INTERNATIONAL STANDARD

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Elastomeric seismic-protection isolators —

Part 3:

Applications for buildings — Specifications

Appareils d'appuis structuraux en élastomère pour protection sismique —

Partie 3: Applications pour bâtiments — Spécifications

Reference number
ISO 22762-3:2010(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 22762-3 was prepared by Technical Committee ISO/TC 45, *Rubber and rubber products*, Subcommittee SC 4, *Products (other than hoses)*.

This second edition cancels and replaces the first edition (ISO 22762-3:2005), which has been technically revised. It also incorporates the Technical Corrigendum ISO 22762-3:2005/Cor.1:2006.

ISO 22762 consists of the following parts, under the general title *Elastomeric seismic-protection isolators*:

— *Part 1: Test methods*

— *Part 2: Applications for bridges — Specifications*

— *Part 3: Applications for buildings — Specifications*

Introduction

ISO 22762 (all parts) consists of two parts related to specifications for isolators, i.e. ISO 22762-2 for bridges and ISO 22762-3 for buildings. This is because the isolator requirements for bridges and buildings are quite different, although the basic concept of the two products is similar. Therefore, ISO 22762-2 and the relevant clauses in ISO 22762-1 are used when ISO 22762 (all parts) is applied to the design of bridge isolators whereas this part of ISO 22762 and the relevant clauses of ISO 22762-1 are used when it is applied to building isolators.

The main differences to be noted between isolators for bridges and isolators for buildings are the following.

a) Isolators for bridges are mainly rectangular in shape and those for buildings are circular in shape.

b) Isolators for bridges are designed to be used for both rotation and horizontal displacement, while isolators for buildings are designed for horizontal displacement only.

c) Isolators for bridges are designed to perform on a daily basis to accommodate length changes of bridges caused by temperature changes as well as during earthquakes, while isolators for buildings are designed to perform only during earthquakes.

d) Isolators for bridges are designed to withstand dynamic loads caused by vehicles on a daily basis as well as earthquakes, while isolators for buildings are mainly designed to withstand dynamic loads caused by earthquakes only.

For structures other than buildings and bridges (e.g. tanks), the structural engineer uses either ISO 22762-2 or ISO 22762-3, depending on the requirements of the structure.

INTERNATIONAL STANDARD **ISO 22762-3:2010(E)**

Elastomeric seismic-protection isolators —

Part 3:

Applications for buildings — Specifications

1 Scope

This part of ISO 22762 specifies minimum requirements and test methods for elastomeric seismic isolators used for buildings and the rubber material used in the manufacture of such isolators.

It is applicable to elastomeric seismic isolators used to provide buildings with protection from earthquake damage. The isolators covered consist of alternate elastomeric layers and reinforcing steel plates. They are placed between a superstructure and its substructure to provide both flexibility for decoupling structural systems from ground motion, and damping capability to reduce displacement at the isolation interface and the transmission of energy from the ground into the structure at the isolation frequency.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 630, *Structural steels — Plates, wide flats, bars, sections and profiles*

ISO 1052, *Steels for general engineering purposes*

ISO 22762-1:2010, *Elastomeric seismic-protection isolators — Part 1: Test methods*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
breaking
rupture of elastomeric isolator due to compression (or tension)-shear loading

3.2
buckling
state when elastomeric isolators lose their stability under compression-shear loading

3.3
compressive properties of elastomeric isolator
K_V
compressive stiffness for all types of rubber bearings

3.4

compression-shear testing machine

machine used to test elastomeric isolators, which has the capability of shear loading under constant compressive load

3.5

cover rubber

rubber wrapped around the outside of inner rubber and reinforcing steel plates before or after curing of elastomeric isolators for the purposes of protecting the inner rubber from deterioration due to oxygen, ozone and other natural elements and protecting the reinforcing plates from corrosion

3.6

design compressive stress

long-term compressive force on the elastomeric isolator imposed by the structure

3.7

effective loaded area

area sustaining vertical load in elastomeric isolators, which corresponds to the area of reinforcing steel plates

3.8

effective width

⟨rectangular elastomeric isolator⟩ the smaller of the two side lengths of inner rubber to which direction shear displacement is not restricted

3.9

elastomeric isolator

rubber bearing, for seismic isolation of buildings, bridges and other structures, which consists of multi-layered vulcanized rubber sheets and reinforcing steel plates

EXAMPLE High-damping rubber bearings, linear natural rubber bearings and lead rubber bearings.

3.10

first shape factor

ratio of effectively loaded area to free deformation area of one inner rubber layer between steel plates

3.11

high-damping rubber bearing

HDR

elastomeric isolator with relatively high damping properties obtained by special compounding of the rubber and the use of additives

3.12

inner rubber

rubber between multi-layered steel plates inside an elastomeric isolator

3.13

lead rubber bearing

LRB

elastomeric isolator whose inner rubber with a lead plug or lead plugs press fitted into a hole or holes of the isolator body to achieve damping properties

3.14

linear natural rubber bearing

LNR

elastomeric isolator with linear shear force-deflection characteristics and relatively low damping properties, fabricated using natural rubber

NOTE Any bearing with relatively low damping can be treated as an LNR bearing for the purposes of isolator testing.

3.15
maximum compressive stress
peak stress acting briefly on elastomeric isolators in compressive direction during an earthquake

3.16
nominal compressive stress
long-term stress acting on elastomeric isolators in compressive direction as recommended by the manufacturer for the isolator, including the safety margin

3.17
roll-out
instability of an isolator with either dowelled or recessed connection under shear displacement

3.18
routine test
test for quality control of the production isolators during and after manufacturing

3.19
second shape factor
⟨circular elastomeric isolator⟩ ratio of the diameter of the inner rubber to the total thickness of the inner rubber

3.20
second shape factor
⟨rectangular or square elastomeric isolator⟩ ratio of the effective width of the inner rubber to the total thickness of the inner rubber

3.21
shear properties of elastomeric isolators
comprehensive term that covers characteristics determined from isolator tests:

- shear stiffness, K_{h}, for LNR;
- shear stiffness, K_{h}, and equivalent damping ratio, h_{eq}, for HDR and LRB;
- post-yield stiffness, K_{d}, and characteristic strength, Q_{d}, for LRB

3.22
structural engineer
engineer who is in charge of designing the structure for base-isolated bridges or buildings and is responsible for specifying the requirements for elastomeric isolators

3.23
type test
test for verification either of material properties and isolator performances during development of the product or that project design parameters are achieved

3.24
ultimate properties
properties at either buckling, breaking, or roll-out of an isolator under compression-shear loading

3.25
ultimate property diagram
UPD
diagram giving the interaction curve of compressive stress and buckling strain or breaking strain of an elastomeric isolator

4 Symbols

For the purposes of this document, the symbols given in Table 1 apply.

Table 1 — Symbols and descriptions

Symbol	Description
A	effective plan area; plan area of elastomeric isolator, excluding cover rubber portion
A_b	effective area of bolt
A_e	overlap area between the top and bottom elastomer area of isolator
A_free	load-free area of isolator
A_load	loaded area of isolator
A_p	area of the lead plug for a lead rubber bearing
a	side length of square elastomeric isolator, excluding cover rubber thickness, or length in longitudinal direction of rectangular isolator, excluding cover rubber thickness
a_e	length of the shorter side of the rectangular isolator, including cover rubber thickness
a'	length in longitudinal direction of the rectangular isolator, including cover rubber thickness
B	effective width for bending of flange
b	length in transverse direction of the rectangular isolator, excluding cover rubber thickness
b'	length in transverse direction of the rectangular isolator, including cover rubber thickness
c	distance from centre of bolt hole to effective flange section
D'	outer diameter of circular isolator, including cover rubber
D_f	diameter of flange
d_i	inner diameter of reinforcing steel plate
d_k	diameter of bolt hole
d_0	outer diameter of reinforcing steel plate
E_ap	apparent Young's modulus of bonded rubber layer
E_c	apparent Young's modulus corrected, if necessary, by allowing for compressibility
E_c^s	apparent Young’s modulus corrected for bulk compressibility depending on its shape factor (S_1)
E_∞	bulk modulus of rubber
E_0	Young's modulus of rubber
F_u	tensile force on isolator by uplift
G	shear modulus
$G_\mathrm{eq}(\gamma)$	equivalent linear shear modulus at shear strain
H	height of elastomeric isolator, including mounting flange
H_n	height of elastomeric isolator, excluding mounting flange
h_eq	equivalent damping ratio
$h_\mathrm{eq}(\gamma)$	equivalent damping ratio as a function of shear strain

Table 1 (*continued*)

Symbol	Description
K_d	post-yield stiffness (tangential stiffness after yielding of lead plug) of lead rubber bearing
K_h	shear stiffness
K_i	initial shear stiffness
K_p	shear stiffness of lead plug inserted in lead rubber bearing
K_r	shear stiffness of lead rubber bearing before inserting lead plug
K_t	tangential shear stiffness
K_v	compressive stiffness
L_f	length of one side of a rectangular flange
M	resistance to rotation
M_f	moment acting on bolt
M_r	moment acting on isolator
n	number of rubber layers
n_b	number of fixing bolts
P	compressive force
P_0	design compressive force
P_max	maximum compressive force
P_min	minimum compressive force
P_Tb	tensile force at break of isolator
Q	shear force
Q_b	shear force at break
Q_buk	shear force at buckling
Q_d	characteristic strength
S_1	first shape factor
S_2	second shape factor
T	temperature
T_0	standard temperature, 23 °C or 27 °C; where specified tolerance is ± 2 °C, T_0 is standard laboratory temperature
T_r	total rubber thickness, given by $T_\mathrm{r} = n \times t_\mathrm{r}$
t_r	thickness of one rubber layer
t_r1, t_r2	thickness of rubber layer laminated on each side of plate
t_s	thickness of one reinforcing steel plate
t_0	thickness of outside cover rubber
$U(\gamma)$	function giving ratio of characteristic strength to maximum shear force of a loop
V	uplift force

Table 1 (*continued*)

Symbol	Description
v	loading velocity
W_d	energy dissipated per cycle
X	shear displacement
X_0	design shear displacement
X_b	shear displacement at break
X_buk	shear displacement at buckling
X_s	shear displacement due to quasi-static shear movement
X_max	maximum shear displacement
X_d	shear displacement due to dynamic shear movement
Y	compressive displacement
Z	section modulus of flange
α	coefficient of linear thermal expansion
γ	shear strain
γ_0	design shear strain
γ_a	upper limit of the total of design strains on elastomeric isolators
γ_b	shear strain at break
γ_c	local shear strain due to compressive force
γ_d	shear strain due to dynamic shear movement
γ_max	maximum design shear strain during earthquake
γ_r	local shear strain due to rotation
γ_s	shear strain due to quasi-static shear movement
γ_u	ultimate shear strain
δ_H	horizontal offset of isolator
δ_v	difference in isolator height measured between two points at opposite extremes of the isolator
ε	compressive strain of rubber
ε_cr	creep strain
ε_T	tensile strain of isolator
ε_Tb	tensile-break strain of isolator
ε_Ty	tensile-yield strain of isolator
ζ	ratio of total height of rubber and steel layers to total rubber height
θ	rotation angle of isolator about the diameter of a circular bearing or about an axis through a rectangular bearing
θ_a	rotation angle of isolator in the longitudinal direction (a)
θ_b	rotation angle of isolator in the transverse direction (b)

Table 1 (*continued*)

Symbol	Description
λ	correction factor for calculation of stress in reinforcing steel plates
η	correction factor for calculation of critical stress
κ	correction factor for apparent Young's modulus according to hardness
$\Sigma\gamma$	total local shear strain
ρ_R	safety factor for roll-out
ρ_T	safety factor for tensile force
σ	compressive stress in isolator
σ_0	design compressive stress
σ_B	tensile stress in bolt
σ_b	bending stress in flange
σ_{bf}	allowable bending stress in steel
σ_{cr}	critical stress in isolator
σ_f	allowable tensile stress in steel
σ_{max}	maximum compressive stress
σ_{min}	minimum compressive stress
σ_{nom}	for building: nominal long-term compressive stress recommended by manufacturer
σ_s	tensile stress in reinforcing steel plate
σ_{sa}	allowable tensile stress in steel plate
σ_{sy}	yield stress of steel for flanges and reinforcing steel plates
σ_{su}	tensile strength of steel for flanges and reinforcing steel plates
σ_t	tensile stress
σ_{te}	allowable tensile stress in isolator
τ_B	shear stress in bolt
τ_f	allowable shear stress in steel
ϕ	factor for computation of buckling stability
ξ	factor for computation of critical stress

5 Classification

5.1 General

Elastomeric isolators are classified by construction, their ultimate properties and tolerances on their performance.

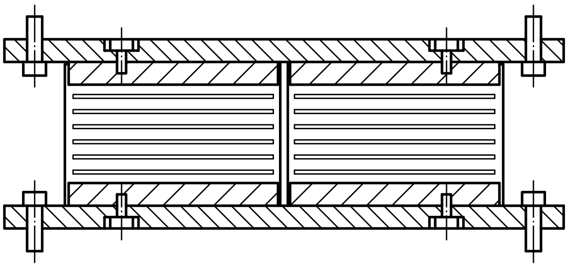
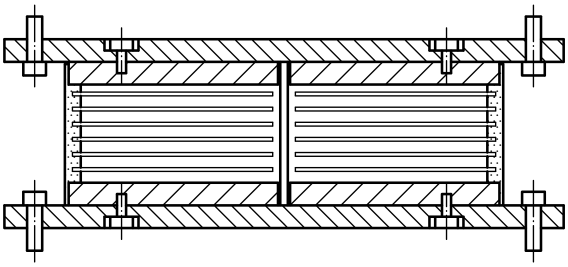
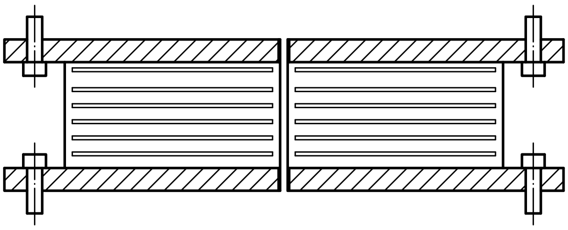
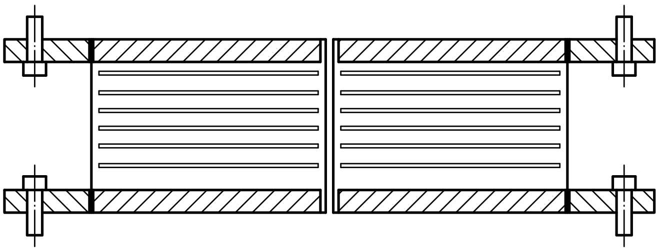
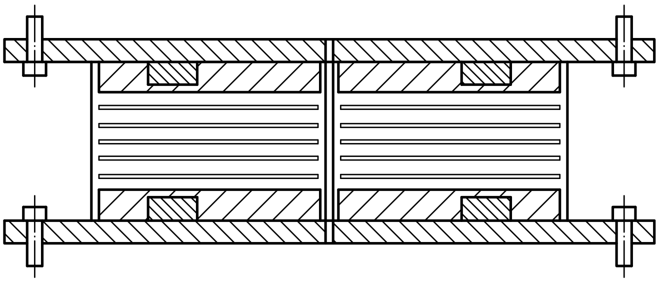
5.2 Classification by construction

Elastomeric isolators are classified by construction, as shown in Table 2.

Other methods not listed in Table 2 may be used to fix flanges to the laminated rubber, if the resulting construction has adequate strength to resist the shear forces and bending moments due to shear deflection.

Furthermore, such constructions shall be capable of resisting tension if the elastomeric isolator is designed for uplift.

