TECHNICAL SPECIFICATION

ISO/TS 22762-4

First edition
2014-07-15

Elastomeric seismic-protection isolators —

Part 4: Guidance on the application of ISO 22762-3

Appareils d'appuis structuraux en élastomère pour protection sismique —

Partie 4: Lignes directrices pour l'application de l'ISO 22762-3

Reference number
ISO/TS 22762-4:2014(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

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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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 45, *Rubber and rubber products*, Subcommittee SC 4, *Products (other than hoses)*.

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*

— *Part 4: Guidance on the application of ISO 22762-3* [Technical Specification]

Elastomeric seismic-protection isolators —

Part 4:
Guidance on the application of ISO 22762-3

1 Scope

This Technical Specification provides guidance on the use of ISO 22762-3:2010. It includes example design calculations and provides data on the characteristics obtained from all types of elastomeric isolators.

2 Normative references

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

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

ISO 22762-3:2010, *Elastomeric seismic-protection isolators — Part 3: Applications for buildings — Specifications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 22762-3:2010 apply.

4 Guidance on the use of Clause 4 of ISO 22762-3

No guidance is given.

5 Guidance on the use of Clause 5 of ISO 22762-3

No guidance is given.

6 Guidance on the use of Clause 6 of ISO 22762-3

6.1 General

Guidance is given for 6.2, 6.4, and 6.5.

6.2 Type tests and routine tests

An example of the scaled test pieces (scales A and B) for the type testing of the specific isolator size is given as follows.

Dimensions and properties of target isolator (isolator-X) are shown in Table 1.

Table 1 — Dimensions and properties of isolator-X

Outer diameter, d_o (mm)	1 000
Inner diameter, d_i (mm)	25
Thickness of one rubber layer, t_r (mm)	6,7
Thickness of reinforcing steel plate, t_s (mm)	4,4
Number of rubber layer, n	30
First shape factor, S_1	36,4
Second shape factor, S_2	5,0
Shear stiffness, K_h (N/mm × 10^3)	2,44
Equivalent damping ratio, h_{eq}	0,225
Compressive stiffness, K_v (N/mm × 10^3)	5 450

In this case, requirement for scales A and B test piece are shown in Table 4 of ISO 22762-3:2010.

An example of dimensions and properties of scales A and B is shown in Table 2.

Table 2 — Examples of Scales A and B for Isolator-X

Characteristics	Scale A	Scale B
Scale	0,25	0,6
Outer diameter, d_o (mm)	250	600
Inner diameter, d_i (mm)	0 (6,3)	15
Thickness of one rubber layer, t_r (mm)	1,7	4,0
Thickness of reinforcing steel plate, t_s (mm)	1,2	2,2
Number of rubber layer, n	30	30
First shape factor, S_1	36,4	36,4
Second shape factor, S_2	5,0	5,0
Shear stiffness, K_h (N/mm × 10^3)	0,61	1,46
Equivalent damping ratio, h_{eq}	0,225	0,225
Compressive stiffness, K_v (N/mm × 10^3)	1 360	3 270

For any dimension, variation of ±5 % from exact scale-downed dimensions can be allowed.

The scaling of reinforcing plate for scale A can be adjusted if the effect on characteristics of isolator is not significant. In the case of scale A in Table 2, the thickness of the plate is computed as 1,1 mm and 1,2 mm is adopted for the test piece.

Number of the test pieces required is not specified in the text. The recommended number of the test pieces is shown in Table 3 when each test piece is tested individually. In the case that double-shear testing arrangement is used for determining the shear properties, it is recommended that two tests are performed and the number of test pieces doubled.

Table 3 — Recommended number of test pieces for each test item

Properties		Number of test pieces
Compressive properties		2
Shear properties		2
Dependency of shear properties	Shear strain dep.	2
	Compressive stress dep.	2
	Others	1
Dependency of compressive properties		1
Ultimate properties		1
Durability		1

In the case shown in Table 4, the available previous test results can be used for substitution of the test required for the newly designed isolator.

