance control tests installed at his plant to the complete satisfaction of the engineer. The test facilities and their operation shall be open to inspection by the engineer on demand.

7.2 All acceptance and process control tests shall be conducted at the manufacturer's plant. Cost of all materials, equipment and labour shall be borne by the manufacturer unless otherwise specified or specially agreed to between the manufacturer and buyer.

7.3 Acceptance testing shall be commenced with the prior submittal of testing programme by the manufacturer to the engineer and after obtaining his approval.

7.4 Any acceptance testing delayed beyond 180 days of production shall require special approval of the engineer and modified acceptance specification, as agreed to between the manufacturer and the buyer.

7.5 All acceptance testing shall be conducted by the inspector with aid of the personnel having adequate expertise and experience in rubber testing provided by the manufacturer, working under the supervision of inspector and to his complete satisfaction.

7.6 Lot by lot inspection and acceptance shall be made.

7.7 Acceptance Lot

A lot under acceptance shall comprise all bearings, including the extra test bearings where applicable (Clause 7.9.1.3) of equal or specified size produced under identical conditions of manufacture to be supplied for a particular project.

7.7.1 For the purpose of grading levels of acceptance testing (Clause 7.9), lots will be classified as below:

A lot size of 24 or larger number of bearings shall be defined as a large lot.

A lot size of less than 24 bearings shall be defined as small lot.

7.8 Levels of Acceptance Inspection

The level of acceptance testing shall generally be graded into the following two levels depending on lot size:

Level 1 acceptance testing

Level 2 acceptance testing

7.8.1 Acceptance testing level 1 is a higher level inspection and shall be applicable to large lots. This level of inspection can be specified for small lots also as per the discretion of the Engineer/ Employer. This shall involve manufacture of extra bearings to be used as test bearing and eventually consumed in destructive testing. The cost of extra test bearings, in such cases shall be borne by the buyer while cost of all other materials, equipment and testing shall be borne by the manufacturer.

7.8.2 Acceptance testing level 2 shall be applicable in general for all lots, unless otherwise specified, and shall not involve any destructive testing of finished bearings.

7.9 Acceptance Testing

Acceptance testing shall comprise:

General inspection

Test on specially moulded test pieces.

Test on complete bearings or sections for measurement of various quality characteristics detailed below:

7.9.1 *Acceptance testing level 1*

7.9.1.1 General inspection

a) All bearings of the lot shall be visually inspected for absence of any defects in surface finish; shape; hardness or any other discernible superficial defects.

b) All bearings of the lot shall be checked for tolerances for overall dimensions, mean bearing thickness, parallelism of bearing surfaces and flatness of load bearing surfaces specified in **Table 5**.

c) All bearing of the lot shall be subjected to an axial load to correspond to the design load at serviceability limit state while visual examination is made to check for discernible defects like

- Misalignment of reinforcing plates
- Poor bond at laminate/steel interface
- Variation in elastomer layer thickness
- Any surface defects developed during testing

The test shall be carried out on all bearings as part of the standard production process. The temperature of the room in which the bearing are tested shall not vary more than 10°C. The main objective of this test is to eliminate poorly made bearings by visual Inspection in a quick and efficient way.

During the test, the deflection between 30 percent and 100 percent of the maximum load for the application shall be recorded and used to check the consistency of the stiffness value. Variation in stiffness of any individual bearing from the mean of the measured values for all such bearings of the lot shall not be larger than 20 percent of the mean value.

During acceptance testing, complete test data shall be furnished by the manufacturer and one bearing per lot shall be selected at random and the same test shall be repeated. The bearings shall then be visually inspected for defects as well as the stiffness shall be measured.

Variation in stiffness of the individual bearing from the mean of the measured values for all such bearings of the lot as provided by the manufacturer shall not be larger than 20 percent of the mean value.

In case of any visual defect or unacceptable stiffness during acceptance testing, all bearings of the lot shall be subjected to the same test again and only the bearing that passes the test in all respect shall be accepted.

7.9.1.2 Tests on specially moulded test pieces.

a) Test pieces shall be moulded by the manufacturer with identical compound and under identical vulcanizing conditions as used in the manufacture of the bearings of the acceptance lot. The process shall be open to inspection by the inspector or engineer.

b) Test pieces offered for inspection shall be identified by suitable markings and duly certified by the manufacturer.

c) The quality characteristics to be tested are listed below. The specification references in parenthesis shall define the corresponding specification for test piece, test method and criterion of acceptance.