Table 2 — Classification by construction

Type	Construction	Illustration
Type I	Mounting flanges are bolted to connecting flanges, which are bonded to the laminated rubber. Cover rubber is added before curing of isolator.	
	Mounting flanges are bolted to connecting flanges, which are bonded to the laminated rubber. Cover rubber is added after curing of isolator.	
Type II	Mounting flanges are directly bonded to the laminated rubber.	
Type III	Isolators without mounting flanges, connected to base by either recess rings or dowell pins.	 **Recess connection**
		 **Dowell connection**

5.3 Classification by tolerance on shear properties

Elastomeric isolators are classified by tolerance on shear properties, as shown in Table 3.

Table 3 — Classification by tolerance of shear properties

Class	Individual	Global
S-A	± 15 %	± 10 %
S-B	± 25 %	± 20 %

6 Requirements

6.1 General

Elastomeric isolators for buildings and the materials used in manufacture shall meet the requirements specified in this clause. For test items (see Table 4) that have no specific required values, the manufacturer shall define the values and inform the purchaser prior to production.

The standard temperature for determining the properties of elastomeric isolators is 23 °C or 27 °C in accordance with prevailing International Standards. However, it is advisable to establish a range of working temperatures taking into consideration actual environmental temperatures and possible changes in temperatures at the work site where the elastomeric isolators are installed.

Table 4 — Test pieces for type testing

Properties	Test item	Test piece
Compressive properties	Compressive stiffness	Full-scale only
Shear properties	Shear stiffness Equivalent damping ratio Post-yield stiffness (for LRB) Characteristic strength (for LRB)	Full-scale only
Tensile properties	Tensile fracture strength Tensile yield strength	Scale B
Dependency of shear properties	Shear strain dependency	Full-scale only
	Compressive stress dependency	Full-scale only
	Frequency dependency	Scale A, STD, SBS
	Repeated loading dependency	Scale B
	Temperature dependency	Scale A, STD, SBS
Dependency of compressive properties	Shear strain dependency	Scale B
	Compressive stress dependency	
Ultimate properties	Shear displacement capacity	Scale B
Durability	Ageing	Scale A, STD, SBS
	Creep	Scale A

Scale A: Scaling such that, for a circular bearing, diameter ⩾ 150 mm, for a rectangular bearing, side length ⩾ 100 mm and, for both types, rubber layer thickness ⩾ 1,5 mm and thickness of reinforcing steel plates ⩾ 0,5 mm.

Scale B: Scaling such that, for a circular bearing, diameter ⩾ 500 mm, for a rectangular bearing, side length ⩾ 500 mm and, for both types, rubber layer thickness ⩾ 1,5 mm and thickness of reinforcing steel plates ⩾ 0,5 mm. Minimum scale factor 0,5.

STD = standard test piece (see Tables 10 and 11 of ISO 22762-1:2010).

SBS = shear-block test piece specified in ISO 22762-1:2010, 5.8.3. With LRB, SBS shall only be used for ageing tests.

Some of these properties may be determined using one of the standard test pieces detailed in Tables 10 and 11 in ISO 22762-1:2010. The standard test pieces are used for non-specific product tests, such as testing in the development of new materials and products.

6.2 Type tests and routine tests

6.2.1 Testing to be carried out on elastomeric isolators is classified into “type tests” and “routine tests”.

6.2.2 Type tests shall be conducted either to ensure that project design parameters have been achieved (in which case the test results shall be submitted to the structural engineer for review prior to production) or to verify isolator performance and material properties during development of the product. The test piece for each type test shall be full-scale or one of the options specified in Table 4. The test piece shall not have been subjected to any previous test programme. The tests shall be performed on test pieces not subjected to any scragging, unless the production isolators are to be supplied after scragging. In that case, the test pieces shall be subjected to the same scragging procedure as the production isolators.

6.2.3 Previous type test results may be substituted, provided the following conditions are met.

a) Isolators are fabricated in a similar manner and from the same compound and adhesive.

b) All corresponding external and internal dimensions are within 10 % of each other. Flange plates are excluded.

c) First and second shape factors are equal to or larger than those in previous tests.

d) The test conditions, such as maximum and minimum vertical load applied in the ultimate property test (see 6.5.7), are more severe.

Routine tests are carried out during production for quality control. Sampling is allowed for routine testing for projects with agreement between structural engineer and manufacturer. Sampling shall be conducted randomly and cover not less than 20 % of the production of any isolator design. For a given project, tests shall cover not less than four test pieces for each size and not less than 20 test pieces in total.

If isolators are supplied after scragging, the routine test shall be performed on scragged isolators.

6.3 Functional requirements

Elastomeric isolators for buildings are designed and manufactured to have the performance characteristics required so that they deform in all directions with the proper stiffness (with damping, if required) during an earthquake.

In the application of elastomeric isolators, attention shall be paid to the following points.

a) The isolators shall be installed horizontally between the structure and foundation.

b) Once installed, the isolators shall not be subjected to a constant shear force.

c) When isolators are to be installed under relatively flexible columns, the rotation at the top of the isolator caused by bending deformation shall be carefully considered.

d) Exposed steel surfaces, such as the surfaces of mounting flanges, shall be properly painted or galvanized to prevent rusting.

e) Proper maintenance shall be carried out on installed isolators to prevent any abnormalities such as distortion, cracks or rust occurring.

f) Fire protection of the isolators may be required.

g) The seismic gap shall be maintained at all times.

6.4 Design compressive force and design shear displacement

6.4.1 The design stress and strain of an isolator are defined by the following relationships with the design force and the displacement.

$$\sigma_0 = \frac{P_0}{A}, \sigma_{\text{max}} = \frac{P_{\text{max}}}{A}, \sigma_{\text{min}} = \frac{P_{\text{min}}}{A}$$

$$\gamma_0 = \frac{X_0}{T_{\text{r}}}, \gamma_{\text{max}} = \frac{X_{\text{max}}}{T_{\text{r}}}$$

6.4.2 The design compressive forces, P_0, and maximum and minimum compressive forces, respectively P_{max} and P_{min}, and the design shear displacements X_0 and the maximum shear displacement X_{max} for an isolator shall be provided by the structural engineer. If the P_0, P_{max}, P_{min}, X_0 and X_{max} are not known at the time of type testing, the design stress and design strain to be used for testing can be determined as follows.

$$\sigma_0 = \sigma_{\text{nom}}, \sigma_{\text{max}} = 2\sigma_{\text{nom}}$$

where

σ_{nom}, σ_{min}, γ_0 and γ_{max} are determined by the manufacturer.

6.5 Performance requirements

6.5.1 General

The isolators shall be tested and the results recorded using the specified test methods. They shall satisfy all of the requirements listed below. The design value for each isolator shall be specified prior to the tests. The test items are summarized in Table 5, which indicates those type tests that are optional, where a material test piece may substitute an isolator, and the tests to be performed as routine tests. Double-shear configuration testing (see ISO 22762-1:2010, 6.2.2.2) can be employed with the approval of the structural engineer.

6.5.2 Compressive properties

6.5.2.1 General requirements

The compressive stiffness, K_{v}, shall be within ± 30 % of the design value.

6.5.2.2 Test piece

The test piece shall be a full-scale isolator for the type test and a production isolator for the routine test.

6.5.2.3 Test condition

As specified in ISO 22762-1:2010, 6.2.1.5.2, method 2, cyclic loading with the design compressive stress $\sigma_0 \pm 30\ \%$ shall be carried out for three cycles.

The compressive stiffness, K_{v}, shall be computed from the third cycle.

The standard test temperature, T_0, is 23 °C or 27 °C. If the test is carried out at a different temperature, the result shall be corrected to the value of the property at T_0 by an appropriate method.

Table 5 — Tests on isolators

Property	Test item	Test method	Routine test	Type test
Compressive properties	Compressive stiffness	ISO 22762-1:2010, 6.2.1, method 2	X	X
Shear properties	Shear stiffness Equivalent damping ratio Post-yield stiffness (for LRB) Characteristic strength (for LRB)	ISO 22762-1:2010, 6.2.2	X	X
Tensile properties	Tensile fracture strength Tensile yield strength	ISO 22762-1:2010, 6.5	N/A	Opt.
Dependency of shear properties	Shear strain dependency	ISO 22762-1:2010, 6.3.1	N/A	X
	Compressive stress dependency	ISO 22762-1:2010, 6.3.2	N/A	X
	Frequency dependency	ISO 22762-1:2010, 6.3.3	N/A	X(m)
	Repeated loading dependency	ISO 22762-1:2010, 6.3.4	N/A	X
	Temperature dependency	ISO 22762-1:2010, 6.3.5 (m) ISO 22762-1:2010, 5.8	N/A	X(m)
Dependency of compressive properties	Shear strain dependency	ISO 22762-1:2010, 6.3.6	N/A	Opt.
	Compressive stress dependency	ISO 22762-1:2010, 6.3.7	N/A	Opt.
Shear displacement capacity	Breaking strain, buckling strain Roll-out strain	ISO 22762-1:2010, 6.4	N/A	X
Durability	Property change	ISO 22762-1:2010, 6.6.1	N/A	X(m)
	Creep	ISO 22762-1:2010, 6.6.2	N/A	X
X = test to be conducted with isolators; X(m) = test can be conducted either with isolators or with shear-block test pieces. N/A = not applicable; Opt. = optional.				

6.5.3 Shear properties

6.5.3.1 General requirements

The following properties shall be within the specified range of design value corresponding to the adopted tolerance class specified in 5.3.

The test items specified for each type of isolator are shown in Table 6. The properties measured for LRB may be selected from either L-1 or L-2, as given in Table 6 below.

Table 6 — Shear property test items

Isolator type	Test item	
LNR	Shear stiffness, K_h	
HDR	Shear stiffness, K_h, equivalent damping ratio, h_{eq}	
LRB	L-1	Shear stiffness K_h, equivalent damping ratio h_{eq}
	L-2	Post-yield stiffness K_d, characteristic strength Q_d

6.5.3.2 Test piece

The test piece shall be a full-scale isolator for the type test and a production isolator for the routine test.

6.5.3.3 Test conditions

6.5.3.3.1 The test piece shall be loaded with the design compressive stress, σ_0.

6.5.3.3.2 The cyclic loading of the design shear strain, γ_0, or of the shear strain which corresponds to $\gamma = 100$ % shall be carried out for three cycles.

6.5.3.3.3 The required properties shall be computed from the third cycle.

If the test is performed at a frequency different from the design isolation frequency, the result shall be corrected to the design frequency or to 0,5 Hz by an appropriate method.

The standard test temperature is 23 °C or 27 °C. If the test is carried out at a different temperature, the result shall be corrected to the value of the property at T_0 by an appropriate method.

6.5.4 Tensile properties

6.5.4.1 General requirements

The tensile properties shall be within the specified range.

6.5.4.2 Test piece

The test piece shall be a full-scale isolator or a scale model, as specified in Table 4.

6.5.4.3 Test conditions

The test conditions shall be as specified in 6.5 of ISO 22762-1:2010.

6.5.5 Dependencies of shear properties

6.5.5.1 Shear strain dependency

6.5.5.1.1 General requirements

The change in each property over the range of test shear strains with respect to the value of the property at the design shear strain, γ_0 (or another reference strain, if employed in the shear property test in 6.5.3), shall be within the specified range.

6.5.5.1.2 Test piece

The test piece shall be a full-scale isolator.

6.5.5.1.3 Test conditions

The shear properties shall be determined at strains between 50 % and the maximum shear strain, γ_{max}, at strain intervals of 50 %; the interval between the last two test strains shall be at least 50 %. The change in the property, normalized using the value corresponding to the design strain, shall be determined. Tests can also be performed at 10 % and 20 % shear strain.

6.5.5.2 Compressive stress dependency

6.5.5.2.1 General requirements

As the compressive stress varies, the change in the shear properties with respect to the value of the property at the design stress, σ_0, shall be within the specified range.

6.5.5.2.2 Test piece

The test piece shall be a full-scale isolator.

6.5.5.2.3 Test conditions

The shear strain amplitude shall be γ_0.

The shear properties shall be determined at 0, $0{,}5\sigma_0$, $1{,}0\sigma_0$, $1{,}5\sigma_0$, $2{,}0\sigma_0$ and the maximum tensile stress, if applicable, and the change in the property, normalized using the value corresponding to the design strain, shall be determined.

6.5.5.3 Frequency dependency

6.5.5.3.1 General requirements

The frequency dependency shall be within the specified range.

6.5.5.3.2 Test piece

The test piece shall be a full-scale isolator, a scale model, a standard test piece or a shear-block test piece, as specified in Table 4.

6.5.5.3.3 Test conditions

The shear strain amplitude shall be γ_0.

Other test conditions shall be as specified in 6.3.3 of ISO 22762-1:2010.

6.5.5.4 Repeated loading dependency

6.5.5.4.1 General requirements

The repeated loading dependency shall be within the specified range.

6.5.5.4.2 Test piece

The test piece shall be a full-scale isolator or a scale model, as specified in Table 4.

6.5.5.4.3 Test conditions

The shear strain amplitude shall be γ_0.

Other test conditions shall be as specified in 6.3.4 of ISO 22762-1:2010.

6.5.5.5 Temperature dependency

6.5.5.5.1 General requirements

The temperature dependency shall be within the specified range.

6.5.5.5.2 Test piece

The test piece shall be a full-scale isolator, a scale model, a standard test piece, or a shear-block test piece, as specified in Table 4.

6.5.5.5.3 Test conditions

The shear strain amplitude shall be γ_0.

Other test conditions shall be as specified in 6.3.5 of ISO 22762-1:2010.

6.5.6 Dependencies of compressive properties

6.5.6.1 Shear strain dependency

6.5.6.1.1 General requirements

The shear strain dependency of the compressive properties shall be within the specified range.

6.5.6.1.2 Test piece

The test piece shall be a full-scale isolator or a scale model, as specified in Table 4.

6.5.6.1.3 Test conditions

The test conditions shall be as specified in 6.3.6 of ISO 22762-1:2010.

6.5.6.2 Compressive stress dependency

6.5.6.2.1 General requirements

The compressive stress dependency of the compressive properties shall be within the specified range.

6.5.6.2.2 Test piece

The test piece shall be a full-scale isolator or a scale model, as specified in Table 4.

6.5.6.2.3 Test conditions

The shear strain amplitude shall be γ_0.

Other test conditions shall be as specified in 6.3.7 of ISO 22762-1:2010.

6.5.7 Shear displacement capacity

6.5.7.1 General requirements

The isolator shall be loaded to the maximum shear displacement under both the maximum and the minimum axial loads. The isolator shall not suffer any failure, such as instability, breaking or roll-out during the test. The variation in axial load used depends on the isolator type (see 5.2) and shall be as specified in Table 7.

Table 7 — Axial stress for each isolator type

Isolator type	Axial stress used in test
Type I, Type II	Maximum stress σ_{max} Minimum stress σ_{min} (when in tension)
Type III	Maximum stress σ_{max} Minimum stress σ_{min}

6.5.7.2 Test piece

The test piece shall be a full-scale isolator or a scale model, as specified in Table 4.

6.5.7.3 Test conditions

The test conditions shall be as specified in 6.4 of ISO 22762-1:2010. For Type I and Type II isolators, a test at P_{min} can be carried out using the procedure given in 6.5 of ISO 22762-1:2010, the shear strain applied shall be γ_{max} and the isolator shall not fail at a load of less than P_{min}.

6.5.8 Durability

6.5.8.1 Change in properties on ageing

6.5.8.1.1 General requirements

The change on ageing in the shear properties, K_h, and, if required, h_{eq}, shall be within the specified range.

6.5.8.1.2 Test piece

The test piece shall be a full-scale isolator, a scale model, a standard test piece or a shear-block test piece, as specified in Table 4. If production isolators are to be supplied after scragging, the test pieces shall be subjected to the same scragging procedure as the production isolators, and the durability test carried out directly after scragging.

6.5.8.2 Creep

6.5.8.2.1 General requirements

The total creep strain [see ISO 22762-1:2010, 6.6.2.6 b) for definition] shall be less than 10 % after 60 years.

6.5.8.2.2 Test piece

The test piece shall be a full-scale isolator or a scale model, as specified in Table 4.