Table 4 — An example of available previous type test results: Comparison of characteristics between newly designed and previously tested isolator

Characteristics	Previously tested isolator	Newly designed isolator (-)	Newly designed isolator (+)	Remarks
Outer diameter, d_o (mm)	1 100	1 000	1 200	within ±10 %
Inner diameter, d_i (mm)	25	25	27	within ±10 %
Thickness of one rubber layer, t_r (mm)	7,0	6,7	7,5	within ±10 %
Thickness of reinforcing plate, t_s (mm)	4,4	4,4	4,8	within ±10 %
Number of rubber layer, n	30	30	30	same
First shape factor, S_1	38,4	36,4	42,0	within ±10 %
Second shape factor, S_2	5,2	5,0	5,3	within ±10 %
Maximum comp. stress for test, σ_{max} (MPa)	30	25	30	Previous test more severe condition
Minimum comp. stress for test, σ_{min} (MPa)	-0,5	5,0	0,5	Previous test more severe condition
Maximum shear strain for test, γ_{max}	3,5	3,0	3,2	Previous test more severe condition

6.3 Functional requirements

No guidance is given.

6.4 Design compressive force and design shear displacement

Design compressive force refers to the force under non-seismic conditions.

Any specification or guidance is not given regarding nominal stress, σ_{nom}. Recommended process to specify σ_{nom} is given as follows:

a) σ_{nom} is determined in the range less than 30 % of critical stress, σ_{cr}. Maximum σ_{nom} is less than or equal to 15 MPa.

b) Adequacy of σ_{nom} is verified so that compressive stress dependency (change of shear property under 0,5 σ_{nom} and 2,0 σ_{nom}) is acceptable. Maximum σ_{nom} is less than or equal to 15 MPa.

6.5 Performance requirements

Examples of tests for each requirement are introduced.

6.5.1 General

No guidance is given.

6.5.2 Compressive properties

Example for 6.5.2 of ISO 22762-3 on compressive properties is given.

6.5.2.1 In case of HDR

a) Test piece and test conditions

Test piece is shown in Table 5.

Table 5 — Test isolators (scaled isolator)

Type	Outer diameter (mm)	Inner diameter (mm)	First shape factor	Second shape factor	Compressive stress (N/mm^2)	Number of test isolator
HDR	700	15	36,4	5,0	12,0	1

Test conditions are given below:

— compressive stress amplitude: 12 MPa ± 30 %;

— number of cycles: 3 cycles;

— compressive stiffness, K_v, is computed from 3rd cycle.

b) Test result

The result for one type of HDR is plotted in Figure 1 and Table 6.

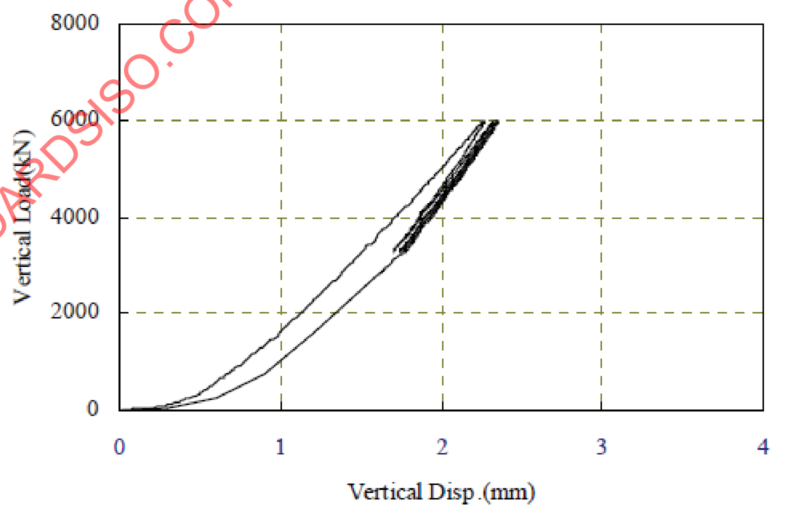


Figure 1 — Compressive property test of HDR

Table 6 — Test results

Characteristics	Test result
Compressive stiffness, K_v	4 592,0 kN/mm

6.5.3 Shear properties

Example for 6.2.2 of ISO 22762-3 on shear properties is given.