- Composition (Clause 4.1.; see **Note 1** below)
- Tensile Strength (Table 1)
- Elongation at Break (Table 1)
- Tear Resistance (Table 1)
- Compression Set (Table1)
- Accelerated Ageing (Table 1)
- Ozone Resistance (Table 1, Clause 4.2.4. see also **Note 2** below)
- Adhesion Strength (Clause 4.2.3)

Note 1: For acceptance testing level 1 the ash content (%) and specific gravity of elastomer of test pieces from test bearing shall be compared with those for corresponding specially moulded test pieces furnished by the manufacturer. The following variations shall be deemed maximum acceptable.

- Specific gravity: ± 0.2
- Ash content: ± 0.5% (e.g. if the ash content of elastomer from test bearing is 4% the ash content of the specially moulded test piece shall be within 3.5% to 4.5% or vice versa)
- Hardness (Table 1)

Note 2: Ozone resistance test can be waived by the engineer, when satisfactory results of ozone resistance tests on similar grade of elastomer may be available from process control records or development test data furnished by the manufacturer.

Where such process control data are not available or the frequency of testing not deemed adequate, ozone resistance test shall be mandatory for acceptance.

7.9.1.3 Tests on complete bearings or samples

a) Two bearings shall be selected at random from the lot as test bearings and the following test shall be conducted.
   - Test for determination of shear modulus (on a pair of bearing).
   - Test for determination of compression stiffness (on one bearing out of the selected pair)
   - The test specifications and acceptance criteria shall conform to those given in **Annexure C**. The tested bearings shall be part of the lot accepted.

b) The following tests shall be conducted on two identical bearing selected at random from the lot or on prototype bearings produced in identical condition as test bearing.
   - Test for determination of shear bond strength

The test specifications and acceptance criteria shall conform to those given in **Annexure C**. This is a destructive test and the test bearings shall not be used in the structure.

7.9.2 *Acceptance testing level 2*

7.9.2.1 General inspection

a) All bearings of the lot shall be visually inspected for absence of any defects in surface finish; shape; hardness or any other discernible superficial defects.

b) All bearings of the lot shall be checked for tolerances for overall dimensions, mean bearing thickness, parallelism of bearing surfaces and flatness of load bearing surfaces specified in **Table 5**.

7.9.2.2 Test on specially moulded test pieces: This shall conform to the provisions in Clause 7.9.1.2 in all respects.

7.9.2.3 Test on complete bearings

Two bearings shall be selected at random from the lot as test bearings and the following test shall be conducted.

- Test for determination of shear modulus (on a pair of bearing).
- Test for determination of compression stiffness (on one bearing out of the selected pair)

The test specifications and acceptance criteria shall conform to those given in **Annexure C**. The tested bearings shall be part of the lot accepted.

7.9.3 *Special Acceptance Inspection*

7.9.3.1 Special acceptance inspection may comprise following:

a) Acceptance testing by a NABL accredited independent external agency with supplemental test facilities provided by it for polymer identification and confirmation about percentage of polymer content and ash content by TGA method.

b) Acceptance testing on test pieces prepared from the surface or body of the test bearings instead of specially moulded test pieces.

c) Acceptance testing on cut sample from finished bearing in order to measure thickness of individual layer of elastomer, dimension of laminates and flatness of laminates.

d) Acceptance test at ULS condition. Bearings tested at ULS condition cannot be used in the structure since its performance at SLS cannot be guaranteed after such treatment.

e) Acceptance tests not covered by this Code and according to the specifications laid down by the engineer.

7.9.3.2 Special acceptance inspection may be specified under the following conditions:

a) Special contract agreement between the manufacturer and the buyer. Cost of additional bearings to be consumed for special acceptance inspection shall be borne by buyer.

b) Unsatisfactory evidence of process or acceptance control.

7.10 Inspection Certificate

7.10.1 A lot under inspection shall be accepted by the inspector and so certified, when no defect is found with respect to any of the quality characteristics tested on samples drawn from the lot according to specifications laid down in Clause 7.9 covering general inspection and tests on specially moulded test pieces and on complete bearings.

In case of any bearing with defect, the lot shall be rejected by the inspector and so certified.

7.10.2 In case any bearing is found defective to any quality characteristic, discerned by general inspection; tests on specially moulded test pieces and complete bearings as applicable shall nevertheless be completed. If the said lot, rejected by general inspection, satisfies the acceptance criteria in respect of these other tests, the lot and individual bearings found defective shall be clearly identified in the inspection certificate.

7.10.3 The manufacturer shall obtain from the inspector, immediately on completion of his inspection, an inspection certificate which shall include the details of a lot or lots accepted/ rejected by him and records of all test measurements.

7.11 Quality Control Certificate

Verification and periodic audit of Factory Production Control (FPC) and Quality Assurance Certification of the manufacturer's plant to be carried out on a regular basis by a Govt. recognized National level laboratory/institute or by an independent and recognized international certifying body (e.g. notified body for EC Certification and CE marking).