6.6 Rubber material requirements

6.6.1 General

The rubber materials used in the manufacture of elastomeric isolators shall be tested as required in Table 8. The test results shall be properly recorded to verify that the specified requirements are satisfied. Recommended minimum values for inner rubber material are given in Annex C. The frequency of each required test shall be determined in accordance with the manufacturer's quality control.

6.6.2 Tensile properties

The following are general requirements for testing tensile properties.

a) Tensile strength: not less than design value.

b) Elongation at break: not less than design value.

c) Other recommended minimum values are given in Annex C.

6.6.3 Properties after ageing in air

6.6.3.1 General requirements

The following are general requirements for testing tensile properties.

a) Change in tensile strength: within ± 25 %.

b) Change in elongation at break: maximum −50 %.

EXAMPLE Original 600 %, elongation at break after ageing shall not be less than 300 %.

Table 8 — Test items for rubber material

Property	Test items	Test method	Routine test		Type test	
			Inner rubber	Cover rubber	Inner rubber	Cover rubber
Tensile properties	Tensile strength	ISO 22762-1:2010, 5.3	X	X	X	X
	Elongation at break		X	X	X	X
	100 % modulus		Opt.	Opt	X	X
Air ageing properties	Tensile strength	ISO 22762-1:2010, 5.4	Opt.	Opt.	X	X
	Elongation at break		Opt.	Opt.	X	X
	100 % modulus		N/A	N/A	X	X
Hardness	Hardness	ISO 22762-1:2010, 5.5	Opt.	Opt.	Opt.	Opt.
Adhesion properties	90° peel strength	ISO 22762-1:2010, 5.6	Opt.	N/A	X	X
Shear properties	Shear modulus	ISO 22762-1:2010, 5.8	Opt.	N/A	X	N/A
	Damping ratio		Opt.	N/A	X	N/A
	Temperature dependency of shear modulus and damping ratio		N/A	N/A	Opt.	N/A
	Fracture strain Fracture stress	ISO 22762-1:2010, 5.9	N/A	N/A	Opt.	N/A
Brittleness point	Brittleness temperature	ISO 22762-1:2010, 5.10	N/A	N/A	Opt.	X[a]
Ozone resistance	Observation of cracks	ISO 22762-1:2010, 5.11	N/A	X	N/A	X
Low-temperature crystallization	Hardness	ISO 22762-1:2010, 5.12	N/A	N/A	X[b]	X[b]

X = test to be carried out; N/A = not applicable; Opt. = optional.

[a] Test is required for service temperatures below 0 °C.

[b] Test is required unless elastomer is not susceptible to crystallization in range of service temperatures (see ISO 22762-1:2010, 5.12).

6.6.3.2 Test conditions

6.6.3.2.1 The recommended conditions for natural rubber- and chloroprene-based isolators are

a) natural rubber: 70 °C for seven days, and

b) chloroprene rubber: 100 °C for 72 h.

6.6.3.2.2 Other conditions can be used by agreement between the structural engineer and the manufacturer. Test conditions and requirements for other elastomers shall be recommended by the manufacturer and agreed to by the structural engineer.

6.6.4 Hardness

6.6.4.1 The design value of IRHD shall be ± 5.

6.6.4.2 Hardness may be used as a quality control test and for other purposes when a relationship has been established with the appropriate shear modulus. Hardness should not be used for primary design purposes.

6.6.5 Ozone resistance

The following conditions shall be met when testing the ozone resistance of an elastomeric isolator.

a) Test conditions: 50 pphm (50 mPa), 20 % elongation, 40 °C for 96 h.

b) There shall be no cracks on cover rubber.

6.6.6 Other properties

Properties other than the ones listed above shall be determined by the test methods listed in Table 5. Each test result shall be within the tolerances specified prior to testing.

6.7 Dimensional requirements

Typical dimensions of elastomeric isolators are given in Table 9 as a guide for the design of elastomeric isolators. Sizes other than those given in Table 9 are permissible as long as the remaining requirements are satisfied.

Table 9 — Typical dimensions of elastomeric isolators

Dimensions a or d_0 mm	Thickness mm			Second shape factor S_2	Inner diameter d_i mm
	Rubber layer t_r		Steel plate t_s		
	min.	max.	min.	min.	max.
400	2,0	5,0	2,0	3,0	$\frac{d_0}{6}$
450	2,0	5,5		3,0	
500	2,5	6,0		3,0	
550	2,5	7,0		3,0	
600	3,0	7,5		3,0	
650	3,0	8,0		3,0	
700	3,5	9,0		3,0	
750	3,5	9,5	2,5	3,0	
800	4,0	10,0		3,0	
850	4,0	10,5		3,5	
900	4,5	11,0		3,5	
950	4,5	11,0		3,5	
1 000	4,5	11,0	3,0	3,5	$\frac{d_0}{5}$
1 050	5,0	11,0		3,5	
1 100	5,5	11,0		3,5	
1 150	5,5	12,0		3,5	
1 200	6,0	12,0		4,0	
1 250	6,0	13,0		4,0	
1 300	6,5	13,0	4,0	4,0	
1 350	6,5	14,0		4,0	
1 400	7,0	14,0		4,0	
1 450	7,0	15,0		4,0	
1 500	7,0	15,0		4,0	

NOTE 1 d_0, a, d_i are the dimensions of the reinforcing steel plate.

NOTE 2 The inside diameter of lead rubber bearings is $\leqslant \frac{d_0}{4}$, $\leqslant \frac{a}{4}$

NOTE 3 a is the side length of square elastomeric isolators.

NOTE 4 The stability of isolators is increased by making S_2 larger and the diameter of the inner hole smaller (see Annex E).

6.8 Requirements on steel used for flanges and reinforcing plates

Steel plates used for flanges, end and inner plates shall meet the strength requirements specified in Table 10.

ISO 630 or ISO 1052 or any other International Standard where yield strength and fracture strength are specified, may be used, as long as the steel specified satisfies the requirements given in Table 10 or is approved by the structural engineer.

Table 10 — Hot- and cold-rolled sheet and strip for flanges and reinforcing steel plates

Designation	**Yield stress** σ_{sy} N/mm^2			**Tensile strength** σ_{su} N/mm^2
	Thickness of steel plate t mm			
	$t \leqslant 16$	$16 < t \leqslant 40$	$40 < t$	
SS400	$\sigma_{sy} \geqslant 245$	$\sigma_{sy} \geqslant 235$	$\sigma_{sy} \geqslant 215$	$400 \leqslant \sigma_{su} \leqslant 510$
SM490A	$\sigma_{sy} \geqslant 325$	$\sigma_{sy} \geqslant 315$	$\sigma_{sy} \geqslant 295$	$490 \leqslant \sigma_{su} \leqslant 610$

7 Design rules

7.1 General

The elastomeric isolators shall be designed to meet the relevant provisions of this clause, in the serviceability limit state determined from the design compressive force, the restraint of wind force and the ultimate limit state caused by an earthquake.

In the serviceability limit state, the design shall be such that the isolators will not suffer damage that would affect their proper functioning, or incur excessive maintenance costs during their intended life.

In the ultimate limit state, the strength and stability of the isolators shall be adequate to withstand the ultimate design forces and movements of the structure.

7.2 Shape factor

7.2.1 First shape factor

7.2.1.1 The first shape factor, S_1, of a rubber layer is defined as the ratio of the effective loaded area, A_{load}, to the free surface area, A_{free}, as in Equation (1):

$$S_1 = \frac{A_{load}}{A_{free}} \tag{1}$$

a) For isolators without holes.

Circular isolators: $$S_1 = \frac{d_0}{4t_r} \tag{2}$$

Square isolators: $$S_1 = \frac{a}{4t_r} \tag{3}$$

b) For isolators with holes.

Circular isolators: $$S_1 = \frac{d_0 - d_i}{4t_r} \tag{4}$$

Square isolators: $$S_1 = \frac{4a^2 - \pi d_i^2}{4t_r\left(4a + \pi d_i\right)} \tag{5}$$

7.2.1.2 If the holes are adequately plugged with rubber or lead, the isolator can be treated as having no holes.

7.2.2 Second shape factor

The second shape factor, S_2, is defined as the ratio of the effective width to the total thickness of the inner rubber, as in a) and b) [Equations (6) and (7)] below.

a) For circular isolators, S_2 is expressed as Equation (6):

$$S_2 = \frac{d_0}{T_r} \tag{6}$$

b) For square isolators, S_2 is expressed as Equation (7):

$$S_2 = \frac{a}{T_r} \tag{7}$$

7.3 Compression and shear properties

7.3.1 Compressive stiffness

7.3.1.1 The compressive stiffness, K_v, is given by Equation (8):

$$K_v = \frac{E_c \times A}{T_r} \tag{8}$$

where

E_c is as given in Annex E.

7.3.1.2 The compressive displacement and compressive strain of an elastomeric isolator are given by Equations (9) and (10):

$$Y = \frac{P}{K_v} \tag{9}$$

$$\varepsilon_c = \frac{Y}{T_r} \tag{10}$$

7.3.2 Shear stiffness and equivalent damping ratio

7.3.2.1 The shear stiffness is given by Equation (11):

$$K_h = G\frac{A}{T_r} \tag{11}$$

7.3.2.2 When the shear strain dependency on shear modulus is considered, the shear stiffness is given by Equation (12):

$$K_h = G_{eq}(\gamma) \times \frac{A}{T_r} \tag{12}$$

where $G_{eq}(\gamma)$ is determined as indicated in Annex E.

7.3.2.3 The shear modulus $G_{\mathrm{eq}}(\gamma)$ for any γ shall be determined from the results of a cyclic dynamic-loading test, using either a full-scale or scale model isolator, under shear strain and under compressive stress, σ. If there is a significant difference between the compressive stress, σ, applied during the measurement of $G_{\mathrm{eq}}(\gamma)$ and the design stress, σ_0, $G_{\mathrm{eq}}(\gamma)$ shall be determined under design conditions, taking into account the effect of compressive stress. The following expression may be used to predict the stiffness under any compressive stress, σ, using $G_{\mathrm{eq}}(\gamma)$ determined from a shear-block test piece:

$$K_{\mathrm{h}} = G_{\mathrm{eq}}(\gamma)\left\{1-\left(\frac{\sigma}{\sigma_{\mathrm{cr}}}\right)^2\right\}\frac{A}{T_{\mathrm{r}}} \tag{13}$$

where

σ_{cr} is calculated using Equation (17).

7.3.2.4 The shear strain, γ, at a given displacement is calculated using Equation (14):

$$\gamma = \frac{X}{T_{\mathrm{r}}} \tag{14}$$

where

X is the horizontal displacement.

7.3.2.5 For LRB, K_{h} is related to K_{d} and Q_{d} as expressed in Equation (15):

$$K_{\mathrm{h}} = \frac{K_{\mathrm{d}} \times X + Q_{\mathrm{d}}}{X} \tag{15}$$

7.3.2.6 The energy dissipated per cycle, W_{d}, is measured from the loop, and the equivalent damping ratio, h_{eq}, is given by Equation (16):

$$h_{\mathrm{eq}} = \frac{1}{2\pi} \times \frac{W_{\mathrm{d}}}{K_{\mathrm{h}} \times X^2} \tag{16}$$

7.4 Ultimate properties

7.4.1 Stability at zero displacement

7.4.1.1 The critical stress, σ_{cr}, is defined as the compressive stress, at zero displacement, under which the isolator loses its stability. It is calculated using Equation (17):

$$\sigma_{\mathrm{cr}} = \frac{\pi}{4} \times \xi \times S_2 \sqrt{E_{\mathrm{b}} \times G} \tag{17}$$

where

E_{b} is the apparent Young's modulus for bending and is given by Equation (18):

$$\frac{1}{E_{\mathrm{b}}} = \frac{1}{E_0(1+\frac{2}{3}\kappa S_1{}^2)} + \frac{1}{E_\infty} \tag{18}$$

(see Table E.1 for values of κ);

G is the shear modulus at $\gamma = 100$ %;

ξ is a coefficient dependent on the cross-sectional shape of the isolator and is defined as:

$\xi = 1$ for circular sections;

$\xi = \dfrac{2}{\sqrt{3}}$ for square sections.

7.4.1.2 For lead rubber bearings, G represents the shear modulus of the rubber portion excluding the lead plug.

7.4.1.3 The isolator shall be designed with a safety factor ρ_c which meets the following requirement with respect to σ_cr and the design stress σ_0:

$$\sigma_0 \leqslant \frac{1}{\rho_\text{c}} \sigma_\text{cr} \tag{19}$$

where the safety factor, ρ_c, shall be provided by the structural engineer.

7.4.2 Stability and failure under large shear displacements

The relationship between compressive stress and shear strain in the ultimate state can be expressed, for an isolator, in the form of an ultimate property diagram (UPD) (see Annex B and Annex G).

7.4.3 Roll-out properties of isolators with recessed or dowelled connections (Type III)

7.4.3.1 The roll-out properties of isolators with either recessed or dowelled connections shall be checked.

7.4.3.2 The effect of a compressive force and a shear force on an isolator is shown in Figure 1. At roll-out, the following relationship applies (see Reference [1]):

$$P \times \left(d - X\right) = Q \times H \tag{20}$$

(for a circular isolator)

For a square isolator, d is replaced by a.

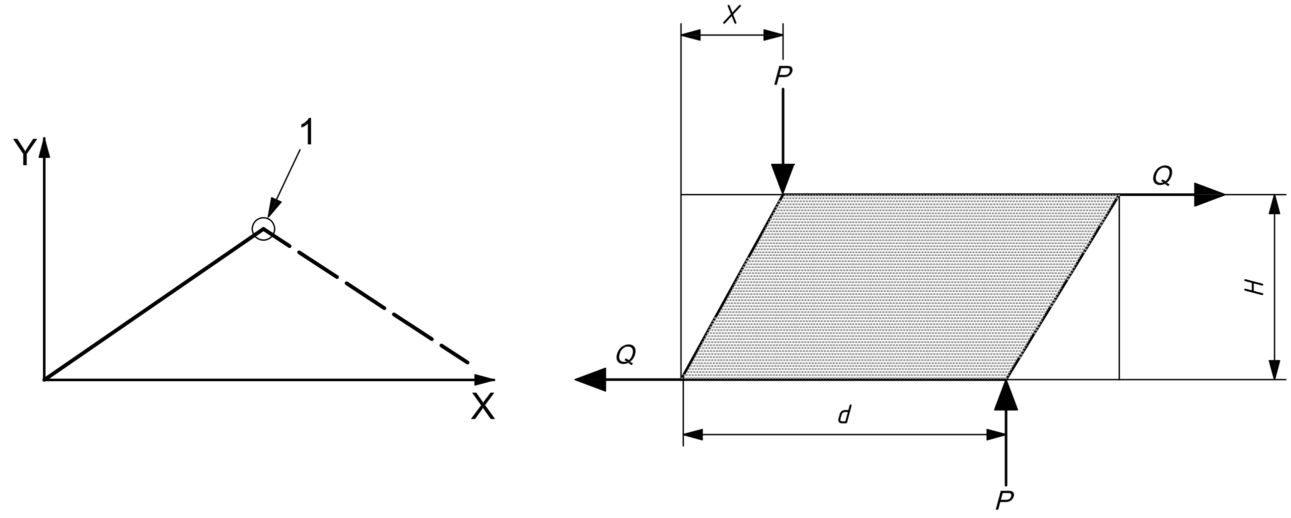
7.4.3.3 From the above relationship, an isolator with recessed or dowelled connections shall satisfy the following requirement with respect to minimum design compressive stress, σ_min, and maximum design strain, γ_max, including the safety factor, ρ_R:

$$\gamma_\text{max} \leqslant \frac{S_2 \times \sigma_\text{min}}{\zeta \times G + \sigma_\text{min}} \times \frac{1}{\rho_\text{R}} \tag{21}$$

where

$$\zeta = \frac{H}{T_\text{r}}$$

The safety factor, ρ_R, shall be provided by the structural engineer.