6.5.3.1 In case of HDR

a) Test piece and test conditions

Test piece is shown in Table 7.

Table 7 — Test isolators (scaled isolator)

Type	Outer diameter (mm)	Inner diameter (mm)	First shape factor	Second shape factor	Compressive stress (N/mm²)	Number of test isolator
HDR	700	15	36,4	5,0	12,0	1

Test conditions are given below:

— compressive stress: 12 MPa;

— shear strain amplitude: ±100 % (141 mm);

— number of cycles: 3 cycles;

— shear stiffness, K_h, and damping ratio, h_{eq}, are computed from 3rd cycle.

b) Test results

The result for one type of HDR is shown in Figure 2 and Table 8.

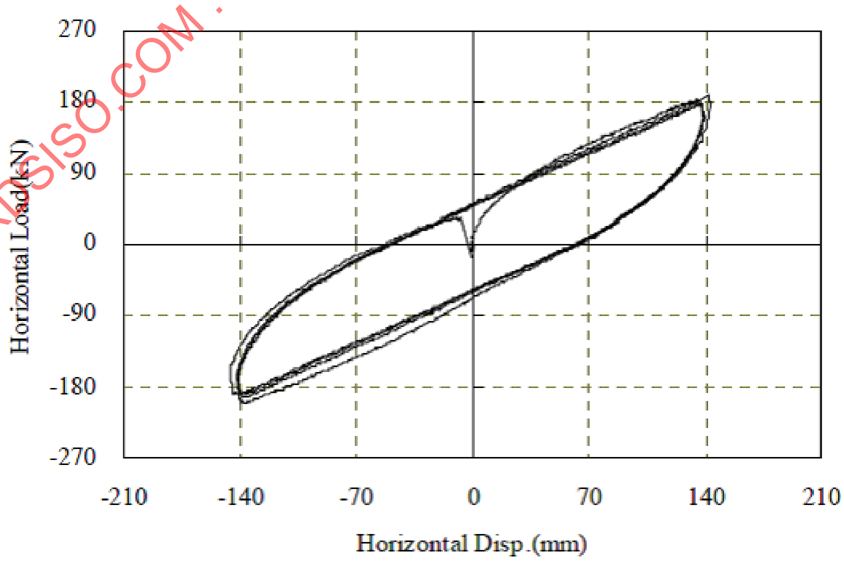


Figure 2 — Shear property test of HDR

Table 8 — Test piece

Characteristics	Test result
Shear stiffness, K_h	4 592,0 kN/mm
Equivalent damping ration, h_{eq}	0,21

6.5.4 Tensile properties

Example for 6.5.4 of ISO 22762-3 on shear properties is given.

6.5.4.1 In case of LNR

a) Test piece and test conditions

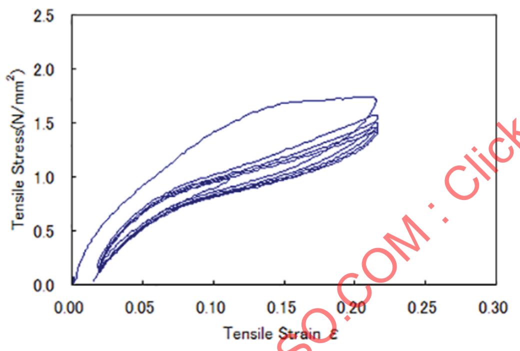
Test pieces are shown in Table 9.

Table 9 — Test piece

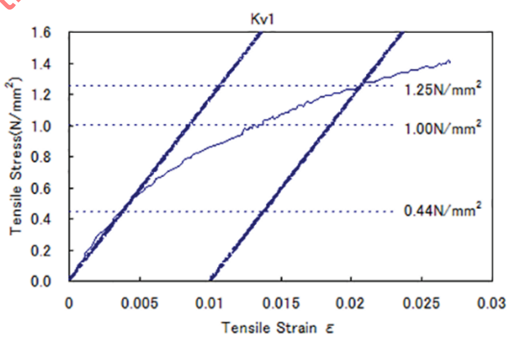
Type	Outer diameter (mm)	S_1	S_2
LNR	500	32,0	5,1
	800	31,7	5,1

b) Test results

Test results are shown in Figures 3 a) and b) and Table 10.