7.11.1 *The manufacturer shall certify for each lot of bearing under acceptance:*

- That an adequate system of continuous quality control was operated in his plant.
- That the entire process remained in control during the production of the lot of bearings under acceptance as verified from the quality control

records/charts which shall be open to inspection of the engineer/ inspector on demand.

A certified copy of results of process control testing done on samples of elastomer used in the production of the lot shall be appended and shall include at least the following information.

Composition of the compound-raw elastomer and ash content, the grade of raw elastomer used (include name, source, age on shelf), test results of hardness, tensile strength, elongation at beak, compression set, accelerated ageing, etc.

7.11.2 A higher level certification of the process quality control may be called for at the sole discretion of the engineer in special cases e.g. where adequate historical information about the process from acceptance inspection of bearings similar to those comprising the lot under inspection produced in the same plant is not available with the engineer or in case of any evidence of process or acceptance control being deemed unsatisfactory. The higher level certification shall comprise submittal of a complete quality control report as given in **Annexure C**, supplementing the quality control certificate.

7.12 Acceptance

7.12.1 The manufacturer shall furnish the following to engineer for the acceptance judgment:

a) Quality control certificate as laid down in Clause 7.11.

b) Inspection certificate as laid down in Clause 7.10.

7.12.2 The manufacturer shall furnish any supplementary information on the system of quality control and or process and acceptance control testing as may be deemed necessary by engineer.

7.12.3 In case of any evidence of process or acceptance control testing being deemed unsatisfactory by him, engineer at his sole discretion may call for a special acceptance inspection of the lot according to specifications laid down by him, without any prejudice to his right to reject the lot. The entire cost of such supplementary inspection shall be borne by the manufacturer.

7.12.4 Engineer shall be the sole authority for acceptance of a lot on scrutiny of the certificates according to Clause 7.12.1 along with any supplementary evidence according to Clauses 7.12.2 and 7.12.3; and complete satisfaction herewith.

7.12.5 In case of rejection of a lot, engineer shall reserve the right to call for special acceptance inspection for the succeeding lots offered for inspection according to the specifications laid down by him. The entire cost of such tightened inspection shall be borne by the manufacturer.

8 CERTIFICATION AND MARKING

8.1 Bearings shall be transported to bridge site after final acceptance by engineer and shall be accompanied by an authenticated copy of the certificate to that effect.

8.2 Each bearing shall be uniquely and individually numbered for identification on its external faces. The identification number shall be unique and as such to enable other bearings manufactured at the same time to be traced through the production control records should the need arise. As a minimum, a label should be vulcanised on the top or bottom of the bearing detailing:

- manufacturer's name
- unique identification number and the manufacturer's name or symbol on one of the edges.

Marking shall be resistant to water and normal wear and tear

Additional information that may be marked on the bearing or supplied separately with the bearing correlating with the unique identification number shall be as follows:

- Date of manufacture
- Bearing dimensions
- Production batch number
- Acceptance lot number
- Specific bridge location, if any
- Explanation of markings used on the bearing

8.3 The top of the bearing and direction of installation shall be indicated.

9 INSTALLATION

9.1 Care shall be taken in packing, transportation, storage and handling to avoid any mechanical damage, contamination with oil, grease and dirt, undue exposure to sunlight and weather.

9.2 Bearings shall be installed in the structure as specified or approved by the engineer to ensure that right bearing is being installed at the right location.

9.3 Bearings must be placed between true horizontal surfaces (maximum tolerance 0.2 per cent perpendicular to load) and at true plan position of their control lines marked on receiving surfaces (maximum tolerance ±3 mm). Concrete surfaces shall be free from local irregularities (maximum tolerance ±1 mm in height).

9.4 Departures from common planarity of twin or multiple bearings shall be within such tolerance as may be specified or approved by the engineer.

9.5 Design shall be checked for the actual inclination in seating if larger inaccuracies than those specified in Clause 9.3 are permitted.

9.6 For cast-in-place concrete construction of superstructure, where bearings are installed prior to its concreting, the forms around the bearings shall be soft enough for easy removal. Forms shall also fit the bearings snugly and prevent any leakage of mortar grout. Any mortar contaminating the bearings during concreting shall be completely removed before setting.

9.7 For precast concrete or steel superstructure elements, fixing of bearing to them may be done by application of epoxy resin adhesive to interface, after specified surface preparation. The specification for adhesive material, workmanship and control shall be approved by the engineer. Care shall be taken to guard against faulty application and consequent behaviour of the adhesive layer as a lubricant. The bonding by the adhesive shall be deemed effective only as a device for installation and shall not be deemed to secure bearing against displacement for purpose of design.

9.8 Lifting of a cast-in-place post-tensioned bridge deck for relieving time dependent deformation shortly after installation of bearings should be avoided. In case such lifting is unavoidable, the lifting arrangement, proper seating of the girder on the bearing, etc. shall be rigidly controlled to avoid any risk of misalignment.