Key

X shear displacement

Y shear force

1 roll-out

Figure 1 — Roll-out properties of isolators with either recessed or dowelled connections

7.4.4 Tensile properties

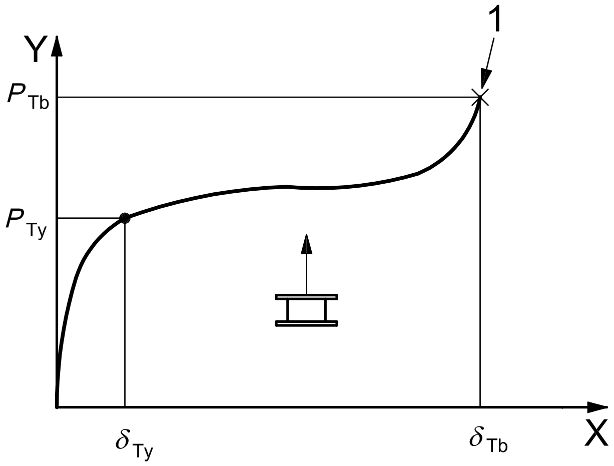
7.4.4.1 If the minimum force at maximum displacement, X_{max}, is an uplift force, F_{u}, shall satisfy the following requirement:

$$F_{\text{u}} \leqslant F_{\text{Ty}} \times \frac{1}{\rho_{\text{T}}} \tag{22}$$

where ρ_{T} is a safety factor which shall be provided by the structural engineer.

7.4.4.2 The typical relationship between tensile force and tensile displacement for isolators is shown in Figure 2.

7.4.4.3 The tensile force, P_{Ty}, of the design isolator, as indicated in Figure 2, shall be determined from the force-displacement curve, as specified in 6.5 of ISO 22762-1:2010.



Key

X tensile displacement

Y tensile force

1 breaking point

Figure 2 — Tensile properties of elastomeric isolators

7.4.4.4 If the stress and strain are calculated from the tensile force and tensile displacement, the values obtained only represent mean values of the non-uniformly distributed stress and strain, which are significantly affected by flange bending.

7.5 Reinforcing steel plates

The reinforcing steel plates in elastomeric isolators shall be designed to satisfy the following requirement:

$$\sigma_{\text{s}} = 2\lambda \times \frac{P \times t_{\text{r}}}{A \times t_{\text{s}}} \leqslant \sigma_{\text{sa}} \tag{23}$$

where λ is as given in Annex A, and σ_{sa} is specified by the structural engineer.

7.6 Connections

Connections, including fixing bolts and flanges, shall be designed for maximum and minimum compressive load and maximum shear displacement during an earthquake. The strength calculation shall be carried out by an appropriate method, such as that given in Annex H.

8 Manufacturing tolerances

8.1 General

Dimensional tolerances for elastomeric isolators for bridges shall be as specified below in this subclause.

Product dimensions shall be specified at a standard laboratory temperature of T_0 (= 23 or 27)°C ± 5 °C. Measurements made at a different temperature shall be corrected to a standard laboratory temperature. Dimensions shall be measured at least 24 h after curing of bearing. The cooling time shall be defined according to the product size and shall be based on measurement of the internal temperature of the product or another appropriate method.

Larger bearings may need more than 24 h after curing.

8.2 Measuring instruments

The following can be used as measuring instruments:

a) vernier calipers;

b) calipers;

c) height gauge;

d) limit gauge, to be calibrated with a gauge certified to match the upper and lower tolerance limits;

e) straight rule;

f) other instruments, such as a tape measure.

8.3 Plan dimensions

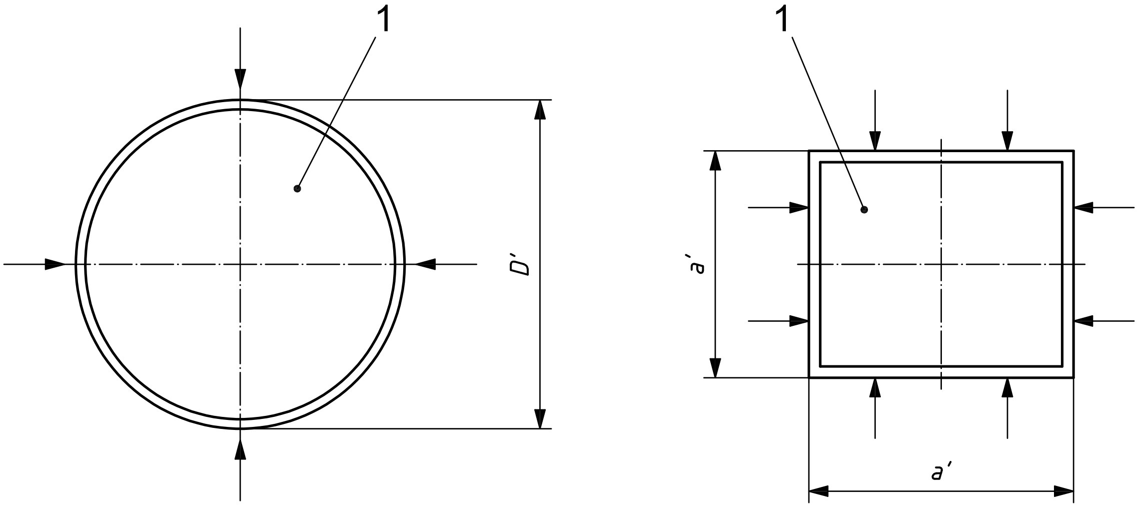
8.3.1 Measurement method

The measurement method to determine the plan dimensions of circular and rectangular isolators shall be as follows.

a) For circular isolators: the plan dimensions shall be determined by measuring the diameter at two different locations.

b) For rectangular isolators: the plan dimensions shall be measured at two positions on each side.

Examples of measurement points are as given in Figure 3 below.



Key

1 reinforcing steel plate

NOTE The measurement points are indicated by arrows.

Figure 3 — Example of plan dimension measurement positions

8.3.2 Tolerances

Tolerances on the diameter D' and side length a' are specified for Type I, Type II and dowelled Type III isolators in Table 11 according to the nominal dimensions of the product.

For recessed Type III isolators, the tolerance shall be ± 2 mm, or ± 0,4 % of the plan dimension, whichever is greater.

Table 11 — Tolerances on plan dimensions of isolators

Nominal plan dimensions (D', a') mm		**Tolerance**
Above	Maximum	
—	500	± 5 mm
500	1 500	± 1 %
1 500	—	± 15 mm

8.4 Product height

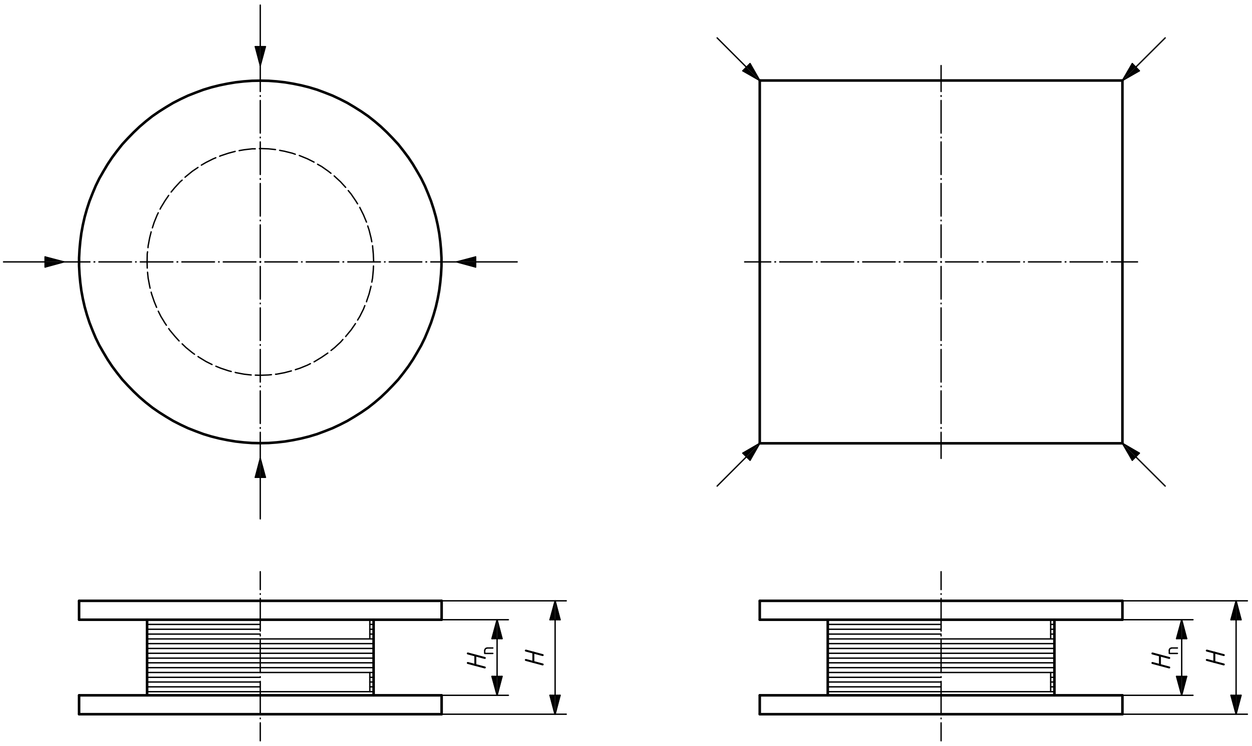
8.4.1 Measurement method

The method to measure the height of circular and rectangular isolators shall be as follows.

a) For circular isolators: the height shall be measured at the four points where two straight lines at right angles to each other which pass through the centre of the circular cross-section intersect the outer circumference (see Figure 4).

b) For rectangular isolators: the height (H or H_0) shall be measured at each of the four corners (see Figure 4).

The product height shall be taken as the arithmetic mean of the four measured values.



NOTE The measurement points are indicated by arrows.

Figure 4 — Height measurement positions

8.4.2 Tolerances

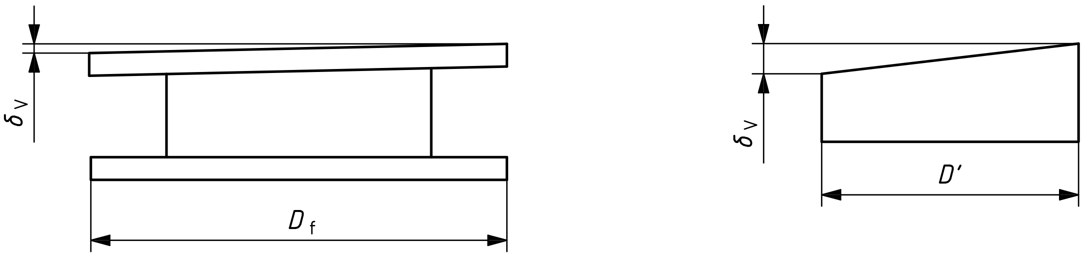
The tolerance on the product height shall be ± 1,5 % or ± 6,0 mm, whichever is smaller.

8.5 Flatness

8.5.1 Measurement method

The flatness is the maximum difference in height at four points on the circumference of the isolator. The measurement positions shall be the same as those for product height (H or H_n) measurements.

$$\text{Flatness } \psi = \left|\frac{\delta_\mathrm{v}}{D_\mathrm{f}}\right| \text{ or } \left|\frac{\delta_\mathrm{v}}{D'}\right| \qquad (24)$$



a) Type II, and Type I after assembly of mounting flange

b) Type III

Figure 5 — Measurement of flatness

8.5.2 Tolerances

The tolerance on the flatness of isolators shall be as follows:

$$\left|\psi\right| \leqslant \pm 0{,}25\ \% \qquad (25)$$

and

$$\left|\delta_{\mathrm{V}}\right| \leqslant 3{,}0\ \text{mm} \qquad (26)$$

8.6 Horizontal offset

For the measurement method, the horizontal offset is measured between the top and bottom edges of the product at two positions. For rectangular isolators, the positions shall be on adjacent sides, and for circular isolators, on orthogonal diameters.

The horizontal offset, δ_{H}, of elastomeric isolators shall be as follows:

$\delta_{\mathrm{H}} \leqslant 5{,}0$ (mm) or 2,5 % of H, whichever is smaller.

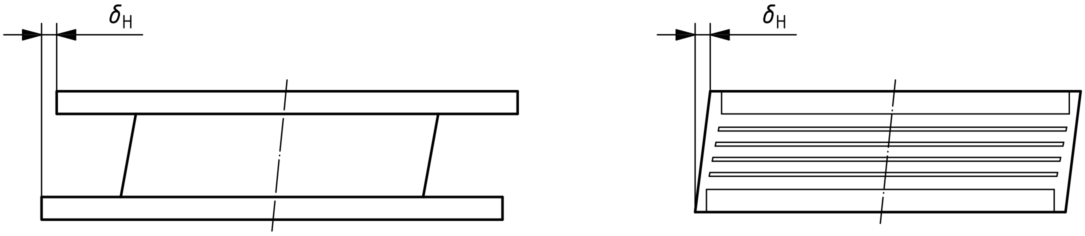


Figure 6 — Measurement of horizontal offset

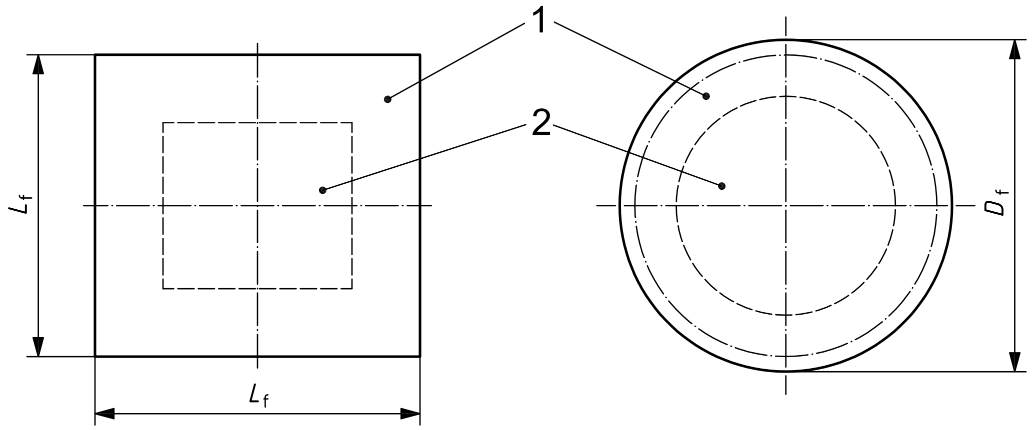
8.7 Plan dimensions of flanges

The tolerances on the plan dimensions of flanges shall be as specified in Table 12.

Table 12 — Tolerances on flange diameter and side length

Dimensions in millimetres

Thickness		D_{f} (or L_{f}) < 1 000	1 000 ⩽ D_{f} (or L_{f}) < 3 150	3 150 ⩽ D_{f} (or L_{f}) < 6 000
Above	Maximum			
6	27	± 2,0	± 2,5	± 3,0
27	50	± 2,5	± 3,0	± 3,5
50	100	± 3,5	± 4,0	± 4,5



Key

1 flange

2 isolator

Figure 7 — Measurement of plan dimensions of flanges

8.8 Flange thickness

The tolerances on flange thickness shall be as specified in Table 13.

Table 13 — Tolerances on thickness of flange (connecting plate for Type I)

Dimensions in millimetres

Nominal dimension		D_f (or L_f) < 1 600	1 600 ⩽ D_f (or L_f) < 2 000
Above	Maximum		
16,0	25,0	± 0,65	± 0,75
25,0	40,0	± 0,70	± 0,80
40,0	63,0	± 0,80	± 0,95
63,0	100,0	± 0,90	± 1,10

8.9 Tolerances on positions of flange bolt holes

The tolerances on the positions of flange bolt holes, including the positions of tapped holes on the connecting plate, shall be as specified in Table 14.

