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Elastomeric seismic-protection isolators —

Part 6: High-durability and high-performance specifications and test methods

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

A list of all parts in the ISO 22762 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document specifies requirements and test conditions for elastomeric seismic isolators used for important buildings and buildings which can be subjected to frequent, large earthquakes; the requirements and test conditions for the rubber material used in the manufacture of such isolators are also specified.

Three grades of requirements for each test item are introduced. Grade I requirements for each test item conform with the requirements given in ISO 22762-3 and are appropriate for standard buildings unlikely to be subjected to frequent, large earthquakes. Grade II and grade III requirements for each test item have to meet the more stringent requirements and be subjected to the more severe test conditions given in this document. Grade III requirements for each test item are intended for the most important buildings, and sites where large earthquakes can be particularly frequent.

There are a wide variety of requirements for seismic isolated buildings; there is no need to request the same grade for all test items in the same project. Structural engineers may select grade II or III for each test item in their requirements in order to perform the optimum building design.

Instances where this document differs from ISO 22762-3 include:

a) the number of test pieces to be used in type testing;

b) smaller tolerances allowed between measured properties and design characteristics;

c) smaller variations, due to effects such as temperature and compressive load, allowed in shear properties.

Elastomeric seismic-protection isolators —

Part 6:
High-durability and high-performance specifications and test methods

1 Scope

This document specifies specifications and test methods for elastomeric seismic isolators used for buildings to guarantee high durability and high performance.

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 documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 22762-1:2018, *Elastomeric seismic-protection isolators — Part 1: Test methods*

ISO 22762-3:2018, *Elastomeric seismic-protection isolators — Part 3: Applications for buildings — Specifications*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
allowable tensile strain
tensile strain whose influence on shear properties does not exceed a certain range

3.2
breaking
rupture of *elastomeric isolator* (3.8) due to compression- (or tension-) shear loading

3.3
buckling
state when *elastomeric isolators* (3.8) lose their stability under compression-shear loading

3.4
compressive properties
K_v
compressive stiffness for all types of rubber bearings

3.5
cumulative shear strain
sum of shear strain of a seismic-protection isolator when it is repeatedly deformed many times

3.6
design compressive stress
long-term compressive force on the *elastomeric isolator* (3.8) imposed by the structure

3.7
effective width
rectangular *elastomeric isolator* (3.8) smaller of the two side lengths of inner rubber to which direction shear displacement is not restricted

3.8
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.

3.9
first shape factor
ratio of effectively loaded area to free deformation area of one inner rubber layer between steel plates

3.10
high-damping rubber bearing
HDR
elastomeric isolator (3.8) with relatively high damping properties obtained by special compounding of the rubber and the use of additives

3.11
horizontal biaxial loading dependency
horizontal biaxial loading effect on various properties

3.12
horizontal shear creep test and residual shear strain test
changes in horizontal deformation that occur when the *elastomeric isolator* (3.8) is subjected to a constant horizontal force for a long time due to strong winds such as a typhoon, and residual deformation after unloading

3.13
inner rubber
rubber between multi-layered steel plates inside an *elastomeric isolator* (3.8)

3.14
lead rubber bearing
LRB
elastomeric isolator (3.8) with a lead plug or lead plugs press fitted into a hole or holes of the isolator body to achieve damping properties

3.15
linear natural rubber bearing
LNR
elastomeric isolator (3.8) with linear shear force-deflection characteristics and relatively low damping properties, fabricated using natural rubber

Note 1 to entry: Any bearing with relatively low damping can be treated as an LNR bearing for the purposes of isolator testing.

3.16
roll-out
instability of an isolator with either dowelled or recessed connection under shear displacement

3.17
routine test
test for quality control of the production isolators during and after manufacturing

3.18
second shape factor
<circular elastomeric isolator> ratio of the diameter of the *inner rubber* (3.13) to the total thickness of the inner rubber

3.19
second shape factor
<rectangular or square elastomeric isolator> ratio of the *effective width* (3.7) of the *inner rubber* (3.13) to the total thickness of the inner rubber

3.20
shear strain dependency of allowable tensile strain
influence of the *allowable tensile strain* (3.1) due to a change of shear strain of *elastomeric isolator* (3.8)

3.21
shear strain dependency of tensile yield strength
influence of the tensile yield strength due to a change of shear strain of *elastomeric isolator* (3.8)

3.22
standard value
value of the isolator property defined by the manufacturer based on the results of the type test

3.23
structural engineer
engineer in charge of designing the structure for base-isolated bridges or buildings and responsible for specifying the requirements for *elastomeric isolators* (3.8)

3.24
tensile fracture strain
strain at which *elastomeric isolator* (3.8) breaks in the tensile direction

3.25
type test
test for the verification of either material properties and isolator performances during the development of the product or the achievement of the project design parameters

3.26
ultimate property
property at either *buckling* (3.3), *breaking* (3.2), or *roll-out* (3.16) of an isolator under compression-shear loading

3.27
ultimate properties under horizontal biaxial loading test
critical characteristics of *elastomeric isolators* (3.8) when loaded in two directions in the horizontal plane

3.28
ultimate property diagram
UPD
diagram giving the interaction curve of compressive stress and *buckling* (3.3) strain or *breaking* (3.2) strain of an *elastomeric isolator* (3.8)

4 Symbols

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

Table 1 — Symbols and descriptions

Symbol	Description
h_{eq}	equivalent damping ratio
K_d	post-yield stiffness (tangential stiffness after yielding of lead plug) of lead rubber bearing
K_h	shear stiffness
P_{Tb}	tensile force at break of isolator
P_{Ty}	tensile yield force
Q_d	characteristic strength
S_1	first shape factor
S_2	second shape factor
γ_{max}	maximum shear displacement
γ_0	design shear strain
γ_φ	maximum torsion strain
γ_b	ultimate shear strain under horizontal biaxial loading
γ_{max}	maximum design shear strain during earthquake
γ_u	ultimate shear strain under horizontal uniaxial loading
ε_{Tl}	allowable limit of tensile strain
τ_B	shear stress in bolt
τ_s	shear static stress

5 Classification

The requirements for each test item of elastomeric seismic-protection isolators are classified into three grades, grade III, grade II, and grade I, depending on durability and performance. Grade III and grade II are high-endurance and high-performance specifications stipulated in this document, and the grade I is a general specification prescribed by ISO 22762-3. In addition, grade III is more durable and has higher performance specification than grade II.

The classification of each grade is shown in Table 2. Requirements for grade III and grade II are listed in 6.5.

Structural engineers may select grade II or III for each test item in their requirements in order to perform the optimum building design.

Table 2 — Classification of each grade

Grade	Required items of performance evaluation	Required performance level	Required specimens
I	Required items of performance evaluation are as in ISO 22762-3:2018, Table 5.	Required performance level is as in ISO 22762-3:2018, Table 3.	Required specimens are as in ISO 22762-3:2018, Table 4.
II	Some new performance items such as tensile property are added to those of grade I.	For some performance items, required performance level is specified severer than grade I.	For some performance items, required number and size of specimens are larger than grade I. In addition, for some performance items, required test condition is severer than grade I.
III		For some performance items, required performance level is specified severer than grade II.	For some performance items, required number and size of specimens are larger than grade II. In addition, for some performance items, required test condition is severer than grade II.

6 Requirements

6.1 General

Elastomeric isolators for buildings and the materials used in manufacture shall meet the requirements specified in this clause. Test items for type test of isolators are shown in Table 3.

6.2 Type tests and routine tests

Type tests and routine tests are specified in ISO 22762-3:2018, 6.2.

6.3 Functional requirements

Functional requirements of elastomeric isolators used for buildings are specified in ISO 22762-3:2018, 6.3.

6.4 Design compressive force and design shear displacement

The design compressive forces, the design shear displacements, the design stress and the design strain of an isolator are defined in ISO 22762-3:2018, 6.4.

6.5 Performance requirements

6.5.1 General

The performance requirements of grade II and III are shown below.

The isolators shall be tested and the results recorded using the specified test methods. They shall satisfy all of the requirements of Grade II and III listed in Table 3. The test items are summarized in Table 3 for type tests and routine tests. The standard value obtained from the tests shall be reported. The standard temperature for determining the properties of elastomeric isolators is specified in ISO 22762-3:2018, 6.1. Double-shear configuration testing (see ISO 22762-1:2018, 6.2.2.2) can be employed with the approval of the structural engineer.

The standard values obtained from the tests satisfy the requirements shown in Table 4, Table 5 and Table 6 depending to the type of isolators.