9.9 After installation, bearing and their surrounding areas shall be left clean.

9.10 Under load, bulging of the rubber layer between the reinforcing steel laminates on free exposed perimeter is a normal phenomenon and is not detrimental to the performance of the bearing unless any crack or evidence of bond failure is detected.

10 MAINTENANCE

10.1 The structure should be designed and detailed in such a way that the bearings are easily accessible after installation for inspection and maintenance. Arrangements for insertion of jacks to lift the bridge deck shall be made in detailing of structure.

10.2 The bearings shall be subjected to planned maintenance care.

10.3 The exposed bearing surface shall be maintained clean and free from contamination with grease or oil, etc.

10.4 Annual routine maintenance inspection or special maintenance inspection of all bearings shall be made to check the following criteria:

- The top and bottom load bearing surfaces shall be in full contact with the plinth (bottom supporting surface) and the soffit (top supporting surface). If there is imperfect contact between the surfaces stated above, the angle between the soffit and the plinth shall be checked against the design specifications.
- Shear deflection is expected phenomenon in Elastomeric bearing. However, the magnitude of the shear deflection of each bearing shall be checked to ensure that it is within the design specifications.
- A visual inspection shall be made of all the accessible edges. A note shall be made of the size and position of any cracks or splits, or uneven bulges. Near uniform bulging is however expected phenomenon in elastomeric bearing.
- Examine the plinth and soffit for signs of displacement from bearing original position (black marks may give an indication of movement).
- If applicable, examine the sliding surfaces for cleanliness and that the movements are within the design range and report results.
- If applicable, examine the protective coating and/or dust protection for signs of deterioration and report results

10.5 Damaged bearings shall be replaced immediately. To avoid differences in stiffness, all adjacent bearings on the same line of support shall also be replaced.

ANNEXURE A

A.1 Typical Bridge Bearing Schedule

Bridge name or reference

Bearing identification mark							
Number off							
Seating materiala	Upper surface						
	Lower surface						
Allowable average contact pressure (N/mm²)	Upper face	Seviceability					
		Ultimate					
	Lower face	Seviceability					
		Ultimate					
Design load effects (kN)	Ultimate limit state	Vertical	max.				
			permanent				
			min.				
		Transverse					
		Longitudinal					
	Serviceability limit state	Vertical					
		Transverse					
		Longitudinal					
Translation (mm)	Ultimate limit state	Transverse					
		Longitudinal					
	Serviceability limit state	Transverse					
		Longitudinal					
Rotation (radians)	Ultimate limit state	Transverse					
		Longitudinal					
Maximum bearing dimensions (mm)		Transverse					
		Longitudinal					
		Overall height					
Tolerable movement of bearing under Vertical transient loads (mm) If relevant		Vertical					
		Transverse					
		Longitudinal					
Allowable resistance to translation under serviceability limit state (kN) If relevant		Transverse					
		Longitudinal					
Allowable resistance to rotation under serviceability limit state (kN.m) If relevant		Transverse					
		Longitudinal					
Type of fixing required		Upper face					
		Lower face					

NOTE: State any other requirements on separate sheet

[a] For example cement mortar, epoxy mortar, in situ concrete, precast concrete, steel, timber

ANNEXURE B

B.1 Typical Sizes of Laminated Bearings

Dimensions a x b (mm) or D	Thickness in mm						Number of Layers n	
	Unloaded Bearing		Elastomer (total *)		Elastomer Layers	Reinforcing Plates		
	min.	max.	min.	max.			min.	max.
100 x 150	30	41	16	24	8	3	2	3
100 x 200	30	41	16	24	8	3	2	3
150 x 200	30	52	16	32	8	3	2	4
φ 200	30	52	16	32	8	3	2	4
150 x 250	30	52	16	32	8	3	2	4
150 x 300	30	52	16	32	8	3	2	4
φ 250	30	52	16	32	8	3	2	4
200 x 250	41	74	24	48	8	3	3	6
200 x 300	41	74	24	48	8	3	3	6
200 x 350	41	74	24	48	8	3	3	6
φ 300	41	74	24	48	8	3	3	6
200 x 400	41	74	24	48	8	3	3	6
250 x 300	41	85	24	56	8	3	3	7
φ 350	41	85	24	56	8	3	3	7
250 x 400	41	85	24	56	8	3	3	7
300 x 400	57	105	36	72	12	4	3	6
φ 400	57	105	36	72	12	4	3	6
300 x 500	57	105	36	72	12	4	3	6
φ 450	57	105	36	72	12	4	3	6
300 x 600	57	105	36	72	12	4	3	6
350 x 450	57	121	36	84	12	4	3	7
φ 500	57	121	36	84	12	4	3	7
400 x 500	73	137	48	96	12	4	4	8
φ 550	73	137	48	96	12	4	4	8
400 x 600	73	137	48	96	12	4	4	8
450 x 600	73	153	48	108	12	4	4	9
φ 600	73	153	48	108	12	4	4	9
500 x 600	73	169	48	120	12	4	4	10
φ 650	73	169	48	120	12	4	4	10
600 x 600	94	199	64	144	16	5	4	9
φ 700	94	199	64	144	16	5	4	9
600 x 700	94	199	64	144	16	5	4	9
φ 750	94	199	64	144	16	5	4	9
700 x 700	94	220	64	160	16	5	4	10
φ 800	94	220	64	160	16	5	4	10
700 x 800	94	220	64	160	16	5	4	10
φ 850	94	220	64	160	16	5	4	10
800 x 800	110	285	80	220	20	5	4	10
φ 900	110	285	80	220	20	5	4	10
900 x 900	110	285	80	220	20	5	4	11