Table 14 — Tolerances on positions of flange bolt holes

Dimensions in millimetres

Nominal dimension		Tolerance
Above	Maximum	
400	1 000	± 0,8
1 000	2 000	± 1,2
2 000	—	± 2,0

9 Marking and labelling

9.1 General

Marking and labelling are required for the purpose of identification of a product and its properties and to ensure traceability of the product's history after installation. Therefore, marking and labelling are considered to be very important for quality control of a product.

9.2 Information to be provided

The following information shall be provided for the marking and labelling of elastomeric isolators.

a) The manufacturer's name or corporate emblem.

b) The type of elastomeric isolator. Types of elastomeric isolator shall be identified as in Table 15.

Table 15 — Identification of elastomeric isolators according to types and designations

Type	Designation
Linear natural rubber bearing	LNR
High-damping rubber bearing	HDR
Lead rubber bearing	LRB

c) The serial number or manufacturing number.

d) The size (optional).

EXAMPLE 1 Cross-sectional area circular and diameter 800 mm: size code D-800.

EXAMPLE 2 Cross-sectional area square and side length 800 mm × 800 mm: size code 800 × 800 or S-800.

9.3 Additional requirements

Additional requirements for marking and labelling include the following.

a) Marking shall be on lateral surfaces.

b) Marking shall be water-resistant and abrasion-resistant.

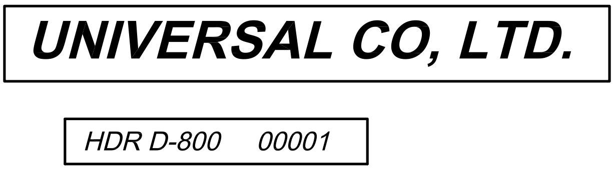
c) Marking shall be large enough to be easily identified. The size of the characters shall be larger than 5 mm in width and height.

9.4 Marking and labelling examples

Marking may be on one line as in Example 1 or on two lines as in Example 2 shown in this subclause.

EXAMPLE 1

EXAMPLE 2



10 Test methods

Test methods prescribed in this clause shall be in accordance with ISO 22762-1.

11 Quality assurance

A quality assurance programme to ensure consistent manufacturing of the isolators, including, but not limited to, preparation of reinforcing steel plates, uniformity of the thickness of the reinforcing steel plates and uniformity of the vulcanized rubber layers, shall be proposed by the manufacturer and approved by the structural engineer.

Annex A
(normative)

Tensile stress in reinforcing steel plate

A.1 Method for checking strength of reinforcing steel plate

The tensile stress in the reinforcing steel plates shall satisfy Equation (A.1):

$$\sigma_{\mathrm{s}} = 2\lambda \times \frac{P \times t_{\mathrm{r}}}{A_{\mathrm{e}} \times t_{\mathrm{s}}} \leqslant \sigma_{\mathrm{sa}} \tag{A.1}$$

where λ is a correction factor, including a safety margin, obtained from experimental data as follows:

a) for plates without holes: $\lambda = 1{,}0$;

b) for plates with holes ($A_{\mathrm{p}}/A = 0{,}03$ to $0{,}1$): $\lambda = 1{,}5$.

A.2 Verification of Equation (A.1) by compressive failure testing of isolators

A.2.1 General

The test described in this clause was carried out to verify the applicability of Equation (A.1).

A.2.2 Test pieces

The test pieces used are described in Table A.1. The test pieces were square, measuring 240 mm × 240 mm, the thickness of one rubber layer being 5,0 mm and the test pieces having six layers of laminated rubber. The thickness of the reinforcing steel plate was 2,3 mm made of SS400 mild steel (see 6.8). One isolator had no hole in the steel plate (RB-1), whereas the other had four holes of diameter 34,5 mm which were plugged with lead cores (RB-2). Two isolators for each type (with/without hole) were subjected to the testing.

Table A.1 — Dimensional characteristics of test pieces

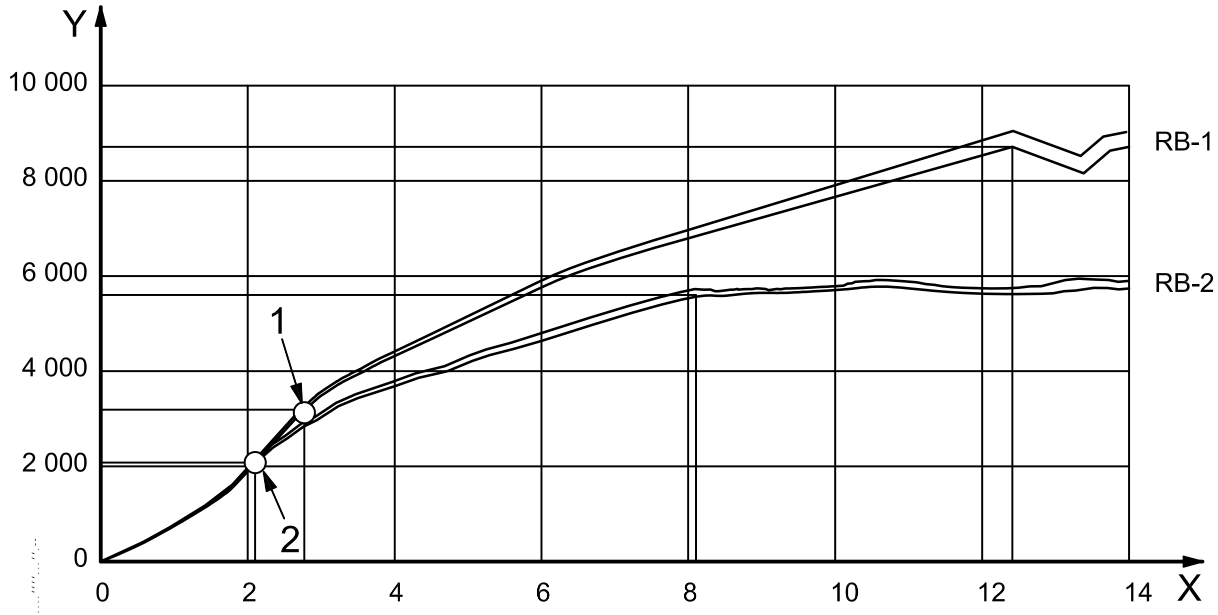
	RB-1	**RB-2**
Type	LNR	LRB
Plan dimension ($a \times a$), mm	240 × 240	
Hole diameter, d, mm	0	4 × 34,5
Thickness of one rubber layer, t_{r}, mm	5	
Number of layers	6	
Reinforcing plate thickness, t_{s}, mm	2,3	

A.2.3 Test conditions

Isolators were subjected to compressive loading until failure was indicated by the force-deflection curve. The horizontal displacement was maintained at zero during testing. The compressive loading rate was 32 kN/s.

A.2.4 Test results

A.2.4.1 Figure A.1 shows the plots of the force-deflection curve obtained during testing. The yield point of the plate was determined as the point on the curve where the second-order derivative of the curve was zero.



Key

X compressive deflection, δ, expressed in millimetres

Y compressive force, P, expressed in kilonewtons

1 yield point of plate for RB-1

2 yield point of plate for RB-2

Figure A.1 — Compressive force-deflection curve for isolator

A.2.4.2 The tensile stresses in the plates calculated from the compressive force at the observed yield point using Equation (A.1) are summarized in Table A.2.

Table A.2 — Summary of test results

	RB-1	RB-2	RB-1/RB-2
A Compressive force, P, at yield point, expressed in kN	3 200	2 100	0,66
B Compressive stress, σ, at yield point, expressed in N/mm^2	55,6	36,5	0,66
C Yield stress in plate, expressed in N/mm^2, computed from P and Equation (A.1)	241,6	237,9	1,016
D Design yield stress of plate, expressed in N/mm^2	235	235	—

A.2.4.3 Comparing the values of C and D in Table A.2, the applicability of Equation (A.1) can be seen to be verified.

For further details, see Reference [1].

Annex B
(informative)

Determination of ultimate property diagram based on experimental results

B.1 Test piece

A scale model isolator may be used for the test. The model shall have a minimum layer thickness of 2 mm and a minimum diameter of 250 mm. The thickness of the reinforcing steel plates need not be scaled down if the scaled thickness is $< 0,5$ mm.

B.2 Testing machine

A combined compression and shear testing machine shall be used.

The compressive load shall be controlled to maintain a constant load.

The vertical (compressive) load, horizontal load and horizontal displacement shall be measured using equipment with sufficient accuracy.

The load-deflection curve shall be recorded during testing.

B.3 Testing parameters

B.3.1 Compressive load

Different compressive loads corresponding to compressive stresses of 0, σ, $0,5\sigma$ and $2,5\sigma$, where σ is the nominal compressive stress recommended by the manufacturer, shall be used.

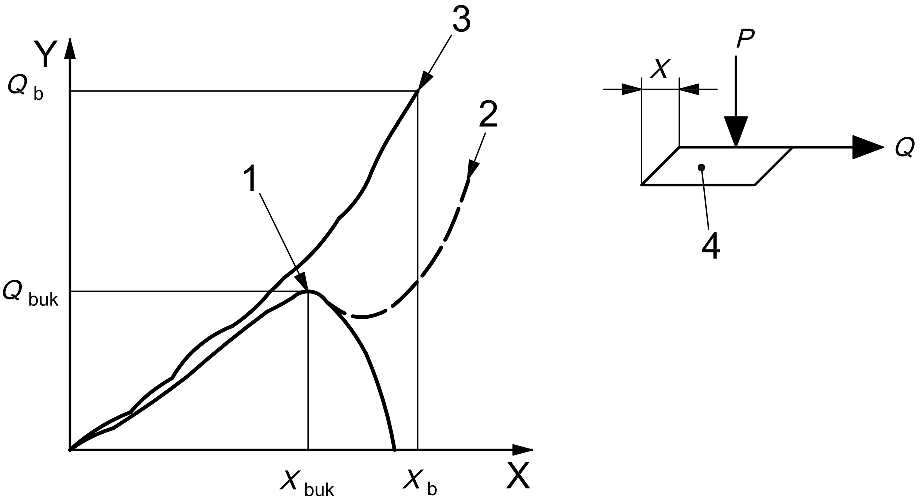
In order to obtain a more accurate load-deflection curve, loadings corresponding to compressive stresses of $1,5\sigma$ and $2,5\sigma$ are also recommended.

B.3.2 Compression-shear testing

Subject the isolator to static monotonic loading until breaking, buckling or roll-out occurs under the compressive stresses specified in B.3.1. The horizontal displacement and load at break (X_b and Q_b), at buckling (X_buk and Q_buk) or at roll-out (X_r0 and Q_r0) shall be determined from the result. If buckling, breaking or roll-out do not occur, the maximum displacement shall be considered as the ultimate property.

B.3.3 Test temperature

The ambient temperature during the test is not specified but is required to be maintained at around 23 °C.



Key

X	shear deflection, X
Y	shear force, Q
1	buckling point
2	break
3	breaking point
4	rubber bearing
P	compressive load
X_{buk}	shear deflection at buckling point
Q_{buk}	shear force at buckling point
X_b	shear deflection at breaking point
Q_b	shear force at breaking point

Figure B.1 — Determination of ultimate properties

B.4 Interpretation of results

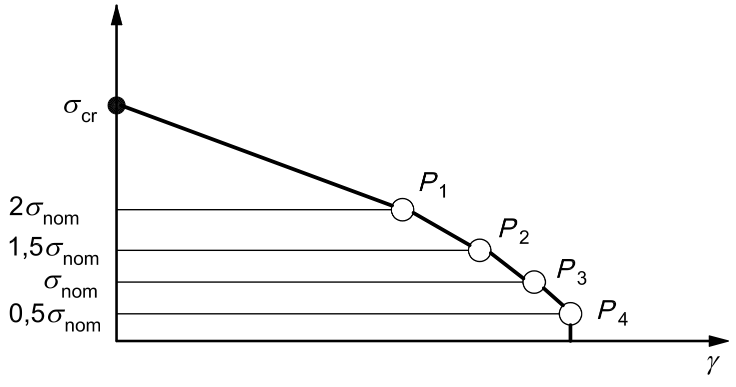
B.4.1 Plot the ultimate shear strain obtained in B.3 against the compressive stress, as shown in Figure B.2 (points P_1, P_2, P_3 and P_4).

B.4.2 Draw a curve through the plotted points. The compressive stress at zero shear strain (the critical stress, σ_{cr}) may be determined using Equation (B.1):

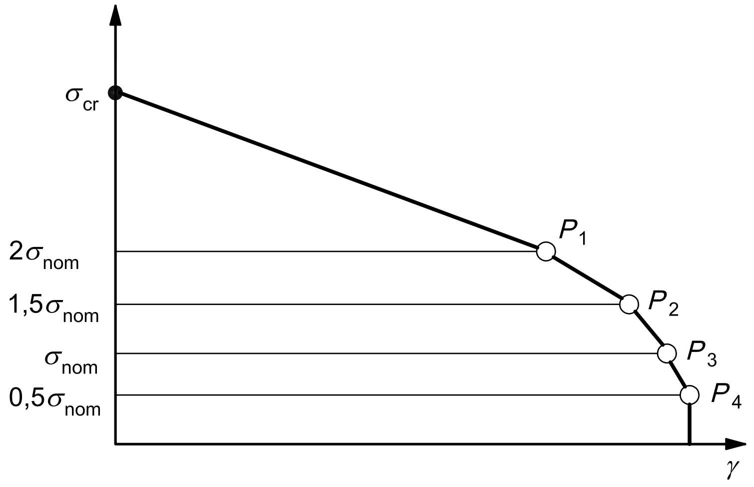
$$\sigma_{cr} = \frac{\pi}{4} \times \xi \times S_2\sqrt{E_b \times G} \qquad (B.1)$$

(see 7.4.1)

B.4.3 The area enclosed by the curve and the X- and Y-axes on the graph shall be considered the stable range of the isolator under compressive-shear loading.



a) Isolator with relatively small S_2



b) Isolator with relatively large S_2

Figure B.2 — Ultimate property diagrams (UPDs) obtained by experiment

Annex C
(informative)

Minimum recommended physical properties of rubber material

Examples of rubber material properties of elastomeric isolators, low-damping rubber bearings and high-damping rubber bearings, are shown in Tables C.1 and C.2.