Table 3 — Tests on elastomeric isolators

Property	Test item	Test method	Routine test	Type test
Compressive properties	Compressive stiffness	ISO 22762-1:2018, 6.2.1, method 2	X	X
Shear properties	Shear stiffness Equivalent damping ratio Post-yield stiffness (for LRB) Characteristic strength (for LRB)	ISO 22762-1:2018, 6.2.2	X	X
Tensile properties	Tensile yield strength	ISO 22762-1:2018, 6.5	N/A	X
	Allowable tensile strain	8.4.1	N/A	X
Dependency of shear stiffness	Shear strain dependency	ISO 22762-1:2018, 6.3.1	N/A	X
	Compressive stress dependency	ISO 22762-1:2018, 6.3.2	N/A	X
	Frequency dependency	ISO 22762-1:2018, 6.3.3	N/A	X
	Repeated loading dependency −1	ISO 22762-1:2018, 6.3.4	N/A	X
	Repeated loading dependency −2	8.2.1	N/A	X
	Temperature dependency	ISO 22762-1:2018, 6.3.5 ISO 22762-1:2018, 5.8	N/A	X
	Horizontal biaxial loading dependency	8.2.2	N/A	X
Dependency of compressive stiffness	Shear strain dependency	ISO 22762-1:2018, 6.3.6	N/A	X
	Compressive stress dependency	ISO 22762-1:2018, 6.3.7	N/A	X
Dependency of tensile properties	Shear strain dependency of tensile yield strength	8.4.2	N/A	X
	Shear strain dependency of allowable tensile strain	8.4.3	N/A	X
Shear strain and displacement capacity	Ultimate shear strain, breaking strain, buckling strain, Ultimate property diagram (UPD) or Ultimate shear displacement, breaking displacement, buckling displacement, Ultimate property diagram (UPD)	ISO 22762-1:2018, 6.4 See Annex A and Annex B for information.	N/A	X
	Ultimate shear strain under horizontal biaxial loading	8.3	N/A	X
Tensile capacity	Tensile fracture strength	ISO 22762-1:2018, 6.5	N/A	X
	Tensile fracture strain	8.4.4	N/A	X
Durability	Property change	ISO 22762-1:2018, 6.6.1	N/A	X
	Compressive creep	ISO 22762-1:2018, 6.6.2	N/A	X
	Cumulative shear strain	8.5.1	N/A	X
	Horizontal shear creep test and residual shear strain test	8.5.2	N/A	X
X = test to be conducted with isolators; N/A = not applicable.				

Table 4 — Performance requirement of LNR

Property	Test item		Grade	
			III	II
Compressive properties	Compressive stiffness	Tolerance	±15 %	±20 %
Shear properties [a]	Shear stiffness	Tolerance	±10 %	±15 %
Tensile properties	Tensile yield strength	Values at design shear strain	No requirement	No requirement
	Allowable tensile strain	Values at design shear strain	≥ 5 %	≥ 5 %
Dependency of shear stiffness	Shear strain dependency	Allowable range of change with respect to property value at design shear strain	−15 % to +10 %	−20 % to +15 %
	Compressive stress dependency [b]	Allowable range of change with respect to property value at design compressive stress	−15 % to +8 %	−30 % to +20 %
	Frequency dependency	Percentage change with respect to value at design frequency [g]	−5 % to +5 %	−10 % to +10 %
	Repeated loading dependency −1 [c]	Maximum decrease allowed with respect to property value at 3rd cycle	5 %	5 %
	Repeated loading dependency −2	Change in property with respect to value at 3rd cycle	No requirement value	No requirement value
	Temperature dependency [d]	Allowable change with respect to value at design temperature [g]	±5 %	±10 %
	Horizontal biaxial loading dependency	Change with respect to value in one directional deformation test	No requirement value	Test not required

[a] Values of shear properties are calculated based on ISO 22762-3:2018, Annex F.

[b] Effect of compressive stress on shear properties is measured by tests under compressive stress of 0,5 σ_0 and 2,0 σ_0. (Refer to ISO 22762-3:2018, Annex D.)

[c] Requirement is based on property values measured for 50th cycle.

[d] Effect of temperature on shear properties is measured by tests at 0 °C and 40 °C.

[e] Ultimate shear strain corresponds to the smaller of breaking strain and buckling strain. (Refer to ISO 22762-3:2018, Annex G.)

[f] Reduction ratio of ultimate shear strain under horizontal biaxial loading to that under horizontal uniaxial loading is calculated. (Refer 8.3.6.)

[g] This is the average value of each measurement used in determining change.

[h] X_{max} is the maximum shear displacement defined in ISO 22762-3.

Table 4 *(continued)*

Property	Test item		Grade	
			III	II
Dependency of compressive stiffness	Shear strain dependency	Change with respect to value at zero shear strain	No requirement value	No requirement value
	Compressive stress dependency	Change with respect to value at 30 % of design compressive strain	No requirement value	No requirement value
Dependency of tensile properties	Shear strain dependency of tensile yield strength	Change with respect to value at design shear strain	No requirement value	No requirement value
	Shear strain dependency of allowable tensile strain	Change with respect to value at design shear strain	No requirement value	No requirement value
Shear strain and displacement capacity	Ultimate shear strain [e] Breaking strain, buckling strain, Ultimate property diagram (UPD) or Ultimate shear displacement Breaking displacement, buckling displacement, Ultimate property diagram (UPD)	Strain under design compressive stress	Shear strain capacity: Buckling strain ≥ 3/4 × S_2 × 100 % Breaking strain ≥ 450 % or Shear displacement capacity: Buckling and breaking displacement ≥ 1,7 X_{max} [h]	Shear strain capacity: Buckling strain ≥ 2/3 × S_2 × 100 % Breaking strain ≥ 400 % or Shear displacement capacity: Buckling and breaking displacement ≥ 1,5 X_{max} [h]
	Ultimate shear strain under horizontal biaxial loading[f]		No requirement value	Test not required
Tensile capacity	Tensile fracture strength	Values at design shear strain	No requirement value	No requirement value
	Tensile fracture strain	Values at design shear strain	≥ 100 %	≥ 50 %

[a] Values of shear properties are calculated based on ISO 22762-3:2018, Annex F.

[b] Effect of compressive stress on shear properties is measured by tests under compressive stress of 0,5 σ_0 and 2,0 σ_0. (Refer to ISO 22762-3:2018, Annex D.)

[c] Requirement is based on property values measured for 50th cycle.

[d] Effect of temperature on shear properties is measured by tests at 0 °C and 40 °C.

[e] Ultimate shear strain corresponds to the smaller of breaking strain and buckling strain. (Refer to ISO 22762-3:2018, Annex G.)

[f] Reduction ratio of ultimate shear strain under horizontal biaxial loading to that under horizontal uniaxial loading is calculated. (Refer 8.3.6.)

[g] This is the average value of each measurement used in determining change.

[h] X_{max} is the maximum shear displacement defined in ISO 22762-3.

Table 4 *(continued)*

Property	Test item		Grade	
			III	II
Durability	Change of shear stiffness	Maximum increase with respect to initial value [g]	10 %	10 %
	Change of ultimate property	Maximum decrease with respect to initial value [g]	15 %	20 %
	Compressive creep		≤6 %	≤8 %
	Cumulative shear strain	Change in property with respect to value at 3rd cycle	No requirement value	No requirement value
	Horizontal shear creep test and residual shear strain test		No requirement value	No requirement value

[a] Values of shear properties are calculated based on ISO 22762-3:2018, Annex F.

[b] Effect of compressive stress on shear properties is measured by tests under compressive stress of 0,5 σ_0 and 2,0 σ_0. (Refer to ISO 22762-3:2018, Annex D.)

[c] Requirement is based on property values measured for 50th cycle.

[d] Effect of temperature on shear properties is measured by tests at 0 °C and 40 °C.

[e] Ultimate shear strain corresponds to the smaller of breaking strain and buckling strain. (Refer to ISO 22762-3:2018, Annex G.)

[f] Reduction ratio of ultimate shear strain under horizontal biaxial loading to that under horizontal uniaxial loading is calculated. (Refer 8.3.6.)

[g] This is the average value of each measurement used in determining change.

[h] X_{max} is the maximum shear displacement defined in ISO 22762-3.

Table 5 — Performance requirement of HDR

Property	Test item		Grade	
			III	II
Compressive properties	Compressive stiffness	Tolerance	±15 %	±30 %
Shear properties [a]	Shear stiffness Equivalent damping ratio	Tolerance	±10 %	±15 %
	Design value of equivalent damping ratio		0,15 to 0,30	
Tensile properties	Tensile yield strength	Values at design shear strain	No requirement	No requirement
	Allowable tensile strain	Values at design shear strain	≥ 5 %	≥ 5 %

[a] Values of shear properties are calculated based on ISO 22762-3:2018, Annex F.

[b] Effect of compressive stress on shear properties is measured by tests under compressive stress of 0,5 σ_0 and 2,0 σ_0. (Refer to ISO 22762-3:2018, Annex D.)