a) relationship of tensile stress and tensile strain of LNR under shear-strain offset of 100%



b) measurement of tensile yield stress

Figure 3 — Tensile performance at γ = 100 %

Table 10 — Test results

Outer diameter (mm)	Tensile yield stress under shear strain of 100% (MPa)
500	1,25
800	1,19

6.5.4.2 In case of HDR

a) Test piece and test conditions

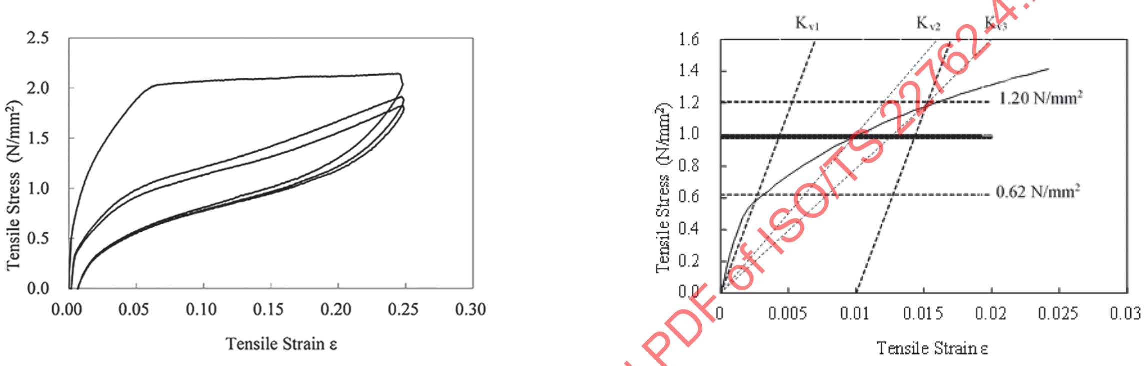
Test pieces are shown in Table 11.

Table 11 — Test piece

Type	Outer diameter (mm)	S_1	S_2
HDR	800	36,1	4,0
	600	36,6	3,0

b) Test results

Test results are shown in Figures 4 a) and b) and Table 12.



a) relationship of tensile stress and tensile strain of HDR under shear-strain offset of 100%

b) measurement of tensile yield stress

Figure 4 — Tensile performance at γ = 100 %

Table 12 — Test results

Outer diameter (mm)	Tensile yield stress under shear strain of 100% (MPa)
800	1,2
600	1,4

6.5.5 Dependencies of shear properties

6.5.5.1 Shear strain dependency

Example for 6.5.5.1 of ISO 22762-3 on shear strain dependency is given.

6.5.5.1.1 In case of HDR

a) Test piece and test conditions

1) Scaled model

Test pieces of scaled model are shown in Table 13.

Table 13 — Test isolators (scaled model)

Type	Outer dia. (mm)	First shape factor	Second shape factor	Compressive stress (N/mm2)	Number of isolators tested
HDR	225	35,2	3,3	9,3	1
	225	35,2	5,0	15,0	2
	225	35,2	8,3	15,0	1

Test conditions are given below:

— test vibration frequency: 0,33 Hz, sinusoidal wave;

— shear strain amplitude: γ = ±10 %, ±20 %, ±50 %, ±100 %, ±150 %, ±200 %, and ±270 %;

— loading cycles: 3 cycles, respectively;

— reference cycle: 3rd cycle;

— test results were corrected to the corresponding value of the property at 20 °C by the specified method in ISO 22762-3, 6.5.3.3.3.

2) Full scale isolators

Test pieces of full scale isolators are shown in Table 14.

Table 14 — Test isolators (full scale)

Type	Outer dia. (mm)	First shape factor	Second shape factor	Compressive stress (N/mm2)	Number of isolators tested
HDR	600	36,6	3,0	6,6	1
	800	36,1	4,0	12,1	1
	1 000	36,4	5,0	15,0	1
	1 200	35,8	6,0	15,0	1
	1 600	36,5	6,4	15,0	1

Test conditions are given below and in Table 15.