* Total thickness without top and bottom cover

B.2 Typical Sizes of Laminated Bearings as per R'20 Series

Dimensions a x b (mm) or D	Thickness in mm						Number of Layers n	
	Unloaded Bearing		Elastomer (total *)		Elastomer Layers	Reinforcing Plates		
	min.	max.	min.	max.			min.	max.
100 x 160	30	41	16	24	8	3	2	3
100 x 200	30	41	16	24	8	3	2	3
160 x 200	30	52	16	32	8	3	2	4
φ 200	30	52	16	32	8	3	2	4
160 x 250	30	52	16	32	8	3	2	4
160 x 320	30	52	16	32	8	3	2	4
φ 250	30	52	16	32	8	3	2	4
200 x 250	41	74	24	48	8	3	3	6
200 x 320	41	74	24	48	8	3	3	6
200 x 360	41	74	24	48	8	3	3	6
φ 320	41	74	24	48	8	3	3	6
200 x 400	41	74	24	48	8	3	3	6
250 x 320	41	85	24	56	8	3	3	7
φ 360	41	85	24	56	8	3	3	7
250 x 400	41	85	24	56	8	3	3	7
320 x 400	57	105	36	72	12	4	3	6
φ 400	57	105	36	72	12	4	3	6
320 x 520	57	105	36	72	12	4	3	6
φ 450	57	105	36	72	12	4	3	6
320 x 630	57	105	36	72	12	4	3	6
360 x 450	57	121	36	84	12	4	3	7
φ 520	57	121	36	84	12	4	3	7
400 x 520	73	137	48	96	12	4	4	8
φ 560	73	137	48	96	12	4	4	8
400 x 630	73	137	48	96	12	4	4	8
450 x 630	73	153	48	108	12	4	4	9
φ 630	73	153	48	108	12	4	4	9
520 x 630	73	169	48	120	12	4	4	10
630 x 630	94	199	64	144	16	5	4	9
φ 710	94	199	64	144	16	5	4	9
630 x 710	94	199	64	144	16	5	4	9
710 x 710	94	220	64	160	16	5	4	10
φ 800	94	220	64	160	16	5	4	10
710 x 800	94	220	64	160	16	5	4	10
φ 850	94	220	64	160	16	5	4	10
800 x 800	110	285	80	220	20	5	4	10
φ 900	110	285	80	220	20	5	4	10
900 x 900	110	285	80	220	20	5	4	11

* Total thickness without top and bottom cover

ANNEXURE C

C.1 Tests on Complete Bearings or Samples (Refer Clauses 7.9.1.3 & 7.9.2.3)

a) All tests shall be conducted on test bearings chosen at random from the lot under acceptance testing or sample bearings, as applicable. All tests shall be carried out on complete bearings only and not on any cut-sample in any case.*

b) All tests shall be conducted by skilled personnel under competent supervision with adequate experience in rubber testing, to the complete satisfaction of the inspector.

c) All testing shall be done at room temperature.

d) No bearings shall be tested earlier than a week after vulcanization.

e) Test for determination of Compression Stiffness may precede that of Shear Modulus, when both tests are conducted on the same test bearings.

f) All details of test equipment, method and specified values, as applicable, shall be furnished with the submittal of the acceptance testing programme according to Clause 7.3.

C.2 Test for Determination of Shear Modulus

C.2.1 *Scope:*

The test shall determine the value of shear modulus under specified short term loading.

C.2.2 *Test Piece*

Two test bearings.