[c] Requirement is based on property values measured for 50th cycle.

[d] Effect of temperature on shear properties is measured by tests at 0 °C and 40 °C.

[e] Ultimate shear strain corresponds to the smaller of breaking strain and buckling strain. (Refer to ISO 22762-3:2018, Annex G.)

[f] Reduction ratio of ultimate shear strain under horizontal biaxial loading to that under horizontal uniaxial loading is calculated. (Refer 8.3.6.)

[g] Average value of each measurement used in determining change.

[h] X_{max} is the maximum shear displacement defined in ISO 22762-3.

Table 5 *(continued)*

Property	Test item		Grade	
			III	II
Dependency of shear stiffness	Shear strain dependency	Allowable range of change with respect to property value at design shear strain	No requirement value	No requirement value
	Compressive stress dependency [b]	Allowable range of change with respect to property value at design compressive stress	K_h: −15 % to +8 % H_{eq}: −8 % to +25 %	K_h: ± 20 % H_{eq}: ± 50 %
	Frequency dependency	Percentage change with respect to value at design frequency [g]	No requirement value	No requirement value
	Repeated loading dependency −1 [c]	Allowable range of change with respect to property value at 3rd cycle	K_h: ≥ −20 % H_{eq}: ± 20 %	K_h: ≥ −30 % H_{eq}: ± 20 %
	Repeated loading dependency −2	Change in property with respect to value at 3rd cycle	No requirement value	No requirement value
	Temperature dependency [d]	Allowable change with respect to value at design temperature [g]	K_h: −15 % to +20 % H_{eq}: ± 10 %	K_h: −20 % to +25 % H_{eq}: −15 % to +10 %
	Horizontal biaxial loading dependency	Change with respect to value in one directional deformation test	No requirement value	No requirement value
Dependency of compressive stiffness	Shear strain dependency	Change with respect to value at zero shear strain	No requirement value	No requirement value
	Compressive stress dependency	Change with respect to value at 30 % of design compressive strain	No requirement value	No requirement value
Dependency of tensile properties	Shear strain dependency of tensile yield strength	Change with respect to value at design shear strain	No requirement value	No requirement value
	Shear strain dependency of allowable tensile strain	Change with respect to value at design shear strain	No requirement value	No requirement value

[a] Values of shear properties are calculated based on ISO 22762-3:2018, Annex F.

[b] Effect of compressive stress on shear properties is measured by tests under compressive stress of 0,5 σ_0 and 2,0 σ_0. (Refer to ISO 22762-3:2018, Annex D.)

[c] Requirement is based on property values measured for 50th cycle.

[d] Effect of temperature on shear properties is measured by tests at 0 °C and 40 °C.

[e] Ultimate shear strain corresponds to the smaller of breaking strain and buckling strain. (Refer to ISO 22762-3:2018, Annex G.)

[f] Reduction ratio of ultimate shear strain under horizontal biaxial loading to that under horizontal uniaxial loading is calculated. (Refer 8.3.6.)

[g] Average value of each measurement used in determining change.

[h] X_{max} is the maximum shear displacement defined in ISO 22762-3.

Table 5 *(continued)*

Property	Test item		Grade III	Grade II
Shear strain and displacement capacity	Ultimate shear strain [e] Breaking strain, buckling strain, Ultimate property diagram (UPD), or Ultimate shear displacement, Breaking displacement, buckling displacement, Ultimate property diagram (UPD)	Strain under design compressive stress	Shear strain capacity: Buckling strain ≥ 3/4 × S_2 × 100 % Breaking strain ≥ 450 % or Shear displacement capacity: Buckling and breaking displacement ≥ 1,7 X_{max} [h]	Shear strain capacity: Buckling strain ≥ 2/3 × S_2 × 100 % Breaking strain ≥ 400 % or Shear displacement capacity: Buckling and breaking displacement ≥ 1,5 X_{max} [h]
	Ultimate shear strain under horizontal biaxial loading[f]		≥ 70 %	No requirement value
Tensile capacity	Tensile fracture strength	Values at design shear strain	No requirement value	No requirement value
	Tensile fracture strain	Values at design shear strain	≥ 100 %	≥ 50 %
Durability	Change of shear properties	Allowable range of change with respect to initial value [g]	K_h: ≤ +10 % H_{eq}: ≥ −10 %	K_h: ≤ +10 % H_{eq}: ≥ −10 %
	Change of ultimate property	Maximum decrease with respect to initial value [g]	15 %	20 %
	Compressive creep		≤ 6 %	≤ 8 %
	Cumulative shear strain	Change in property with respect to value at 3rd cycle	No requirement value	No requirement value
	Horizontal shear creep test and residual shear strain test		No requirement value	No requirement value

[a] Values of shear properties are calculated based on ISO 22762-3:2018, Annex F.

[b] Effect of compressive stress on shear properties is measured by tests under compressive stress of 0,5 σ_0 and 2,0 σ_0. (Refer to ISO 22762-3:2018, Annex D.)

[c] Requirement is based on property values measured for 50th cycle.

[d] Effect of temperature on shear properties is measured by tests at 0 °C and 40 °C.

[e] Ultimate shear strain corresponds to the smaller of breaking strain and buckling strain. (Refer to ISO 22762-3:2018, Annex G.)

[f] Reduction ratio of ultimate shear strain under horizontal biaxial loading to that under horizontal uniaxial loading is calculated. (Refer 8.3.6.)

[g] Average value of each measurement used in determining change.

[h] X_{max} is the maximum shear displacement defined in ISO 22762-3.

Table 6 — Performance requirement of LRB

Property	Test item		Grade	
			III	II
Compressive properties	Compressive stiffness	Tolerance	±15 %	±20 %
Shear properties [a]	Post-yield stiffness Characteristic strength	Tolerance	±10 %	±15 %
	Design value of shear yield stress		7,0 to 8,5 MPa	
Tensile properties	Tensile yield strength	Values at design shear strain	No requirement value	No requirement value
	Allowable tensile strain	Values at design shear strain	≥ 5 %	≥ 5 %
Dependency of shear stiffness	Shear strain dependency	Allowable range of change with respect to property value at design shear strain	No requirement value	No requirement value
	Compressive stress dependency [b]	Allowable range of change with respect to property value at design compressive stress	K_d: −25 % to +10 % Q_d: ± 8 %	K_d: −40 % to +20 % Q_d: ± 15 %
	Frequency dependency	Percentage change with respect to value at design frequency [g]	No requirement value	No requirement value
	Repeated loading dependency −1 [c]	Allowable range of change with respect to property value at 3rd cycle	K_d: ≥ −10 % Q_d: ≥ −30 %	K_d: ≥ −10 % Q_d: ≥ −30 %
	Repeated loading dependency −2	Change in property with respect to value at 3rd cycle	No requirement value	No requirement value
	Temperature dependency [d]	Allowable change with respect to value at design temperature [g]	K_d: ± 5 % Q_d: ± 25 %	K_d: ± 10 % Q_d: ± 25 %
	Horizontal biaxial loading dependency	Change with respect to value in one directional deformation test	No requirement value	Test not required

[a] Values of shear properties are calculated based on ISO 22762-3:2018, Annex F.

[b] Effect of compressive stress on shear properties is measured by tests under compressive stress of 0,5 σ_o and 2,0 σ_0. (Refer to ISO 22762-3:2018, Annex D.)

[c] Requirement is based on property values measured for 50th cycle.

[d] Effect of temperature on shear properties is measured by tests at 0 °C and 40 °C.

[e] Ultimate shear strain corresponds to the smaller of breaking strain and buckling strain. (Refer to ISO 22762-3:2018, Annex G.)

[f] Reduction ratio of ultimate shear strain under horizontal biaxial loading to that under horizontal uniaxial loading is calculated. (Refer 8.3.6.)

[g] Average value of each measurement used in determining change.

[h] X_{max} is the maximum shear displacement defined in ISO 22762-3.

Table 6 *(continued)*

Property	Test item		Grade	
			III	II
Dependency of compressive stiffness	Shear strain dependency	Change with respect to value at zero shear strain	No requirement value	No requirement value
	Compressive stress dependency	Change with respect to value at 30 % of design compressive strain	No requirement value	No requirement value
Dependency of tensile properties	Shear strain dependency of tensile yield strength	Change with respect to value at design shear strain	No requirement value	No requirement value
	Shear strain dependency of allowable tensile strain	Change with respect to value at design shear strain	No requirement value	No requirement value
Shear strain and displacement capacity	Ultimate shear strain [e] Breaking strain, buckling strain, Ultimate property diagram (UPD) or Ultimate shear displacement Breaking displacement, buckling displacement, Ultimate property diagram (UPD)	Strain under design compressive stress	Shear strain capacity: Buckling strain ≥ 3/4 × S_2 × 100 % Breaking strain ≥ 450 % or Shear displacement capacity: Buckling and breaking displacement ≥ 1,7 X_{max}[h]	Shear strain capacity: Buckling strain ≥ 2/3 × S_2 × 100 % Breaking strain ≥ 400 % or Shear displacement capacity: Buckling and breaking displacement ≥ 1,5 X_{max}[h]
	Ultimate shear strain under horizontal biaxial loading[f]		≥ 70 %	No requirement value
Tensile capacity	Tensile fracture strength	Values at design shear strain	No requirement value	No requirement value
	Tensile fracture strain	Values at design shear strain	≥ 100 %	≥ 50 %

[a] Values of shear properties are calculated based on ISO 22762-3:2018, Annex F.