Table C.1 — Properties of inner rubber materials for linear natural rubber bearings

Property	**Test item**	**Unit**	**Shear modulus** MPa (see ISO 22762-1:2010, 5.8)							**Test method**
			0,30	0,35	0,40	0,45	0,60	0,80	1,0	
Tensile properties	Tensile strength	MPa	⩾ 12,0	⩾ 14,0	⩾ 14,0	⩾ 15,0	⩾ 15,0	⩾ 20,0	⩾ 20,0	ISO 22762-1:2010, 5.3
	Elongation at break	%	⩾ 650	⩾ 600	⩾ 600	⩾ 600	⩾ 500	⩾ 500	⩾ 500	
Hardness	Hardness	IRHD	30 ± 5	35 ± 5	35 ± 5	40 ± 5	45 ± 5	50 ± 5	65 ± 5	ISO 22762-1:2010, 5.5
Adhesion properties	90° peel strength	N/mm	⩾ 6	⩾ 6	⩾ 6	⩾ 6	⩾ 6	⩾ 6	⩾ 6	ISO 22762-1:2010, 5.6
	Failure mode	—	Rubber failure	Rubber failure	Rubber failure	Rubber failure	Rubber failure	Rubber failure	Rubber failure	
Brittleness temperature	Brittleness temperature	°C	⩽ –40	⩽ –40	⩽ –40	⩽ –40	⩽ –40	⩽ –40	⩽ –40	ISO 22762-1:2010, 5.10

Table C.2 — Properties of inner rubber materials for high-damping rubber bearings

Property	**Test item**	**Unit**	**Shear modulus** MPa (see ISO 22762-1:2010, 5.8)			**Test method**
			0,40	0,60	0,80	
Tensile properties	Tensile strength	MPa	⩾ 8,0	⩾ 8,0	⩾ 10,0	ISO 22762-1:2010, 5.3
	Elongation at break	%	⩾ 650	⩾ 650	⩾ 650	
Hardness	Hardness	IRHD	(60 to 70) ± 5	(60 to 70) ± 5	(60 to 70) ± 5	ISO 22762-1:2010, 5.5
Brittleness temperature	Brittleness temperature	°C	⩽ –40	⩽ –40	⩽ –40	ISO 22762-1:2010, 5.10

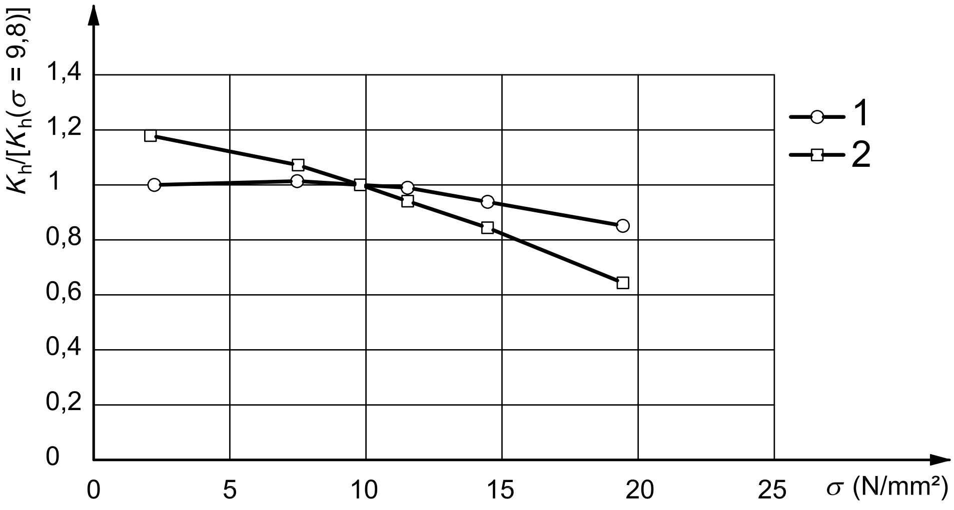
NOTE The shear modulus is that for 100 % strain.

Annex D
(informative)

Effect of inner-hole diameter and second shape factor on shear properties

D.1 Effect of inner-hole diameter on compressive-stress dependency of shear stiffness

The inner-hole diameter of an isolator has a significant effect on the compressive stress dependency of the shear stiffness. The larger the inner-hole diameter, the larger the dependency, as shown in Figure D.1, the data for which were obtained using test pieces with the properties given in Table D.1



Key

1 G 4,0-40

2 G 4,0-120

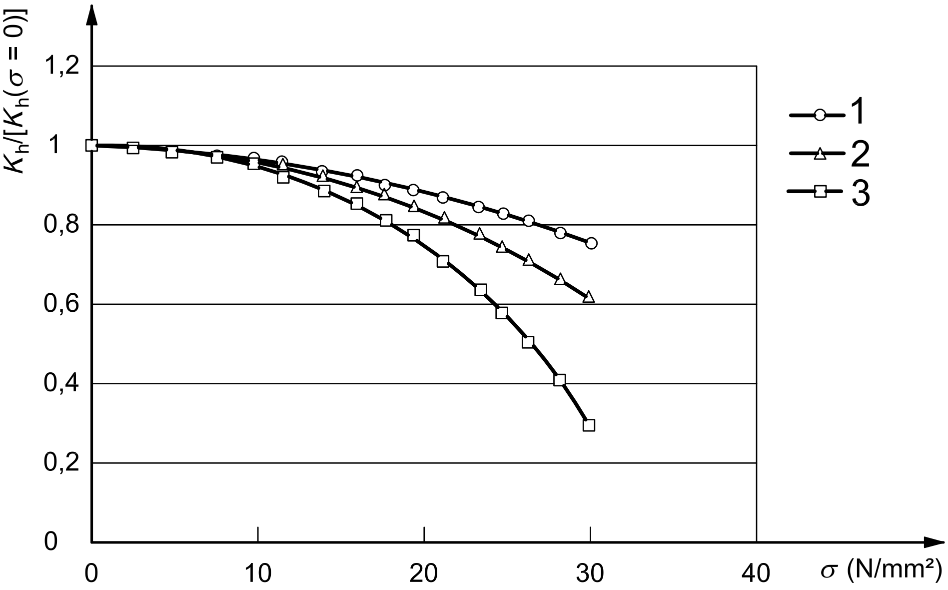
Figure D.1 — Compressive-stress dependency of shear stiffness of isolators with different inner-hole diameters

Table D.1 — Test pieces used

Property	Unit	G4,0-40	G4,0-120
G	MPa	0,39	0,39
d_o	mm	800	800
d_i	mm	40	120
d_i/d_o	—	0,05	0,15
t_r	mm	6,5	6,5
n_r	—	25	25
S_1	—	29,2	26,2
S_2	—	4,9	4,9

D.2 Effect of second shape factor on compressive-stress dependency of shear stiffness

The smaller the second shape factor, the larger the compressive stress dependency of the shear stiffness, as shown in Figure D.2.



Key

1 $S_2 = 5{,}0$

2 $S_2 = 4{,}0$

3 $S_2 = 3{,}0$

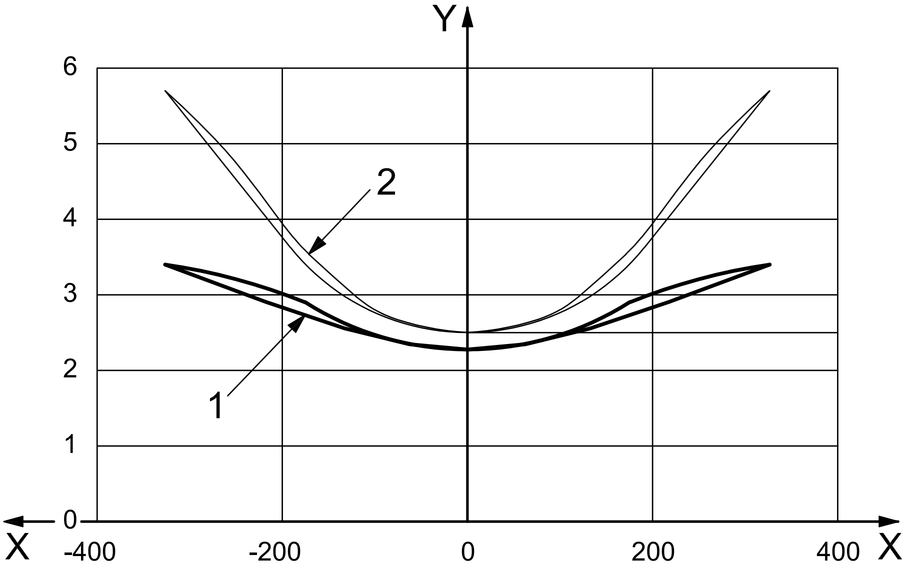
Test piece: $S_1 = 35$, $d_o = 225$ mm, $d_i = 0$ mm.

Figure D.2 — Compressive stress dependency of shear stiffness for various second shape factors

D.3 Effect of second shape factor on change in isolator height during compression-shear loading

As the inner-hole diameter becomes larger and/or the second shape factor smaller, the change in isolator height during compression-shear loading becomes larger.

Figure D.3 shows the effect of inner-hole diameter on the change in isolator height during compression-shear loading.



Key

X shear displacement, expressed in millimetres

Y decrease in isolator height, expressed in millimetres

1 *G* 4,0-40

2 *G* 4,0-120

Test piece: same as that shown in Table D.1.

Test conditions: $\sigma = 9{,}8$ MPa, $\gamma = \pm\ 200$ %.

Figure D.3 — Effect of inner-hole diameter on the change in isolator height during compression-shear loading

Annex E
(informative)

Determination of compressive properties of elastomeric isolators

E.1 The compressive (vertical) stiffness of an elastomeric isolator, K_v, is given by Equation (E.1).

$$K_\mathrm{v} = \frac{A \times E_\mathrm{c}}{n_\mathrm{r} \times t_\mathrm{r}} \tag{E.1}$$

where

A is the cross-sectional area of the rubber bearing;

$n_\mathrm{r} \times t_\mathrm{r}$ is (number of layers) × (thickness of one layer), i.e. the total rubber height;

E_c is the apparent Young's modulus, corrected for the bulk modulus (compressibility).

E.2 E_c is calculated using Equation (E.2):

$$E_\mathrm{c} = \left(\frac{1}{E_\mathrm{ap}} + \frac{1}{E_\infty} \right)^{-1} \tag{E.2}$$

E.3 Various formulae can be used to determine E_ap such as in E.3.1 and E.3.2.

E.3.1 Formula 1 (see References [1] and [2])

$$E_\mathrm{ap} = E_0 \times \left(1 + 2\kappa S_1{}^2 \right) \tag{E.3}$$

where

E_0 is Young's modulus of rubber (E_0 may be approximated as $3G$, where G is the shear modulus of rubber);

E_∞ is the bulk modulus of rubber;

κ is a correction factor;

S_1 is the first shape factor $\left(S_1 = \dfrac{d_\mathrm{o}}{4t_\mathrm{r}} \right)$;

d_0 is the outer diameter of the isolator;

t_r is the thickness of one layer of rubber.

Examples of constants for several natural rubber compounds are given in Table E.1. In practice, manufacturers apply their own constants for the design of isolators.

Table E.1 — Examples of values of the constant κ used in the design of elastomeric isolators

IRHD	E_0 MPa	G MPa	κ	E_∞ MPa
30	0,92	0,30	0,93	$1{,}00 \times 10^3$
40	1,50	0,45	0,85	$1{,}00 \times 10^3$
50	2,20	0,64	0,73	$1{,}03 \times 10^3$
60	5,34	1,06	0,57	$1{,}15 \times 10^3$
70	7,34	1,72	0,53	$1{,}27 \times 10^3$
NOTE See Reference [2].				

E.3.2 Formula 2

$$E_\mathrm{ap} = 3G_\mathrm{eq}(\gamma) \times \left(1 + 2{S_1}^2\right) \tag{E.4}$$

where G_eq (γ) is the shear modulus at the average shear strain γ produced by the compressive load.

γ may be estimated from the expression:

$$\gamma = \sqrt{6} S_1 \varepsilon \tag{E.5}$$

where ε is the compressive strain on the rubber layer.

Neither of the equations proposed here consider the non-linearity introduced when ε becomes greater than about 0,1.

E.4 E_0 and E_∞ may be determined by experiment, as follows:

$$\frac{1}{E_\mathrm{c}} = \frac{1}{E_0} \times \frac{1}{1 + 2\kappa S_1^2} + \frac{1}{E_\infty} \tag{E.6}$$

When the compressive stiffness of isolators with various values of S_1 is measured and E_c is derived, $\frac{1}{E_\mathrm{c}}$ and $\frac{1}{1 + 2\kappa {S_1}^2}$ can be plotted as shown in Figure E.1.

The best straight line is fitted to the plotted points. The slope a of the curve and its intercept b with the Y-axis give $\frac{1}{E_0}$ and $\frac{1}{E_\infty}$. Any correction factor, κ, may be selected, as long as it does not affect the accuracy of the approximated line.

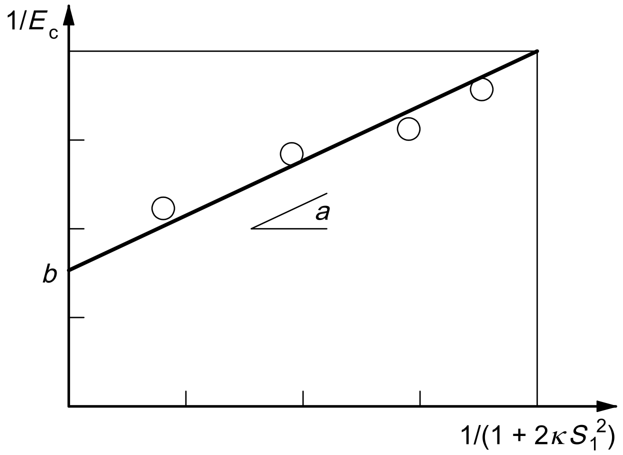


Figure E.1 — Relationship between $\frac{1}{E_c}$ and $\frac{1}{1+2\kappa S_1{}^2}$

For isolators with an unplugged central hole, formulae for the compression stiffness are given in Reference [1]. Expressions for compression stiffness based on shape factor, S_1, modified to take account of a hole, might not give reliable results.

Annex F
(informative)

Determination of shear properties of elastomeric isolators

F.1 Shear properties of linear natural rubber bearings

The shear stiffness, K_h, of LNR can be calculated from Equation (F.1):

$$K_\mathrm{h} = G\frac{A}{T_\mathrm{r}} \tag{F.1}$$

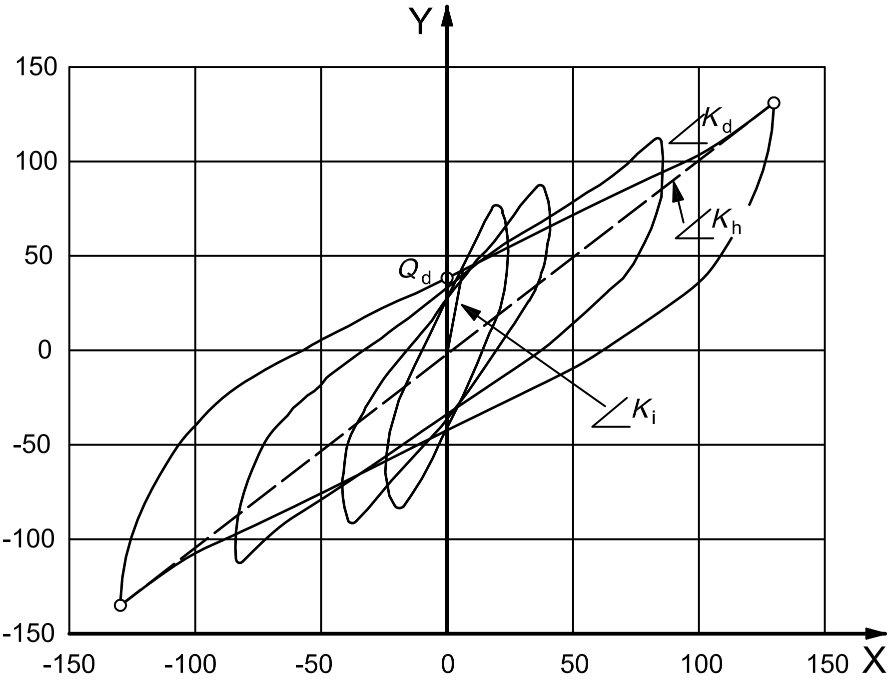
Alternatively, the tangential stiffness, K_t can be taken as a representative shear property of LNR. K_t can be determined as indicated in ISO 22762-1:2010, Annex F.

F.2 Shear properties of high-damping rubber bearings

F.2.1 A typical force-displacement curve for high-damping rubber bearings is shown in Figure F.1. The shear stiffness, K_h, or the equivalent of this shear stiffness, which is defined as the secant slope from peak to peak of the loop, is dependent on the deflection of the elastomeric isolator. The shear stiffness, K_h, can be calculated from Equation (F.2):

$$K_\mathrm{h} = G_\mathrm{eq}\left(\gamma\right) \times \frac{A}{T_\mathrm{r}} \tag{F.2}$$

where $G_\mathrm{eq}(\gamma)$ is the apparent shear modulus, derived from experimental data, expressed as a function of the shear strain γ.