C.2.3 *Test Procedure*

C.2.3.1 Test assembly

As in **Fig. 2**

C.2.3.2 Conditioning load

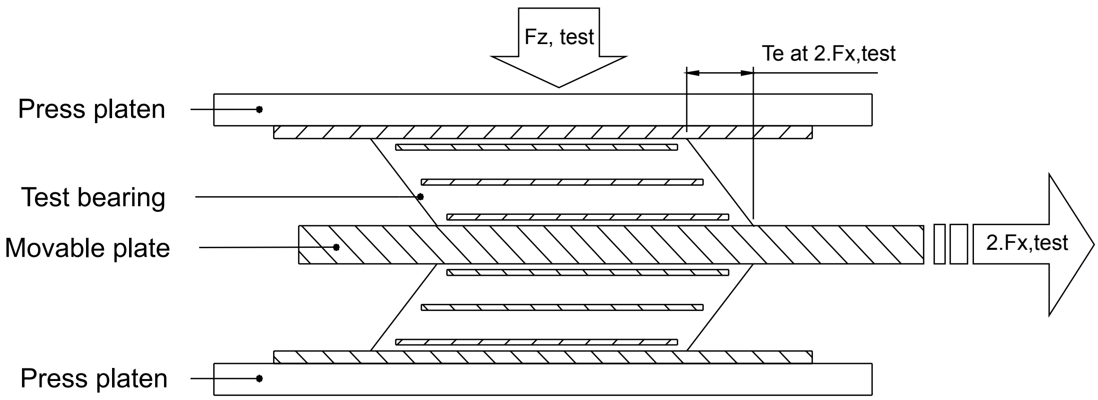
Bearings shall be preloaded with maximum horizontal load 2 x F_x (with $F_{z,test}$ held constant) and unloaded before test loading.

C.2.3.3 Rate of loading

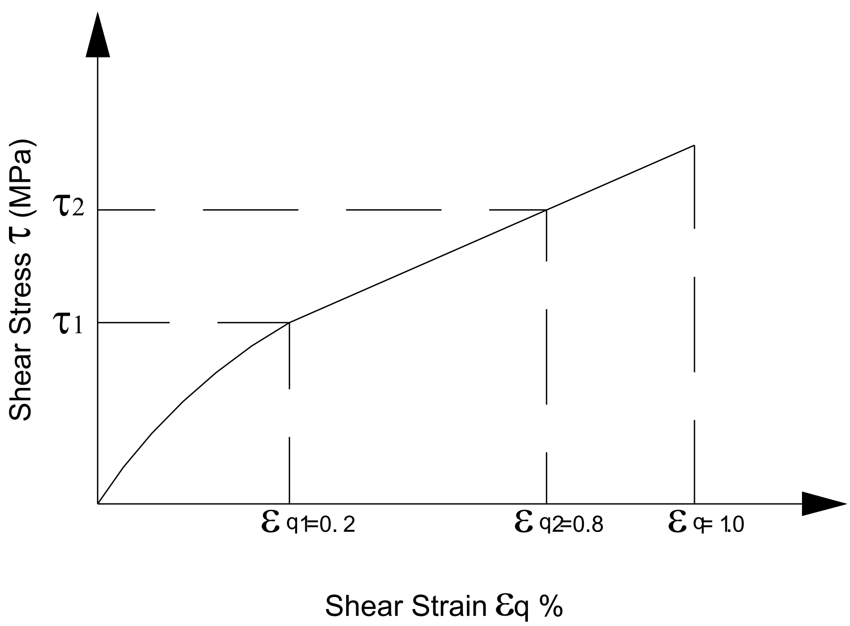
$F_{z,test}$ corresponding to σ_m = *5 MPa* shall be held constant during test and the horizontal loading 2 x F_x shall be gradually increased to yield a shear stress rate of approximately *0.05 to 0.5 MPa* per minute.

C.2.3.4 Maximum test loading

The horizontal loading 2 x F_x shall be increased up to a maximum 2 x $F_{x,test}$ which corresponds to horizontal deflection equal to T_e



(a) Test Assembly



$$\varepsilon_{q1} = V_{x1}/T_q \, , \varepsilon_{q2} = V_{x2}/T_q$$

$$\tau_1 = F_{x1}/A \, , \tau_2 = F_{x2}/A$$

$$G = (\tau_2 - \tau_1)/(\varepsilon_{q2} - \varepsilon_{q1})$$

(b) Shear Stress Strain Curve and G

Fig. 2 Determination of Shear Modulus

C.2.3.5 Measurement

Load and deflection measurements shall be made at approximately equal intervals not less than 5.

C.2.4 *Evaluation*

C.2.4.1 A shear stress strain curve shall be plotted and the value of shear modulus determined as shown in **Fig. 2 (b)**.

C.2.4.2 The test result shall be deemed- satisfactory if G determined is within the tolerance limit of value specified in **Table 2** of the main text and provided there is no evidence of instability, defect or damage discovered by close inspection during the test.

C.3 Test for determination of Compressive Stiffness

C.3.1 *Scope*

The test shall determine the value of apparent Compression Stiffness under specified short term axial loading.