[b] Effect of compressive stress on shear properties is measured by tests under compressive stress of 0,5 σ_o and 2,0 σ_0. (Refer to ISO 22762-3:2018, Annex D.)

[c] Requirement is based on property values measured for 50th cycle.

[d] Effect of temperature on shear properties is measured by tests at 0 °C and 40 °C.

[e] Ultimate shear strain corresponds to the smaller of breaking strain and buckling strain. (Refer to ISO 22762-3:2018, Annex G.)

[f] Reduction ratio of ultimate shear strain under horizontal biaxial loading to that under horizontal uniaxial loading is calculated. (Refer 8.3.6.)

[g] Average value of each measurement used in determining change.

[h] X_{max} is the maximum shear displacement defined in ISO 22762-3.

Table 6 *(continued)*

Property	Test item		Grade	
			III	II
Durability	Change of shear stiffness	Maximum increase with respect to initial value [g]	K_d: 10 % Q_d: No requirement value	K_d: 10 % Q_d: No requirement value
	Change of ultimate property	Maximum decrease with respect to initial value [g]	15 %	20 %
	Compressive creep		≤6 %	≤8 %
	Cumulative shear strain	Change in property with respect to value at 3rd cycle	No requirement value	No requirement value
	Horizontal shear creep test and residual shear strain test		No requirement value	No requirement value

[a] Values of shear properties are calculated based on ISO 22762-3:2018, Annex F.

[b] Effect of compressive stress on shear properties is measured by tests under compressive stress of 0,5 σ_o and 2,0 σ_0. (Refer to ISO 22762-3:2018, Annex D.)

[c] Requirement is based on property values measured for 50th cycle.

[d] Effect of temperature on shear properties is measured by tests at 0 °C and 40 °C.

[e] Ultimate shear strain corresponds to the smaller of breaking strain and buckling strain. (Refer to ISO 22762-3:2018, Annex G.)

[f] Reduction ratio of ultimate shear strain under horizontal biaxial loading to that under horizontal uniaxial loading is calculated. (Refer 8.3.6.)

[g] Average value of each measurement used in determining change.

[h] X_{max} is the maximum shear displacement defined in ISO 22762-3.

6.5.2 Compressive properties

General requirements, the test piece and test conditions are specified in ISO 22762-3:2018, 6.5.2.2 and 6.5.2.3 and shall be followed.

6.5.3 Shear properties

General requirements, the test piece and test conditions are specified in ISO 22762-3:2018, 6.5.3.2 and 6.5.3.3 and shall be followed.

6.5.4 Tensile properties

General requirements, the test piece and test conditions are specified in ISO 22762-3:2018, 6.5.4 and shall be followed.

6.5.5 Dependencies of shear properties

General requirements, the test piece and test conditions are specified in ISO 22762-3:2018, 6.5.5 and shall be followed.

6.5.6 Dependencies of compressive properties

General requirements, the test piece and test conditions are specified in ISO 22762-3:2018, 6.5.6. General requirements, the test piece and test conditions are specified in ISO 22762-3:2018, 6.5.6 and shall be followed.

6.5.7 Shear displacement capacity

General requirements, the test piece and test conditions are specified in ISO 22762-3:2018, 6.5.7. General requirements, the test piece and test conditions are specified in ISO 22762-3:2018, 6.5.7 and shall be followed.

6.5.8 Durability

General requirements, the test piece and test conditions are specified in ISO 22762-3:2018, 6.5.8 and shall be followed.

6.6 Test pieces for type testing

6.6.1 General

The scale and minimum number of test pieces for type testing are shown in Table 7. The scale includes full-scale, scale A, scale B, scale C and scale D. These scale models are defined in Table 8.

Table 7 — Test pieces for type testing

Property	Test item	Scale		Minimum number	
		Grade III	Grade II	Grade III	Grade II
Compressive properties	Compressive stiffness	Full-scale only		6.6.2 a)	
Shear properties	Shear stiffness Equivalent damping ratio [e] Post-yield stiffness (for LRB) Characteristic strength (for LRB) [f]	Full-scale only			
Tensile properties [a]	Tensile yield strength	Full-scale, Scale C		3 [b]	
	Allowable tensile strain	Full-scale, Scale C		3 [b]	
Dependency of shear stiffness	Shear strain dependency	Full-scale, Scale C		3 [b]	
	Compressive stress dependency	Full-scale, Scale C		3 [b]	
	Frequency dependency	Scale B	Scale A	3	
	Repeated loading dependency −1	Full-scale, Scale C	Scale B	3	
	Repeated loading dependency −2	Full-scale, Scale C	Scale B	3	
	Temperature dependency	Scale B	Scale A	3	
	Horizontal biaxial loading dependency	Full-scale, Scale C	Scale A	2	
Dependency of compressive stiffness	Shear strain dependency	Full-scale, Scale C		3	
	Compressive stress dependency	Full-scale, Scale C		3	

[a] In tensile tests, the shape of flanges should be decided by considering the influence of their out-of-plane deformation.

[b] Test piece with ±10 % of minimum value of first shape factor S_1 of the series, and test piece with ±5 % of minimum value of second shape factor S_2 of the series should be included.

[c] Test piece with ±10 % of minimum value of first shape factor S_1 should be used.

[d] Test piece with ±10 % of minimum value of first shape factor S_1 of the series, and test piece with ±5 % of minimum value of second shape factor S_2 of the series, or test piece with ±10 % of maximum value of first shape factor S_1 of the series, and test piece with ±5 % of maximum value of second shape factor S_2 of the series should be included.

[e] HDR only.

[f] LRB only.

Table 7 *(continued)*

<table>
<tr><td rowspan="2">Dependency of tensile properties</td><td colspan="2">Shear strain dependency of tensile yield strength</td><td colspan="2">Full-scale, Scale C</td><td colspan="2">3</td></tr>
<tr><td colspan="2">Shear strain dependency of allowable tensile strain</td><td colspan="2">Full-scale, Scale C</td><td colspan="2">3</td></tr>
<tr><td rowspan="3">Shear strain and displacement capacity</td><td colspan="2">Ultimate shear strain
Breaking strain,
buckling strain,
Ultimate property diagram (UPD)
or
Ultimate shear displacement
Breaking displacement,
buckling displacement,
Ultimate property diagram (UPD)</td><td>Full-scale</td><td>Full-scale, Scale C</td><td colspan="2">6.6.2 b)</td></tr>
<tr><td rowspan="2">Ultimate shear strain under horizontal biaxial loading</td><td>Standard ultimate shear strain under uniaxial loading</td><td>Full-scale, Scale C</td><td>Scale A</td><td colspan="2">3</td></tr>
<tr><td>Reduction of ultimate shear strain due to biaxial loading</td><td>Full-scale, Scale C</td><td>Scale A</td><td colspan="2">3 [d]</td></tr>
<tr><td rowspan="2">Tensile capacity [a]</td><td colspan="2">Tensile fracture strength</td><td colspan="2">Full-scale, Scale C</td><td colspan="2">3 [d]</td></tr>
<tr><td colspan="2">Tensile fracture strain</td><td colspan="2">Full-scale, Scale C</td><td colspan="2">3 [d]</td></tr>
<tr><td rowspan="4">Durability</td><td colspan="2">Property change</td><td>Scale B</td><td>Scale A</td><td colspan="2">3</td></tr>
<tr><td colspan="2">Compressive creep</td><td colspan="2">Scale A</td><td>3 [c]</td><td>2 [c]</td></tr>
<tr><td colspan="2">Cumulative shear strain</td><td colspan="2">Scale B</td><td>3</td><td>2</td></tr>
<tr><td colspan="2">Horizontal shear creep test and residual shear strain test</td><td>Scale B</td><td>Scale A</td><td colspan="2">4</td></tr>
</table>

[a] In tensile tests, the shape of flanges should be decided by considering the influence of their out-of-plane deformation.

[b] Test piece with ±10 % of minimum value of first shape factor S_1 of the series, and test piece with ±5 % of minimum value of second shape factor S_2 of the series should be included.