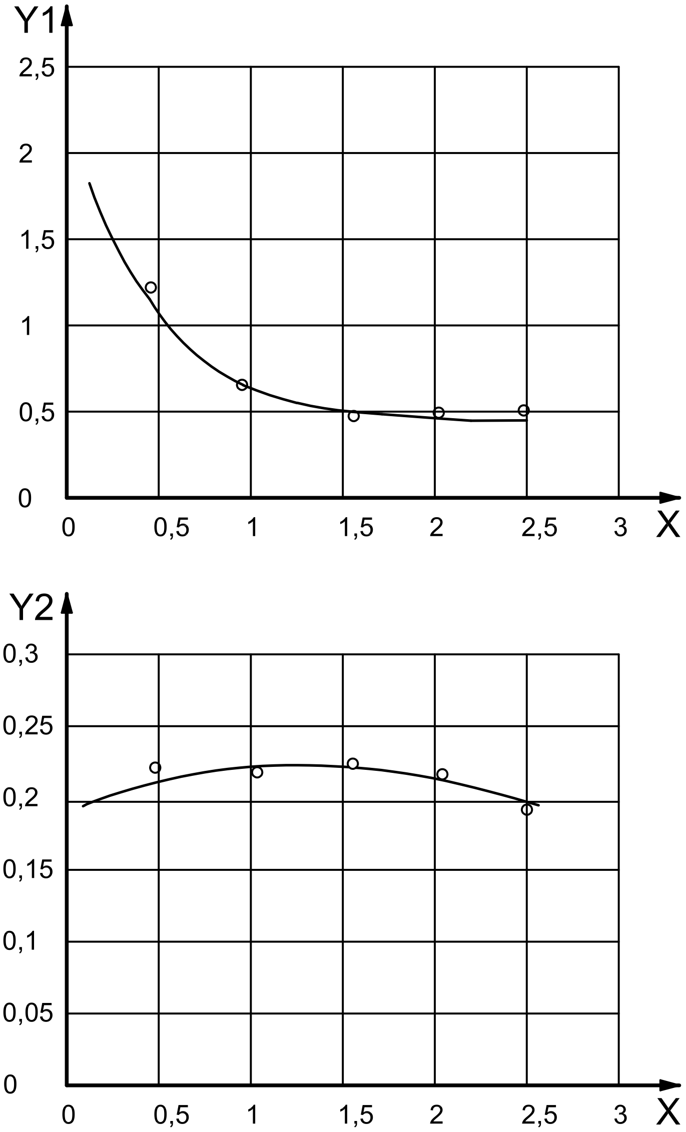
Key

X shear displacement, X, expressed in millimetres

Y shear force, Q, expressed in kilonewtons

Figure F.1 — Shear force vs. displacement curve for high-damping rubber bearing

F.2.2 Figure F.2 shows an example of the strain dependence of the apparent shear modulus and damping ratio for a high-damping rubber.



Key

X shear strain, γ

Y1 shear modulus, $G_{\text{eq}}(\gamma)$ (MPa)

Y2 equivalent damping ratio, $h_{\text{eq}}(\gamma)$

Figure F.2 — Examples of strain dependence of $G_{\text{eq}}(\gamma)$ and $h_{\text{eq}}(\gamma)$ for high-damping rubber bearing

F.2.3 $G_{\text{eq}}(\gamma)$ is expressed as a function of the shear strain, γ, such as a polynomial function as shown in Equation (F.3):

$$G_{\text{eq}}(\gamma) = a_0 + a_1 \times \gamma + a_2 \times \gamma^2 + a_3 \times \gamma^3 + a_4 \times \gamma^4 + a_5 \times \gamma^5 + \cdots = \sum_{j=0}^{n} a_j \times \gamma^j \qquad \text{(F.3)}$$

F.2.4 The equivalent damping ratio, h_{eq}, is also expressed as a function of the shear strain, γ, as follows:

$$h_{\text{eq}}(\gamma) = \sum_{j=0}^{n} b_j \times \gamma^j \qquad \text{(F.4)}$$

where $h_{\text{eq}}(\gamma)$ at each shear strain is calculated from experimental data using Equation (F.5):

$$h_{\text{eq}}(\gamma) = \frac{1}{\pi} \times \frac{W_{\text{d}}}{2K_{\text{h}}\left(T_{\text{r}} \times \gamma\right)^2} \tag{F.5}$$

where W_{d} is the amount of energy dissipated per cycle.

F.2.5 The characteristic strength of HDR is a function of the amplitude of the cyclic shear strain loading, $U(\gamma)$. This is defined as the ratio of the characteristic strength to the maximum shear force of the loop, as shown in Equation (F.6).

$$U(\gamma) = \frac{Q_{\text{d}}}{K_{\text{eq}} \times \left(T_{\text{r}} \times \gamma\right)} \tag{F.6}$$

As with $G_{\text{eq}}(\gamma)$ and $h_{\text{eq}}(\gamma)$, $U(\gamma)$ is expressed empirically as a function of the shear strain, γ, as follows:

$$U(\gamma) = \sum_{j=0}^{n} c_j \times \gamma^j \tag{F.7}$$

F.2.6 The initial stiffness, K_{i}, and post-yield stiffness, K_{d}, for HDR, assuming bi-linear modelling of the hysteresis loop, can be calculated using Equations (F.8) and (F.9).

$$K_{\text{d}} = \left[1 - U(\gamma)\right] \times K_{\text{eq}} \tag{F.8}$$

$$K_{\text{i}} = \frac{2U(\gamma) - \pi \times h_{\text{eq}}(\gamma) \times \left[1 - U(\gamma)\right]}{2U(\gamma) - \pi \times h_{\text{eq}}(\gamma)} \times K_{\text{eq}} \tag{F.9}$$

F.3 Shear properties of lead rubber bearings

F.3.1 The horizontal properties of a lead rubber bearing are represented by the equivalent shear stiffness, K_{h}, post-yield stiffness, K_{d}, and sectional load (characteristic strength), Q_{d}:

$$K_{\text{h}} = \frac{Q_{\text{d}}}{\gamma \times T_{\text{r}}} + K_{\text{d}} \tag{F.10}$$

The post-yield stiffness, K_{d}, is given by Equation (F.11):

$$K_{\text{d}} = C_{\text{r}}(\gamma) \times K_{\text{r}} + C_{\text{p}}(\gamma) \times K_{\text{p}} \tag{F.11}$$

where

K_{r} is the shear stiffness of the elastomeric isolator $\left(K_{\text{r}} = G\dfrac{A}{T_{\text{r}}}\right)$;

K_{p} is the stiffness of the inserted lead plug;

$C_{\text{r}}(\gamma)$ is a correction factor for the shear stiffness of the isolator;

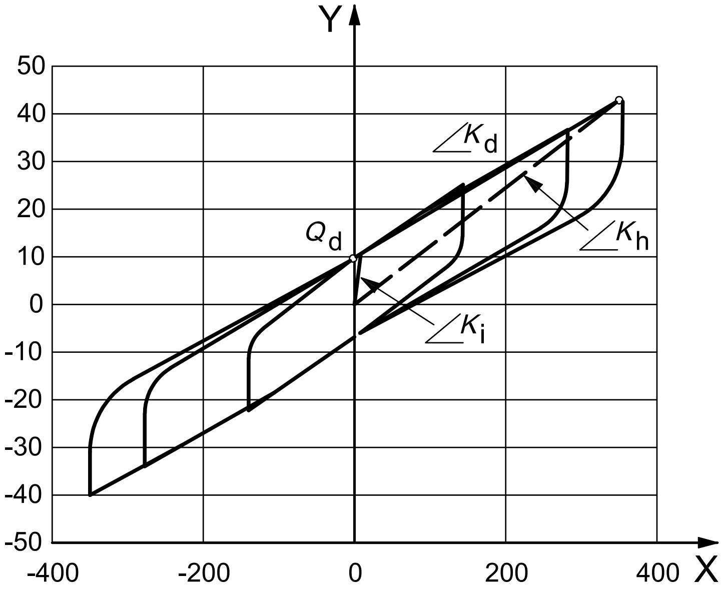
$C_{\text{p}}(\gamma)$ is a correction factor for the stiffness of the inserted lead plug.

$C_{\text{r}}(\gamma)$ and $C_{\text{p}}(\gamma)$ are derived empirically from experimental data.

F.3.2 The initial stiffness, K_i, can be derived by multiplying K_d by a constant α_i, as follows:

$$K_\text{i} = \alpha_\text{i} \times K_\text{d} \tag{F.12}$$

A typical reference value for α_i is 5 to 15.



Key

X shear displacement, expressed in millimetres

Y shear force, expressed in kilonewtons

Figure F.3 — Shear force vs. shear displacement curve for lead rubber bearing

Annex G
(informative)

Method of predicting buckling limit at large deformations

G.1 General

This annex in intended to propose design guidelines to both manufacturers and structural engineers, particularly in predicting the buckling limit at large deformations.

G.2 Buckling-limit calculation

G.2.1 The buckling limit of elastomeric isolators at large deformations can be predicted by the following simplified equation.

$$\gamma \leqslant S_2\left(1-\frac{\sigma}{\sigma_{\mathrm{cr}}}\right) \tag{G.1}$$

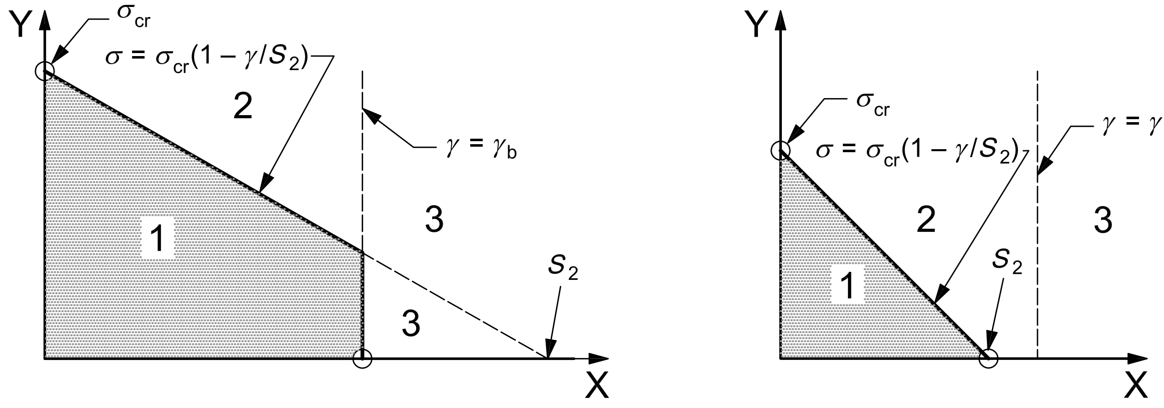
where

$$\sigma_{\mathrm{cr}} = \frac{\pi}{4}\times\xi\times S_2\sqrt{E_{\mathrm{b}}\times G} \tag{G.2}$$

(see 7.4)

$$\frac{1}{E_{\mathrm{b}}} = \frac{1}{E_0\left(1+{}^2\!/_3\,\kappa S_1{}^2\right)}+\frac{1}{E_\infty} \tag{G.3}$$

G.2.2 The failure envelope is shown on plots of compressive stress versus ultimate shear strain in Figure G.1.



a) **Isolator with large S_2**

b) **Isolator with small S_2**

Key

X shear strain, γ

Y compressive stress, σ

1 stable (no failure)

2 unstable

3 failure by breaking

Figure G.1 — Buckling-limit curve

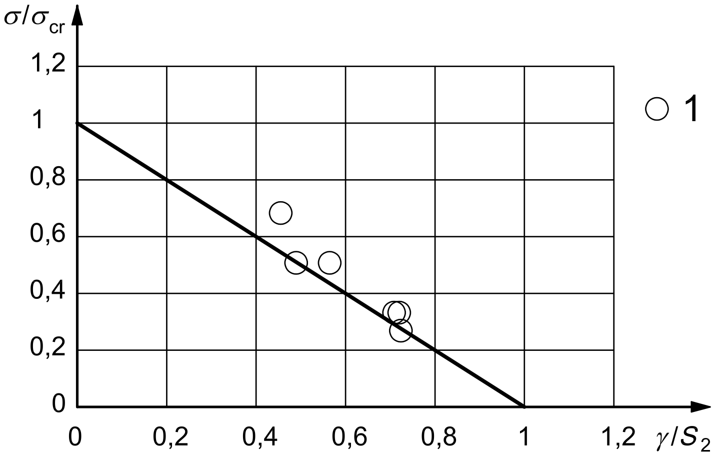
G.3 Verification of Equation (G.1) by isolator tests

G.3.1 The proposed equation has been verified by large-scale isolator testing on LNR, LRB and HDR isolators with various diameters and shape factors. The number of test pieces, and their dimensions, first and second shape factors and rubber shear moduli, are shown in Table G.1.

Table G.1 — Dimensional characteristics of test isolators

	Outer diameter d_o mm	**Inner diameter** d_i mm	S_1	S_2	G MPa
LNR: Number of isolators tested = 59					
Min.	482	0	17,1	3,00	0,29
Max.	820	150	43,7	5,41	0,49
Ave.	602	22,6	32,7	4,75	0,39
LRB: Number of isolators tested = 25					
Min.	120	24	20,0	3,00	0,390
Max.	950	190	43,6	5,59	0,392
Ave.	618	113	33,8	4,20	0,391
HDR: Number of isolators tested = 35					
Min.	500	0	25,0	3,00	0,354
Max.	1 100	200	38,3	5,40	0,810
Ave.	683	52,4	32,7	4,33	0,486

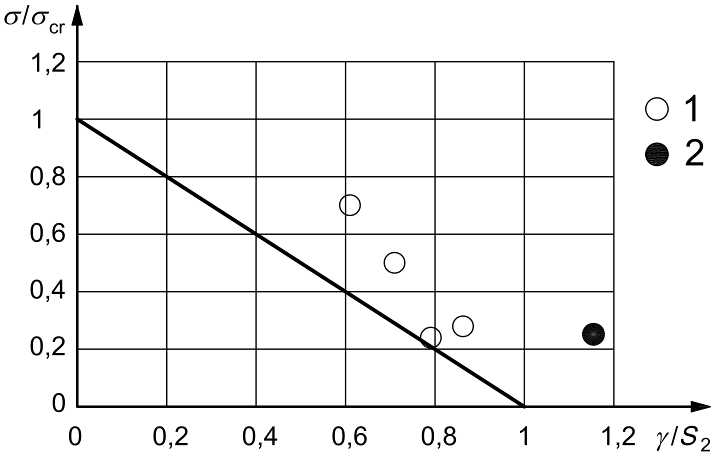
G.3.2 The test results are plotted on normalized scales of σ/σ_{cr} versus γ/S_2 for each type of isolator in Figures G.2 to G.10. Except for the HDR isolators in the range $S_2 < 3{,}5$, the plots indicate that the buckling-limit equation gives a conservative prediction for buckling of the isolator under large shear deformations. For HDR isolators with $S_2 < 3{,}5$, the inclusion of a sufficient safety margin should be considered.