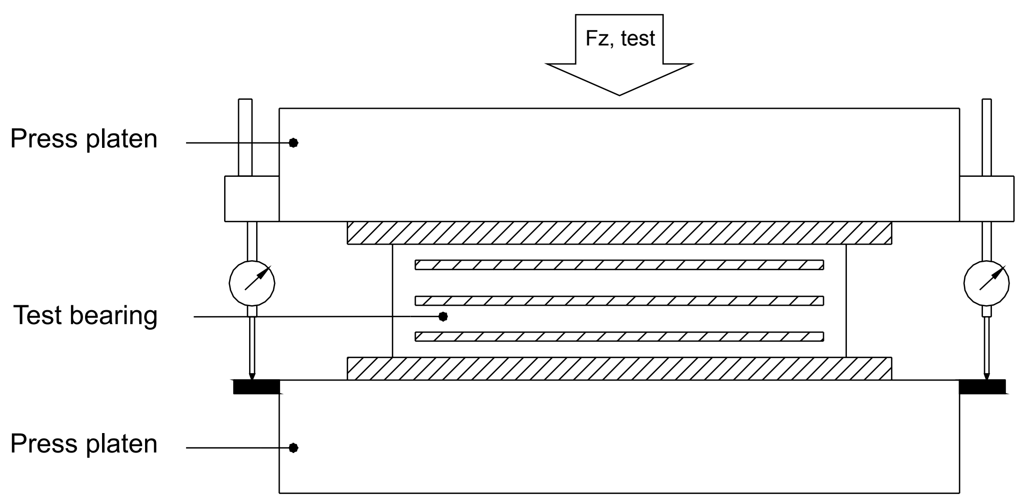
C.3.2 *Test Piece*

One test bearing.

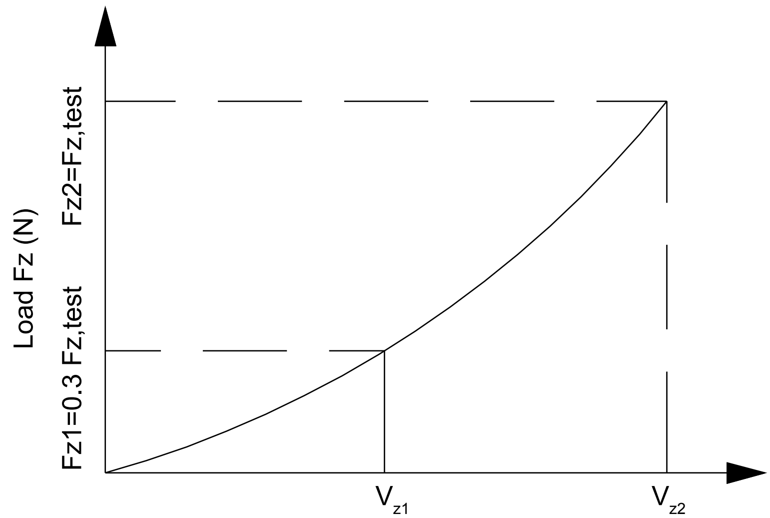
C.3.3 **Test Procedure**

C.3.3.1 *Test assembly*

As shown in **Fig. 3 (a)**



(a) Test Assembly



$$E_a = (F_{z2} - F_{z1})/(V_{z2} - V_{z1})$$

b) Stress Strain Curve

Fig. 3 Determination of Compression Stiffness

C.3.3.2 Conditioning load

Bearing shall be preloaded up to $F_{z,test}$. The load shall be retained for 10 minutes and unloaded up to σ_m = 2 MPa before test loading.

C.3.3.3 Rate of loading

The axial load $F_{z,test}$ is increased gradually at a rate yielding approximately σ_m = *5 MPa* per minute.

C.3.3.4 Maximum test loading

Maximum test loading shall correspond to $F_{z,test} = \frac{5 \times G \times S \times A_1}{1.5}$

C.3.3.5 Measurement

Load and deflection measurements for complete bearing shall be made in approximately equal load intervals not less than 5. Deflection shall be measured at four edges and mean value accounted for.

C.3.4 *Evaluation*

C.3.4.1 A compressive load deformation curve shall be plotted and the value of apparent compression stiffness E_a shall be determined as shown in **Fig. 3 (b)**.

C.3.4.2 The test result shall be deemed satisfactory if the value of apparent compression stiffness determined from the deflection between 30 percent and 100 percent of the test load is within ± 20 percent of the value specified by the manufacturer and no discernible defect is found by visual examination. The manufacturer should specify the value along with the submittal for acceptance testing programme.

C.4 Test for Determination of Shear Bond

C.4.1 *Scope*

This test shall determine whether requisite adhesion exists between the elastomer and steel laminates.