[c] Test piece with ±10 % of minimum value of first shape factor S_1 should be used.

[d] Test piece with ±10 % of minimum value of first shape factor S_1 of the series, and test piece with ±5 % of minimum value of second shape factor S_2 of the series, or test piece with ±10 % of maximum value of first shape factor S_1 of the series, and test piece with ±5 % of maximum value of second shape factor S_2 of the series should be included.

[e] HDR only.

[f] LRB only.

6.6.2 Number of test pieces

a) The following are requirements for compressive properties and shear properties testing.

1) In case of testing a series of isolators, three or more for the representative size, two or more for the size close to the representative size, and one or more in the other sizes. However, the test may be omitted for isolators which have outer diameter within ±10 % of that of isolator with test results.

2) The total number of test pieces shall be 50 or more for grade III and 30 or more for grade II.

b) The following are requirements for ultimate properties.

1) The number of test pieces shall be the quantity that can produce ultimate property diagram specified in ISO 22762-3:2018, Annex B.

2) The ultimate property diagram for each S_2 in a series of isolators should be produced. However, by preparing an ultimate property diagram based on the experiment on isolators with minimum, intermediate and maximum S_2 in a series, and using the appropriate method (refer ISO 22762-3:2018, Annex G), ultimate property diagrams of other sizes may be created.

c) Numbers of test pieces for the other test items are specified in Table 7.

d) If the same specimen is used for several tests, the effects of repetition must be taken into account.

6.6.3 Scale of test pieces

If the minimum allowed scaled dimension exceeds that of full-size isolator, the test piece shall not be a scaled one.

Table 8 — Type and definition of scale model

Type	Circular bearing (diameter)	Rectangular bearing (side length)	First shape factor S_1	Second shape factor S_2
Scale A	> 150 mm	> 100 mm	Within range of the series	Within range of the series
Scale B	> 450 mm	> 400 mm	Within range of the series	Within range of the series
Scale C	1/2 or more of the maximum value of the series and 800 mm or more		Within range of the series	Within range of the series

6.7 Rubber material requirements

Rubber material requirements are specified in ISO 22762-3:2018, 6.6.

6.8 Dimensional requirements

Dimensional requirements are specified in ISO 22762-3:2018, 6.7.

6.9 Requirements on steel used for flanges and reinforcing plates

Requirements on steel used for flanges and reinforcing plates are specified in ISO 22762-3:2018, 6.8.

6.10 Requirements on lead material for LRB

Requirements on lead material for LRB are specified in ISO 22762-3:2018, 6.9.

7 Marking and labelling

7.1 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.

7.2 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 9;

Table 9 — 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.

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.

7.3 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.

7.4 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

Key

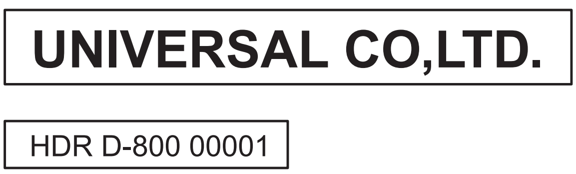
1 name of manufacturer

2 type

3 size (mm)

4 serial number

EXAMPLE 2



8 Test methods

8.1 General

Test methods are specified to confirm the performance requirements of elastomeric isolators as described in 6.5.

When the same test piece is used for several tests, it shall be noted if the performance is influenced by repetition.

In case of testing more than one test piece, all test results shall be reported together with their average value.

NOTE Some of these properties can be determined using one of the standard test pieces detailed in ISO 22762-1:2018, Tables 10 and 11. The standard test piece is used for non-specific product testing, such as testing for the development of new materials and products.

8.2 Various dependence tests

8.2.1 Repeated deformation dependence of shear properties

8.2.1.1 Principle

A test piece is attached to a compression-shear testing machine and loaded with a constant compressive force. In this state, the test piece is subjected to 50 m or more of total shear displacement, or for total shear displacement specified by the structural engineer. The shear force and the shear displacement are measured. The shear properties, such as shear stiffness and equivalent damping ratio, are evaluated and their dependence on the number of repetitions determined.

In order to differentiate between the change in properties due to temperature rise and that due to repeated deformation, the test piece is cooled down to the initial pre-load temperature after the repeated cycles of deformation. The shear properties are then evaluated again.

8.2.1.2 Test machine

The test machine shall be as specified in ISO 22762-1:2018, 6.2.2.2.

8.2.1.3 Test piece

The test piece shall be as specified in Table 7.

8.2.1.4 Test conditions

8.2.1.4.1 Test temperature

The test temperature shall be as specified in ISO 22762-1:2018, 6.2.1.4.1.

8.2.1.4.2 Conditioning time for test piece

The conditioning time for test piece shall be as specified in ISO 22762-1:2018, 6.2.1.4.2.

8.2.1.4.3 Compressive force

The compressive force shall be as specified in ISO 22762-1:2018, 6.2.2.4.3.

8.2.1.4.4 Test shear strain amplitude

The shear strain amplitude shall be 2,0 γ_0.

8.2.1.4.5 Input wave

The input wave shall be as specified in ISO 22762-1:2018, 6.2.2.4.5.

8.2.1.4.6 Test vibration frequency

The test vibration frequency shall be between 0,2 Hz and the isolation frequency or 0,5 Hz. When any other frequency is used, it shall be selected with the agreement of both the structural engineer and the manufacturer.

8.2.1.5 Procedure

8.2.1.5.1 Attachment of test piece

The test piece shall be attached to a compression-shear testing machine as specified in ISO 22762-1:2018, 6.2.2.5.1.

It is better to provide a heat insulating material between the test piece and the testing machine.

8.2.1.5.2 Loading of test piece

The test piece shall be loaded as follows.

a) Subject the test piece to a compressive force that is equivalent to the design compressive stress, σ_0, as defined in ISO 22762-3.

b) Subject the test piece with the specified 50 m or more of total shear displacement.

8.2.1.6 Expression of results

With the method used in ISO 22762-1:2018, 6.2.2.6, determine each property value from the 1st, 3rd, 5th, 10th, and every subsequent 10th cycle or as specified by the structural engineer. Determine the reference value of the property from the first 3 cycles or 11 cycles in accordance with ISO 22762-1:2018, 6.2.2. Determine the change in properties after the repeated cycling from the 3 cycles or 11 cycles of loading executed.

The change in each property shall be expressed as the ratio of each value to the reference value.

8.2.1.7 Test report

The test report shall include the following:

a) reference to this document, i.e. ISO 22762-6:2022;

b) type and classification, shape and dimensions, first shape factor and second shape factor of test piece;

c) name of test machine;

d) test temperature;

e) input wave and vibration frequency;

f) direction of shear force applied to test piece;

g) compressive force and shear displacement amplitude (or compressive stress and shear strain);

h) properties, such as shear stiffness and equivalent damping ratio, at each cycle for which they were determined;

i) change in each property with cycling;

j) graph showing relationship between the percentage change of each property and the number of repetitions;

k) graph showing relationship between compressive force and shear displacement, if requested;

l) plots of shear force versus shear displacement (hysteresis loop);

m) test date.

8.2.2 Horizontal biaxial loading dependency

8.2.2.1 Principle

A test piece is attached to a compression-shear testing machine and subjected to a constant compressive force. In this state, the test piece is subjected to multiple levels of shear displacement. The shear force and the shear displacement are measured. Afterwards, the test piece is subjected to multiple levels of two horizontal directional displacement. The two directional shear force and the two directional shear displacement are measured. By means of these measurements, the dependence of the two direction shear properties to one direction shear strain (shear stiffness and equivalent damping ratio) is determined.

8.2.2.2 Test machine

For bi-directional horizontal test, test machines shall be capable of compressing and two direction shearing the elastomeric isolator under controlled conditions. They shall also provide a method of measuring the compressive force, compressive displacement, shear force and shear displacement to an accuracy of 1 % of the maximum values recorded. The force calibration of the machine shall be based on ISO 7500-1. The machines shall maintain the parallelism of the upper and lower loading platens for the test piece attachment during the test. A Class 1 machine, as defined in ISO 7500-1 is recommended.

For uni-directional horizontal test, test machines can be used as specified in ISO 22762-1:2018, 6.2.2.2.

8.2.2.3 Test piece

The test piece shall be as specified in Table 7.

8.2.2.4 Test conditions

8.2.2.4.1 Test temperature

The test temperature shall be as specified in ISO 22762-1:2018, 6.2.1.4.1.

8.2.2.4.2 Conditioning time for test piece

The conditioning time for test piece shall be as specified in ISO 22762-1:2018, 6.2.1.4.2.

8.2.2.4.3 Compressive force

The compressive force shall be as specified in ISO 22762-1:2018, 6.2.2.4.3.

8.2.2.4.4 Test shear strain amplitudes

The test piece is loaded in two directions as an elliptical orbit in the horizontal plane.