Key

1 buckling

Figure G.2 — LNR ($S_2 < 3{,}5$)

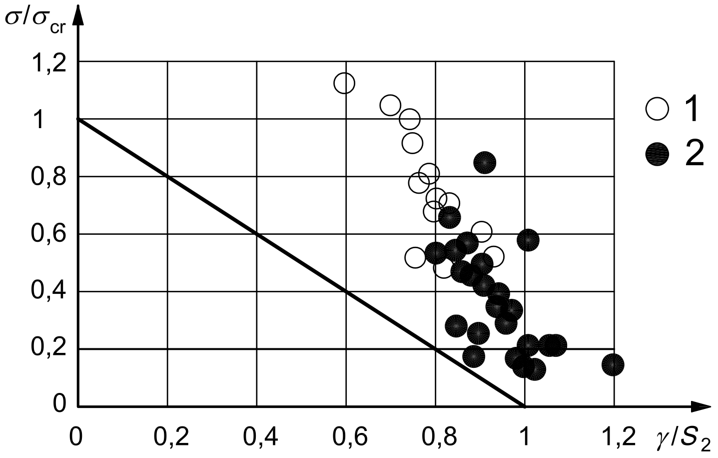


Key

1 buckling

2 stable

Figure G.3 — LNR ($3{,}5 \leqslant S_2 < 4{,}0$)

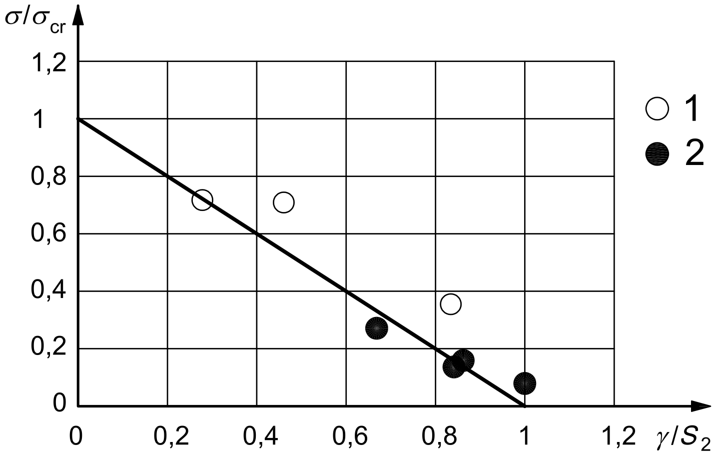


Key

1 buckling

2 stable

Figure G.4 — LNR ($S_2 \geqslant 4,5$)

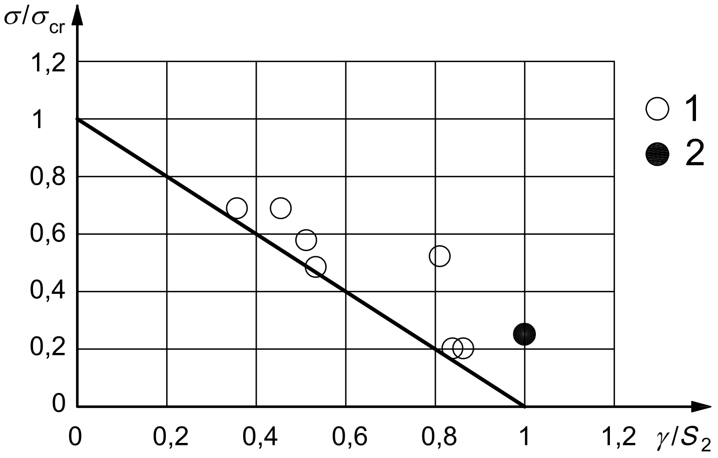


Key

1 buckling

2 stable

Figure G.5 — LRB ($S_2 < 3,5$)

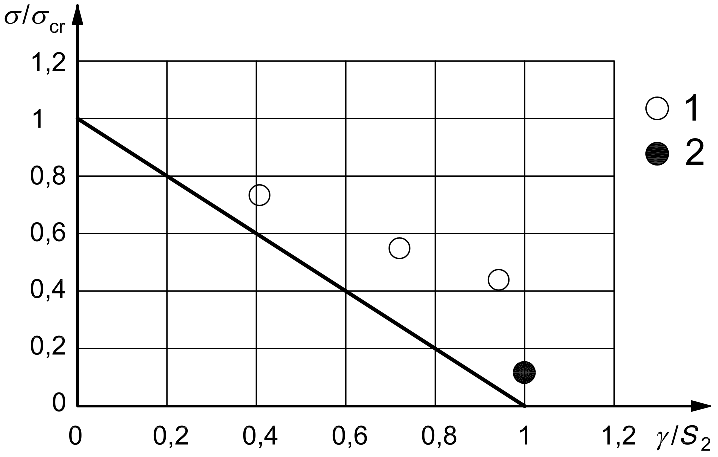


Key

1 buckling

2 stable

Figure G.6 — LRB ($3,5 \leqslant S_2 < 4,0$)

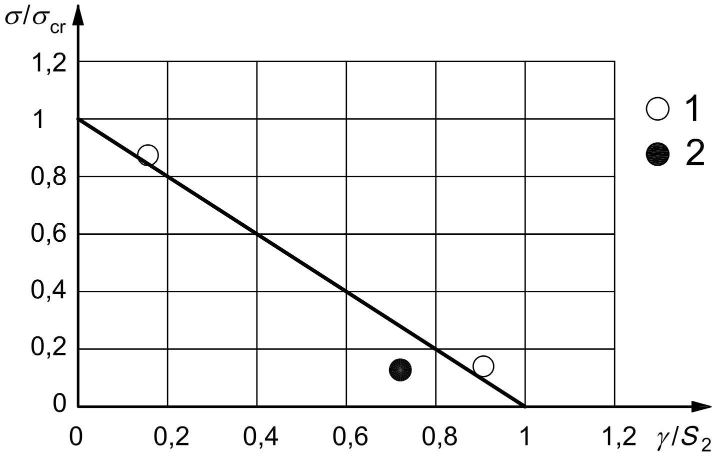


Key

1 buckling

2 stable

Figure G.7 — LRB ($S_2 \leqslant 4,5$)

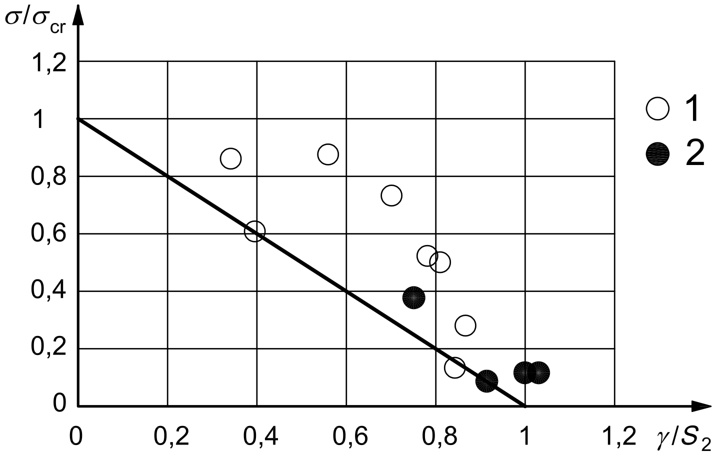


Key

1 buckling

2 stable

Figure G.8 — HDR ($S_2 < 3{,}5$)

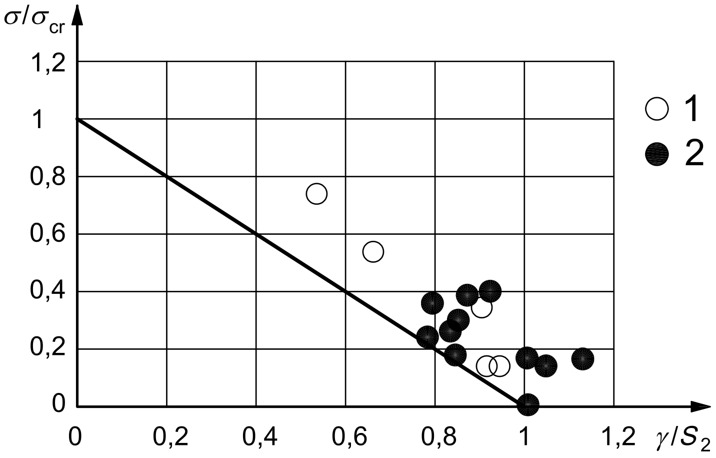


Key

1 buckling

2 stable

Figure G.9 — HDR ($3{,}5 \leqslant S_2 < 4{,}0$)



Key

1 buckling

2 stable

Figure G.10 — HDR ($S_2 \leqslant 4,5$)

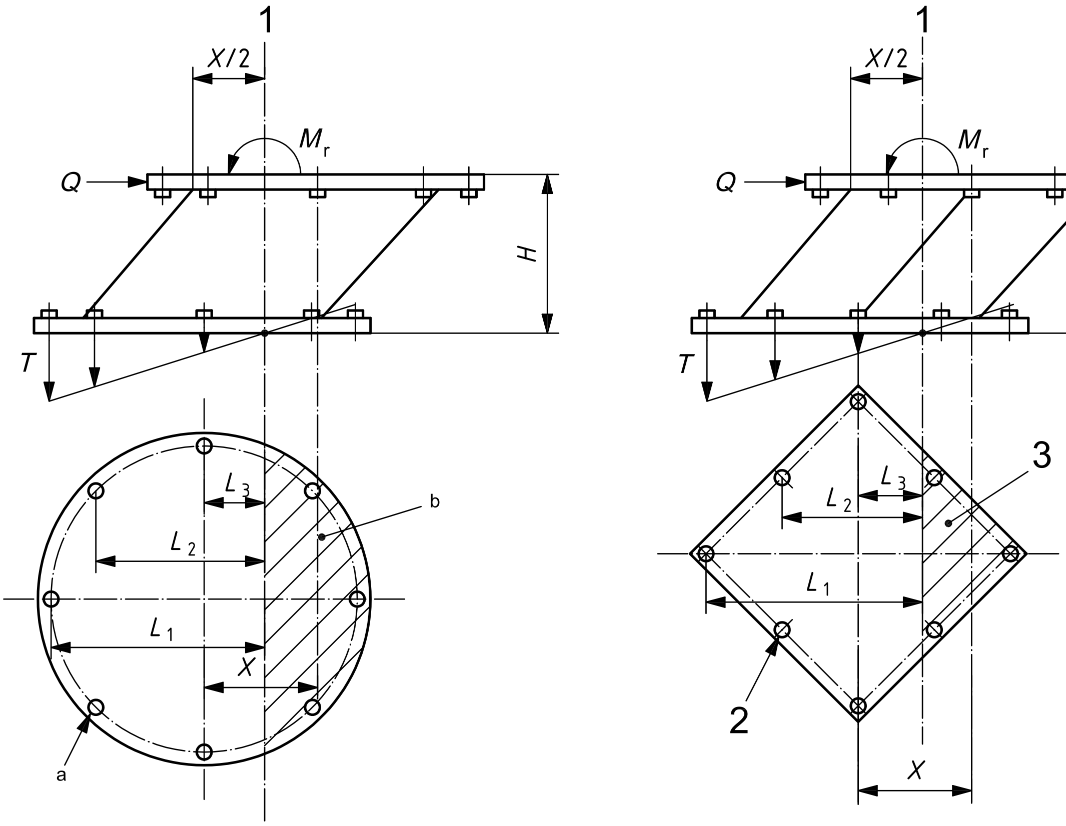
Annex H
(informative)

Design of fixing bolts and flanges

H.1 Fixing bolts

H.1.1 The tensile stress and shear stress in fixing bolts caused by shear displacement of an elastomeric isolator can be calculated using the procedure from H.1.2 to H.1.5.

H.1.2 The maximum tensile force on the bolts is calculated using the moment due to the shear force and the distance of the shear force from the so-called “neutral axis”. The relationship between the tensile force and the moment is shown in Figure H.1.



Key

1 neutral axis

[a] Tension in bolts.

[b] Compression.

Figure H.1 — Tension in bolts of elastomeric isolators under shear displacement

H.1.3 The maximum tensile force is generated when the horizontal load(shear force), Q, moment (acting on isolator), M_r, and uplift force, F_u, act simultaneously on the isolator:

$$\begin{aligned} Q &= K_\mathrm{h} \times X \\ M_\mathrm{r} &= \frac{1}{2} Q \times H \end{aligned} \tag{H.1}$$

Assuming that

a) a neutral line exists at the centre of the area where the top and bottom flanges overlap, and

b) the flanges are kept perpendicular to the vertical axis, and the tensile strain in the bolts and the compressive strain on the base have a linear relationship with the distance from the neutral axis,

then

$$T_1 / L_1 = T_2 / L_2 = \cdots = T_i / L_i \tag{H.2}$$

where $i = 1, 2, 3, \ldots$ for the different bolts.

Neglecting the contribution of compressive stress to the moment, the maximum value of the tension, T_1, in bolt No. 1 is calculated from the following equations:

$$T_1 = \frac{M_\mathrm{r}}{\left(L_1 + 2\frac{L_2^2}{L_1} + 2\frac{L_3^2}{L_1} + \cdots \right)} \tag{H.3}$$

$$T_\mathrm{max} = T_1 + F_\mathrm{u} / n_\mathrm{b} \tag{H.4}$$

$$\sigma_\mathrm{B} = \frac{T_\mathrm{max}}{A_\mathrm{b}} \tag{H.5}$$

H.1.4 The shear force, as expressed in Equation (H.6), is assumed to be sustained evenly by all bolts:

$$\tau_\mathrm{B} = \frac{Q}{n_\mathrm{b} \times A_\mathrm{b}} \tag{H.6}$$

H.1.5 The combined stresses (tensile and shear) in each bolt should satisfy the following inequality:

$$\left(\frac{\sigma_\mathrm{B}}{\sigma_\mathrm{f}} \right)^2 + \left(\frac{\tau_\mathrm{B}}{\tau_\mathrm{f}} \right)^2 \leqslant 1 \tag{H.7}$$

H.2 Flanges

The bending stress, σ_b, on the flanges caused by bolt tension can be calculated and checked using Equations (H.8):

$$\sigma_\mathrm{b} = \frac{M_\mathrm{F}}{Z} \leqslant \sigma_\mathrm{bf} \tag{H.8}$$

where

$$M_F = T \times c \tag{H.9}$$

$$Z = \frac{1}{6} \times t_f^2 \times B \tag{H.10}$$

$$B = 2c + d_k \tag{H.11}$$

The effective width, B, of the flange is defined as shown in Figure H.2.

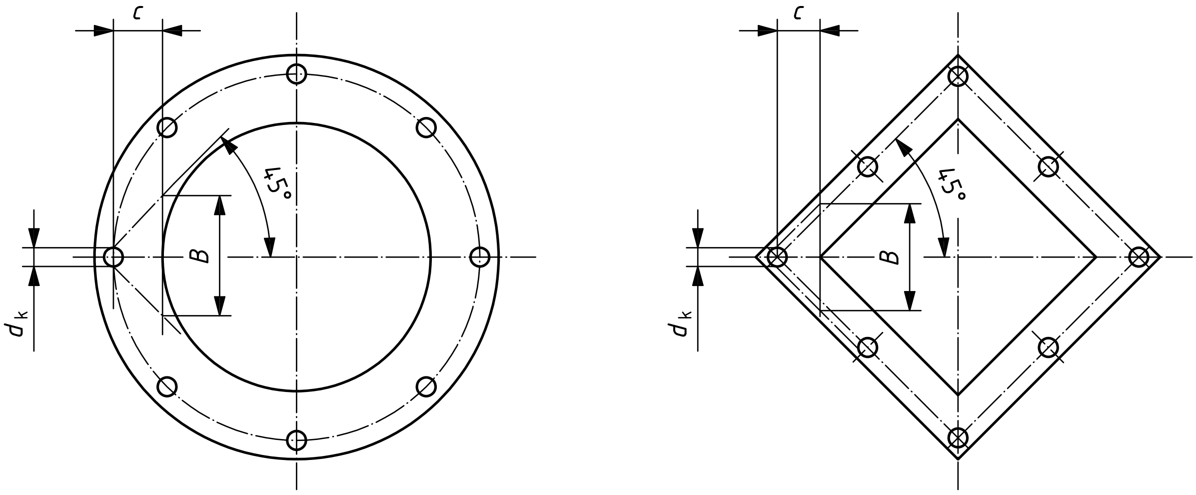


Figure H.2 — Bending of flanges

Bibliography

[1] KELLY, J. M. *Earthquake-Resistant Design with Rubber*, 2nd Edition, Springer-Verlag, London, 1997

[2] LINDLEY, P.B. *Engineering Design with Natural Rubber*, Malaysian Rubber Producers Research Association, London, 1974

[3] NISHI, T., SAKAGUCHI, T., YAZAKI, F., SAITOU, J., MIYAZAKI, M. and YOSHIZAWA, T. *Evaluation of Marginal Capacities of Elastomeric Isolator for Seismic Isolation for Buildings and Bridges*, International Rubber Conference, Prague, 2002

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