C.4.2 *Test Piece*

Two identical bearing selected at random from the lot as test bearing or on prototype bearings produced in identical condition:

C.4.3 Test Procedure

C.4.3.1 *Test assembly*

As shown in **Fig. 4**.

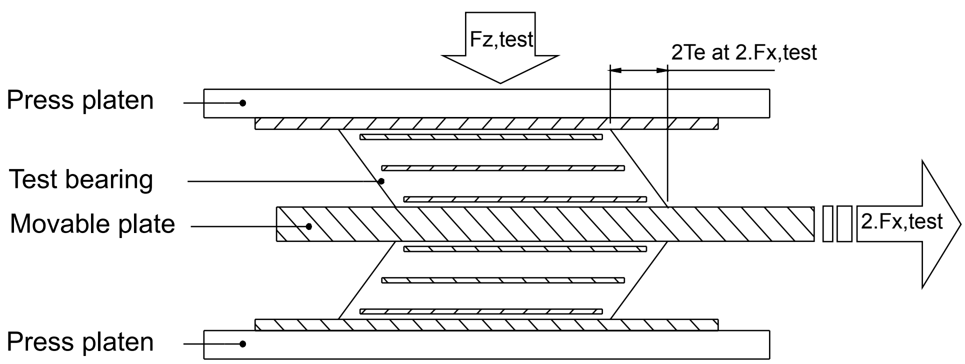


Fig. 4 Determination of Adhesion Strength

C.4.3.2 Maximum test loading: $F_{z,test}$ Corresponding to σ_m = 12 *MPa* is to be held constant during the test. If necessary the compressive load shall be increased to prevent slippage but it should not exceed the maximum test loading as given in Clause C.3.3.4

Horizontal loading shall be gradually increased to yield a shear stress rate of approximately 0.05 to 0.5 *MPa* per minute.

C.4.3.3 The horizontal loading $2F_x$ shall be increased gradually up to a maximum $2F_{xtest}$ which corresponds to horizontal deflection equal to $2T_e$ (i.e., 58 mm for the specified size 200 mm x 300 mm x 41 mm). When the maximum deflection is reached (shear strain = 2) the deflection shall be maintained for 5 min in order to allow flaws to develop.

C.4.3.4 Measurement

Load and deflection measurements shall be made at approximately equal intervals not less than 5

C.4.4 *Evaluation*

C.4.4.1 Examine the test bearing for evidence of cracking or peeling both in the strained and unstrained state. After removal of the shear force the bearing should be examined visually, whilst still under the compressive load, and any bulges which could indicate bond failure should be noted. It may be necessary to cut the edge cover to confirm the presence of flaws arising from bond failure.

C.4.4.2 If neither of the test bearings shows evidence of peeling or separation at or near the interface between rubber and reinforcement layers and there is no sign of bond failure the test shall be deemed to be satisfactory.

ANNEXURE D

D.1 Considerations for Seismic Resistance

D.1.1 Elastomeric bearings considered in this Part are Low damping elastomeric bearings with an equivalent viscous damping ratio ξ less than 0.06. Such bearings have a cyclic behaviour similar to hysteretic behaviour with very slender hysteresis loops. Their behaviour should be approximated by that of a linear elastic member with equivalent elastic stiffness in the horizontal direction equal to $G \times A/T_q$ where G is the shear modulus of the elastomer, A its effective horizontal area and T_q is the total thickness of the elastomer.

D.1.2 The seismic behaviour of bridges, in which the design seismic action is resisted entirely by elastomeric bearings on all supports, is governed by the large flexibility of the bearings and shall be analysed as seismic isolation system. The elastomeric bearings may be considered as linear elastic members between the substructure and superstructure, deforming in shear (and also in compression) enhancing flexibility and thereby natural period of the system. Their damping may be assumed equal to the global viscous damping of the structure. The deformation of bridges supported exclusively by normal elastomeric bearings is predominantly elastic and does not lead in general to ductile behavior. In this case the seismic response of substructure and Superstructure shall remain essentially elastic and therefore response reduction factor (R) for design shall be considered as ‘1’.

D.1.3 Simple low-damping elastomeric bearings covered in this part may be used as isolators, without being subjected to special tests for seismic performance.

D.1.4 The shear strain $\xi_{q,d}$ of the elastomer due to translatory movement, caused due to combination of all possible loads and effects that may coexist during earthquake, shall not exceed 1.00

D.1.5 In bridges with elastomeric bearings intended to resist seismic action, structural members which resist shear forces from the bearings shall be designed on the basis of the maximum deformation of the bearings corresponding to the design displacement of the deck and a bearing stiffness increased by 30%.

D.1.6 Elastomeric bearings used as isolators for application in seismic Zone IV and Zone V shall be secured in position by means of positive anchorage.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)