The phase between major and minor shear displacement should be 90°.

Levels of shear strain of major axis direction at the two horizontal directional test shall be 0,5 γ_0, γ_0, 1,5 γ_0, 2,0 γ_0.

It is desirable to add shear strain amplitude 2,5 γ_0 for test piece with a secondary shape factor of 4 or more.

Levels of shear strain of minor axis direction at the two horizontal directional test shall be half of the shear strain of major axis direction.

The tolerance shall be within ±5 % of each shear strain amplitude value.

The sequence of shear loading shall be in the order of increasing strain, considering loading history dependency.

8.2.2.4.5 Input wave

The input wave shall be as specified in ISO 22762-1:2018, 6.2.2.4.5.

8.2.2.4.6 Test vibration frequency

The test vibration frequency shall be as specified in ISO 22762-1:2018, 6.2.2.4.6. The test vibration frequency of each shear strain level shall be the same.

8.2.2.5 Procedure

8.2.2.5.1 Attachment of test piece

The test piece shall be attached to a compression-shear testing machine as specified in ISO 22762-1:2018, 6.2.2.5.1.

8.2.2.5.2 Loading of test piece

The test piece shall be loaded as follows.

a) Subject the test piece to a compressive force that is equivalent to the design compressive stress, σ_0.

b) Load the test piece in one direction with shear displacements equivalent to each of the major axis shear strain amplitude to be tested. Load the test piece in the order of increasing shear strain, in the number of cycles specified in ISO 22762-1:2018, 6.2.2.5.2 for each shear strain.

c) Load the test piece in two directions with shear displacements equivalent to each of the major and the minor axis shear strain amplitude to be tested. Load the test piece in the order of increasing shear strain, in the number of cycles specified in ISO 22762-1:2018, 6.2.2.5.2 for each shear strain.

8.2.2.6 Expression of results

With the method used in ISO 22762-1:2018, 6.2.2.6, determine each property value for each test shear strain.

Determine the change of the major axis properties in a two direction test with respect to the properties in one direction test.

The change in each property shall be expressed as the ratio of each value to the reference value.

8.2.2.7 Test report

The test report shall include the following items:

a) reference to this document, i.e. ISO 22762-6:2022;

b) type and classification, shape and dimensions, first shape factor and second shape factor of test piece;

c) name of test machine;

d) test temperature;

e) input wave and vibration frequency;

f) direction of shear force applied to test piece;

g) compressive force and shear displacement (or compressive stress and shear strain);

h) essential parameters such as shear stiffness, equivalent damping ratio, method of determination (e.g. the third loop or the average of the second to the eleventh loop);

i) change of each property in two-direction test with respect to one direction test;

j) graph showing the relationship between each property in two-direction test with respect to one direction test;

k) graph showing the relationship between compressive force and shear displacement, if requested;

l) plot of shear force versus shear displacement (hysteresis loop);

m) test date.

8.2.3 Dependence of compression properties on shear strain

The test of dependence of compression properties on shear strain shall be as specified in ISO 22762-1.

The test piece shall be subjected to constant shear displacement. The shear displacement shall be defined in Table 10.

γ_0 in Table 10 is the design shear strain defined in ISO 22762-3. The tolerance shall be within ±5 % of each shear strain.

Table 10 — Shear strains

Shear strain **%**	0	γ_0	2,0 γ_0

If 2,0 γ_0 is larger than γ_{max}, γ_{max} may be selected instead of 2,0 γ_0.

8.3 Ultimate properties under horizontal biaxial loading test

8.3.1 Principle

When elastomeric isolators with damping function such as high damping rubber bearings and lead rubber bearings deform in two horizontal directions, shear strain occurs due to not only horizontal deformation but also torsion. In these cases, ultimate shear strain is reduced compared to the strain in one direction. Therefore, it is necessary to consider the effect of deformation in two directions on ultimate properties.

Reduction ratio of ultimate shear strain in case of considering two directions shall be determined based on results of horizontal uniaxial loading tests and horizontal biaxial loading tests.

In the horizontal uniaxial loading test, test pieces are loaded with increasing shear deformation in one direction until failure (breaking or buckling) occurs under constant compressive stress. The standard ultimate shear strain under uniaxial loading is determined by this test.

In the horizontal biaxial loading test, test pieces are loaded with increasing shear deformation in two directions until failure (breaking or buckling) occurs under constant compressive stress. The reduction of ultimate shear strain under biaxial loading is determined by this test.

If a more detailed test is required, refer to Annex B.

8.3.2 Test machine

The test machine shall be as specified in 8.2.2.2.

8.3.3 Test piece

The test piece shall be a full-scale isolator or a scale model, as specified in Table 7.

The test piece used for horizontal uniaxial loading test and the test piece used for horizontal biaxial loading test shall have the same shape and dimensions.

8.3.4 Test conditions

8.3.4.1 Test temperature

The test temperature shall be as specified in ISO 22762-1:2018, 6.2.1.4.1.

8.3.4.2 Conditioning time for test piece

The conditioning time for test piece shall be as specified in ISO 22762-1:2018, 6.2.1.4.2.

8.3.4.3 Compressive force

The compressive force shall be as specified in ISO 22762-1:2018, 6.2.2.4.3.

8.3.4.4 Shear strain amplitudes

In the horizontal biaxial loading test, the horizontal forces are applied in two directions by moving on elliptical orbits. In the elliptical orbits, a ratio of minor axis amplitude to major axis amplitude shall be 1/2 and the phase angle of minor axis displacement to major axis displacement shall be 90°.

Shear strain amplitude in the horizontal uniaxial loading test and major axis shear strain amplitude in the horizontal biaxial loading test shall be γ_0, 2,0 γ_0, and thereafter, values increased by 0,5 γ_0.

The tolerance shall be within ±5 % of each shear strain amplitude value.

The sequence of shear loading shall be in the order of increasing strain, considering loading history dependency.

8.3.4.5 Input wave

The input wave shall be as specified in ISO 22762-1:2018, 6.2.2.4.5.

8.3.4.6 Test vibration frequency

The test vibration frequency shall be as specified in ISO 22762-1:2018, 6.2.2.4.6. The test vibration frequency of each shear strain level shall be the same.

8.3.5 Procedure

8.3.5.1 Attachment of test piece

The test piece shall be attached to a compression-shear testing machine as specified in ISO 22762-1:2018, 6.2.2.5.1.

8.3.5.2 Loading of test piece

8.3.5.2.1 Horizontal uniaxial loading test

The compressive force corresponding to the design compressive stress, σ_0 is applied. The horizontal strain is applied in one direction with amplitudes specified in 8.3.4.4 until failure (breaking or buckling) occurs. The number of loading cycle is three until shear amplitude of 2,0 γ_0, and one over 2,0 γ_0.

8.3.5.2.2 Horizontal biaxial loading test

The compressive force corresponding to the design compressive stress, σ_0 is applied. The horizontal strain is applied in two directions by moving on elliptical orbits with major axis amplitude specified in 8.3.4.4 until failure (breaking or buckling) occurs. The number of loading cycle is three until shear amplitude of 2,0 γ_0, and one over 2,0 γ_0.

8.3.6 Expression of results

The standard ultimate shear strain under uniaxial loading, γ_u shall be the amplitude of the step immediately before the amplitude at which the failure occurs in the horizontal uniaxial loading test.

Ultimate shear strain under biaxial loading, γ_b shall be the amplitude of the step immediately before the amplitude at which the failure occurs in horizontal biaxial loading test.

Ratio of ultimate shear strain under horizontal biaxial loading to that under horizontal uniaxial loading shall be calculated by dividing γ_b by γ_u.

8.3.7 Test report

The test report shall include the following items:

a) reference to this document, i.e. ISO 22762-6:2022;

b) type and classification, shape and dimensions, first shape factor and second shape factor of test piece;

c) name of test machine;

d) test temperature;

e) input wave and vibration frequency;

f) direction of shear force applied to test piece;

g) compressive force and shear displacement (or compressive stress and shear strain);

h) ultimate conditions (breaking or buckling) in horizontal uniaxial loading test and horizontal biaxial loading test;

i) ratio of ultimate shear strain under biaxial loading to ultimate shear strain under horizontal uniaxial loading;

j) graph showing the relationship between compressive force and shear displacement, if requested;

k) plot of shear force versus shear displacement (hysteresis loop);

l) test date.

8.4 Tensile testing

8.4.1 Allowable tensile strain

8.4.1.1 Principle

A test piece is attached to a tensile shear test machine, subjected to a constant shear displacement and loaded with tensile force until tensile displacement reaches three times the allowable tensile strain or fracture occurs. The tensile force, tensile displacement, shear force and shear displacement are measured. Measure the shear characteristics before and after the test and check that the change is small.

8.4.1.2 Test machine

The test machine shall be as specified in ISO 22762-1:2018, 6.5.

8.4.1.3 Test piece

The test piece shall be as specified in Table 7.

8.4.1.4 Test conditions

8.4.1.4.1 Test temperature

The test temperature shall be as specified in ISO 22762-1:2018, 6.2.1.4.1.

8.4.1.4.2 Conditioning time for test piece

The conditioning time for test piece shall be as specified in ISO 22762-1:2018, 6.2.1.4.2.

8.4.1.4.3 Test shear strain

The test shear strain shall be 1,0 γ_0. The tolerance shall be within ±5 %.

8.4.1.4.4 Test speed

The test speed shall be as specified in ISO 22762-1:2018, 6.5.4.4.

8.4.1.5 Procedure

8.4.1.5.1 Attachment of test piece

The test piece shall be attached to a compression-shear testing machine as specified in ISO 22762-1:2018, 6.5.5.1.

8.4.1.5.2 Loading

The test piece shall be loaded as follows.

a) Apply the prescribed shear strain to the test piece.

b) Apply the tensile force to the test piece until tensile displacement reaches 3,0 ε_{Tl} or load it until failure is observed.

8.4.1.6 Expression of results

The allowable tensile strain shall be checked as follows.

a) Measure the shear properties of a test piece defined in ISO 22762-1:2018, 6.2.2.

b) Test as defined in 8.4.1.5.

c) Measure the shear properties of a test piece defined in ISO 22762-1:2018, 6.2.2. Determine the change of the shear properties compared with the results from a).

d) Measure the ultimate shear displacement of a test piece under the design compressive stress, σ_0 defined in ISO 22762-1:2018, 6.4.

e) Check the allowable limit of tensile strain is $\varepsilon_{\mathrm{Tl}}$, i.e. the change of the shear properties determined in c) are within ±10 % and the ultimate shear strain measured in d) is greater than the defined ultimate shear strain in ISO 22762-1:2018, 6.4.

8.4.1.7 Test report

The test report shall include the following:

a) reference to this document, i.e. ISO 22762-6:2022;

b) type and classification, shape and dimensions, first shape factor and second shape factor of test piece;

c) name of test machine;

d) test temperature;

e) test speed;

f) shear displacement (if any);

g) allowable limit of tensile strain, $\varepsilon_{\mathrm{Tl}}$;

h) tensile force-displacement curve;

i) plot of shear force versus shear displacement (hysteresis loop) from shear property test without and with tensile strain applied;

j) plot of shear force versus shear displacement (hysteresis loop) from ultimate shear displacement test with tensile strain applied;

k) test date.

8.4.2 Shear strain dependency of tensile yield strength

8.4.2.1 Principle

The test of dependence of tensile yield force on shear strain shall be as specified in ISO 22762-1:2018, 6.5.

The test piece shall be as specified in Table 7.

The test piece shall be subjected to constant shear displacement. The shear displacement shall be defined in Table 10.

γ_0 in Table 10 is the design shear strain defined in ISO 22762-3. The tolerance shall be within ±5 % of each shear strain.

If 2,0 γ_0 is larger than $\gamma_{\max}$, $\gamma_{\max}$ may be selected instead of 2,0 γ_0.

8.4.2.2 Expression of results

With the method used in ISO 22762-1:2018, 6.5, determine each property value for each test shear strain.

8.4.2.3 Test report

The test report shall include the following:

a) reference to this document, i.e. ISO 22762-6:2022;

b) type and classification, shape and dimensions, first shape factor and second shape factor of test piece;

c) name of test machine;

d) test temperature;

e) test speed;

f) shear displacement (or shear strain);

g) tensile yield force, P_{Ty}, or tensile break force, P_{Tb};

h) graph showing the relationship between each property and shear strain;

i) test date;

j) tensile force-displacement curve.

8.4.3 Shear strain dependency of allowable tensile strain

8.4.3.1 Principle

The test of dependence of allowable limit of tensile strain on shear strain shall be as specified in 8.4.1.

The test piece shall be as specified in Table 7.

The test piece shall be subjected to constant shear displacement. The shear displacement shall be defined in Table 10.

γ_0 in Table 10 is the design shear strain defined in ISO 22762-3. The tolerance shall be within ±5 % of each shear strain.

If 2,0 γ_0 is larger than γ_{max}, γ_{max} may be selected instead of 2,0 γ_0.

8.4.3.2 Expression of results

With the method used in 8.4.1, determine each property value for each test shear strain.

8.4.3.3 Test report

The test report shall include the following:

a) reference to this document, i.e. ISO 22762-6:2022;

b) type and classification, shape and dimensions, first shape factor and second shape factor of test piece;

c) name of test machine;

d) test temperature;

e) test speed;

f) shear displacement (or shear strain);

g) allowable limit of tensile strain, $\varepsilon_{\mathrm{Tl}}$;

h) graph showing the relationship between each property and shear strain;

i) tensile force-displacement curve;

j) plot of shear force versus shear displacement (hysteresis loop) of shear property test before and after test described in 8.4.3;

k) plot of shear force versus shear displacement (hysteresis loop) of ultimate shear displacement test after test described in 8.4.3;

l) test date.

8.4.4 Tensile fracture strain

8.4.4.1 Principle

A test piece is attached to a tensile shear test machine, subjected to a constant shear displacement and loaded with tensile force until fracture occurs. The tensile force, tensile displacement, shear force and shear displacement are measured. The tensile force and the tensile displacement of the test piece at fracture are determined.

8.4.4.2 Test machine

The test machine shall be as specified in ISO 22762-1:2018, 6.5.

8.4.4.3 Test piece

The test piece shall be as specified in Table 7.

8.4.4.4 Test conditions

8.4.4.4.1 Test temperature

The test temperature shall be as specified in ISO 22762-1:2018, 6.2.1.4.1.

8.4.4.4.2 Conditioning time for test piece

The conditioning time for test piece shall be as specified in ISO 22762-1:2018, 6.2.1.4.2.

8.4.4.4.3 Test shear strain

The shear strain shall be 2,0 γ_0. The tolerance shall be within ±5 %.

8.4.4.4.4 Test speed

The test speed shall be as specified in ISO 22762-1:2018, 6.5.4.4.

8.4.4.5 Procedure

8.4.4.5.1 Attachment of test piece

The test piece shall be attached to a compression-shear testing machine as specified in ISO 22762-1:2018, 6.5.5.1.

8.4.4.5.2 Loading

The test piece shall be loaded as follows.

a) Apply the prescribed shear strain to the test piece.

b) Apply the tensile force to the test piece, until failure is observed.

8.4.4.6 Expression of results

The tensile force and the tensile displacement at break shall be recorded. Otherwise, it shall be recorded that no obvious signs of failure were observed at the maximum applied tensile force.

8.4.4.7 Test report

The test report shall include the following:

a) reference to this document, i.e. ISO 22762-6:2022;

b) type and classification, shape and dimensions, first shape factor and second shape factor of test piece;

c) name of test machine;

d) test temperature;

e) test speed;

f) shear displacement (or shear strain);

g) tensile break force, P_{Tb}, tensile break displacement (or tensile break stress, tensile break strain);

h) test date;

i) tensile force-displacement curve.

8.5 Durability

8.5.1 Cumulative shear strain

8.5.1.1 Principle

A test piece is attached to a compression-shear testing machine and loaded with a constant compressive force. In this state, the test piece is subjected to cyclic shear displacement for the number of cycles specified. The shear force and the shear displacement are measured. The shear properties, such as shear stiffness and equivalent damping ratio, are evaluated and their dependence on the number of cycles determined.

In order to differentiate between the change in properties due to temperature rise and that due to repeated deformation, the test piece is cooled down to the initial pre-load temperature after the repeated cycles of deformation. The shear properties are then evaluated again.

8.5.1.2 Test machine

The test machine shall be as specified in ISO 22762-1:2018, 6.2.2.2.

8.5.1.3 Test piece

The test piece shall be as specified in Table 7.

8.5.1.4 Test conditions

8.5.1.4.1 Test temperature

The test temperature shall be as specified in ISO 22762-1:2018, 6.2.1.4.1.

8.5.1.4.2 Conditioning time for test piece

The conditioning time for test piece shall be as specified in ISO 22762-1:2018, 6.2.1.4.2.

8.5.1.4.3 Compressive force

The compressive force shall be as specified in ISO 22762-1:2018, 6.2.2.4.3.

8.5.1.4.4 Test shear strain amplitude

Two or more values of shear strain amplitude between 0,01 γ_0 and 0,5 γ_0 shall be used.

8.5.1.4.5 Input wave

The input wave shall be as specified in ISO 22762-1:2018, 6.2.2.4.5.

8.5.1.4.6 Test vibration frequency

The test vibration frequency shall be between 0,1 Hz and 2,0 Hz. When any other frequency is used, it shall be selected with the agreement of both the structural engineer and the manufacturer.

8.5.1.5 Procedure

8.5.1.5.1 Attachment of test piece

The test piece shall be attached to a compression-shear testing machine as specified in ISO 22762-1:2018, 6.2.2.5.1.

8.5.1.5.2 Loading of test piece

The test piece shall be loaded as follows.

a) Subject the test piece to a compressive force that is equivalent to the design compressive stress, σ_0, as defined in ISO 22762-2 or ISO 22762-3.

b) Subject the test piece to three cycles or 11 cycles of 1,0 γ_0 shear displacement. The number of cycles shall be as specified by the structural engineer.

c) Subject the test piece to the shear displacement amplitude specified in 8.5.1.4.4 for a number of cycles, depending on the level of the shear strain amplitude. For example:

   — subject the test piece to 0,01 γ_0 shear displacement for 5 000 000 or more cycles;

   — subject the test piece to 0,05 γ_0 shear displacement for 25 000 or more cycles;

— subject the test piece to 0,1 γ_0 shear displacement for 7 000 or more cycles;

— subject the test piece to 0,5 γ_0 shear displacement for 400 or more cycles.

d) Subject the test piece to three cycles or 11 cycles of 1,0 γ_0 shear displacement. The number of cycles shall be as specified by the structural engineer.

8.5.1.6 Expression of results

With the method used in ISO 22762-1:2018, 6.2.2.6, determine each property value and from the 1st, 3rd, 10th cycles, from cycles at an interval of 0,1 times or more of the total number of cycles and from the final cycle. Determine the change in properties.

The change in each property shall be expressed as the ratio of each value to the reference value.

8.5.1.7 Test report

The test report shall include the following:

a) reference to this document, i.e. ISO 22762-6:2022;

b) type and classification, shape and dimensions, first shape factor and second shape factor of test piece;

c) name of test machine;

d) test temperature;

e) input wave and vibration frequency;

f) direction of shear force applied to test piece;

g) compressive force and shear displacement amplitude (or compressive stress and shear strain);

h) properties, such as shear stiffness and equivalent damping ratio, at each cycle for which they were determined;

i) change in each property with cycling;

j) graph showing relationship between the percentage change of each property and the number of cycles;

k) graph showing relationship between compressive force and shear displacement, if requested;

l) plots of shear force versus shear displacement (hysteresis loop);

m) test date.

8.5.2 Horizontal shear creep test and residual shear strain test

8.5.2.1 Principle

This test evaluates the performance of the elastomeric isolator when the seismic isolated building is subjected to a strong wind for a long time. The shear stress on isolator due to the wind is the sum of the static shear stress τ_S and the dynamic shear stress τ_D, corresponding to the average static shear force and dynamic vibration force of the wind respectively. Also, it is confirmed that the isolator returns to the original position after this wind force is over.

A test piece is attached to a compression-shear testing machine and loaded with a constant compressive force. In this state, the test piece is subjected to static shear load and dynamic shear load for a time specified by the structural engineer. The shear force and the shear displacement are measured.

The horizontal shear creep properties are evaluated, and the residual shear strain are evaluated by measuring shear displacement after the test.

8.5.2.2 Test machine

The test machine shall be as specified in ISO 22762-1:2018, 6.2.2.2.

8.5.2.3 Test piece

The test piece shall be as specified in Table 7.

8.5.2.4 Test conditions

8.5.2.4.1 Test temperature

The test temperature shall be as specified in ISO 22762-1:2018, 6.2.1.4.1.

8.5.2.4.2 Conditioning time for test piece

The conditioning time for test piece shall be as specified in ISO 22762-1:2018, 6.2.1.4.2.

8.5.2.4.3 Compressive force

The compressive force shall be as specified in ISO 22762-1:2018, 6.2.2.4.3.

8.5.2.4.4 Test shear static load

Two or more values of static shear stress between 0,1 MPa and 0,6 MPa shall be selected.

$0,1\ \text{MPa} \leq \tau_S \leq 0,6\ \text{MPa}$

8.5.2.4.5 Test shear dynamic load

Two or more values of dynamic shear stress between 0,2 τ_B and 1,0 τ_B shall be selected.

$0,2\ \tau_S \leq \tau_D \leq 1,0\ \tau_S$

8.5.2.4.6 Input wave

The input wave shall be as specified in ISO 22762-1:2018, 6.2.2.4.5.

8.5.2.4.7 Test vibration frequency

The test vibration frequency shall be between 0,1 Hz and the isolation frequency or 2,0 Hz. When any other frequency is used, it shall be selected with the agreement of both the structural engineer and the manufacturer.

8.5.2.5 Procedure

8.5.2.5.1 Attachment of test piece

The test piece shall be attached to a compression-shear testing machine as specified in ISO 22762-1:2018, 6.2.2.5.1.

8.5.2.5.2 Loading of test piece

The test piece shall be loaded as follows.

a) Subject the test piece to a compressive force that is equivalent to the design compressive stress, σ_0, as defined in ISO 22762-3.

b) Subject the test piece to the specified τ_S of shear static load and τ_D of shear dynamic load for 2 h.

c) Maintain the compressive force for 1 h after unloading shear load of the test piece to 0.

8.5.2.6 Expression of results

Record the hysteresis loop of shear force and shear displacement during shear loading 2 h. Determine the horizontal shear creep from the maximum shear displacement of the test piece. Determine the residual shear strain from the last shear displacement of the test piece for 1 h after unload shear load to 0.

8.5.2.7 Test report

The test report shall include the following:

a) reference to this document, i.e. ISO 22762-6:2022;

b) type and classification, shape and dimensions, first shape factor and second shape factor of test piece;

c) name of test machine;

d) test temperature;

e) input wave and vibration frequency;

f) direction of shear force applied to test piece;

g) compressive force, shear static force and shear dynamic force (or compressive stress, shear static stress and shear dynamic stress);

h) properties, such as shear stiffness and equivalent damping ratio, at each cycle for which they were determined;

i) properties, horizontal shear creep and residual shear strain, as determined in test;

j) change in each property with cycling;

k) graph showing relationship between the rate of change of each property and the test time;

l) graph showing relationship between compressive force and shear displacement, if requested;

m) plots of shear force versus shear displacement (hysteresis loop);

n) test date.

9 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
(informative)

Shear displacement capacity of various elastomeric seismic-protection isolators

A.1 General

Breaking tests were carried out on 11 isolators produced in five countries. The isolators having diameters of around 800 mm, and total rubber thicknesses of around 160 mm were tested with increasing shear strain under constant compressive stress using a multi-axial testing system. All of the isolators had high flexibility in the horizontal direction although the degree of flexibility varied between isolators. The breaking shear strain was distributed between (300 and 450) % or more.

For further details, see Reference [2].

A.2 Elastomeric isolators used for breaking tests

In the breaking tests, 11 elastomeric isolators were collected from China, Italy, Japan, Malaysia and the United States. Outlines of these isolators are shown in Table A.1. Three types of isolators (LNR, HDR and LRB) were used for the tests. D_o is around 800 mm; inner diameter of the isolators D_i is (20 – 40) mm; diameter of the lead core D_p is (130 – 160) mm; the first shape factor S_1 is 25,9 – 36,1; and the secondary shape factor S_2 is approximately 5,0. Shear modulus of the rubber G is 0,4 – 0,8 MPa at 100 % shear strain.

Figure A.1 shows a sample of an isolator, HDR from Japan. The outer diameter is 800 mm, the first shape factor is 36,1, and the second shape factor is 4,9. Shear modulus of the high-damping rubber is 0,62 MPa at 100 % shear strain, and the equivalent damping coefficient is 0,24 at the same shear strain.

Table A.1 — Elastomeric isolators used for the breaking tests

Specimen	Type	D_o (mm)	D_i (mm)	D_p (mm)	G (MPa)	S_1	S_2	σ_0 (MPa)
TS01	LNR	800	40	-	0,4	31,7	5,1	15
TS02	HDR	800	20	-	0,6	36,1	4,9	15
TS03	LRB	800	-	130	0,4	27,0	5,0	15
TS04	HDR	780	20	-	0,8	28,5	4,9	8,4
TS05	LRB	800	-	130	0,4	27,0	5,0	15
TS06	LNR	800	40	-	0,4	25,9	5,0	15
TS07	LRB	800	-	160	0,4	33,3	5,1	15
TS08	LRB	800	-	160	0,44	35,1	5,0	6,0

D_o: Outer diameter of isolator

D_i: Inner diameter of isolator

D_p: Diameter of lead plug

G: Shear modulus of rubber (at 100 % shear strain)

S_1: First shape factor

S_2: Second shape factor

σ_0: Nominal compressive stress