— test wave: triangular wave;

— shear strain amplitude: γ = ±50 %, ±100 %, and ±200 %;

— loading cycles: 3 cycles, respectively;

— reference cycle: 3rd cycle;

— test results were corrected to their counterpart with 0,33 Hz by the specified method in ISO 22762-3, 6.5.5.3;

— test results were corrected to the corresponding value of the property at 20 °C by the specified method in ISO 22762-3, 6.5.5.5.

Table 15 — Test velocities

Test velocity (mm/sec) [frequency (Hz)]		
±50 %	±100 %	±200 %
13,0 (0,033)	13,0 (0,017)	10,0 (0,006)

b) Test results

1) Scaled model

Figure 5 shows the test results by the scaled model specimens.

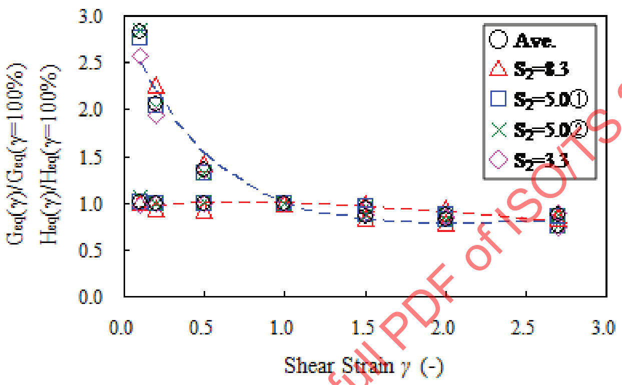


Figure 5 — Shear strain dependency of shear properties of HDR (scaled isolator)

The shear strain dependence of the shear properties (shear modulus, damping, and *u* function introduced in ISO 22762-1, Annex E) of HDR, as measured in dynamic loading tests are expressed by polynomial functions of shear strain, as shown in Table 16.

Table 16 — An example of function for HDR

Properties at γ = 100 %	Polynomial function
G_{eq} = 0,62 (N/mm^2) H_{eq} = 0,240 u_0 = 0,408	$G_{eq}(\gamma)=G_{eq}\times(2{,}855-3{,}878\gamma+2{,}903\gamma^2-1{,}016\gamma^3+0{,}1364\gamma^4)$ $H_{eq}(\gamma)=H_{eq}\times(0{,}9150+0{,}2364\gamma-0{,}1804\gamma^2+0{,}02902\gamma^3)$ $u_0(\gamma)=u_0\times(0{,}9028+0{,}2711\gamma-0{,}2083\gamma^2+0{,}03421\gamma^3)$

c) Full scale isolator

The test results for the full scale isolators are shown in Table 17.

Table 17 — Test result: Horizontal characteristics normalized by value at 100 % strain

Diameter (mm)	Items	Shear strain	
		±50 %	±200 %
600	K_{eq}	1,40	0,84
	H_{eq}	0,98	0,95
800	K_{eq}	1,27	0,91
	H_{eq}	0,96	0,95

Table 17 *(continued)*

Diameter (mm)	Items	Shear strain	
		±50 %	±200 %
1 000	K_{eq}	1,37	0,91
	H_{eq}	0,98	0,91
1 200	K_{eq}	1,38	0,89
	H_{eq}	0,95	0,95
1 600	K_{eq}	1,35	0,91
	H_{eq}	0,95	0,95

6.5.5.2 Compressive stress dependency

Example for 6.5.5.2 of ISO 22762-3 on compressive stress dependency is given.

6.5.5.2.1 In case of HDR

a) Test piece and test conditions

Test pieces are shown in Table 18.

Table 18 — Test piece

Type	Outer diameter (mm)	Inner diameter (mm)	S_1	S_2	Nominal compressive stress, σ_S (N/mm^2)	Total thickness of rubber (mm)
HDR	600 (15)	15	36,6	3,0	6,6	200
	800 (20)	20	36,1	4,0	12,1	200
	1 200 (55)	55	35,8	6,0	15,0	200

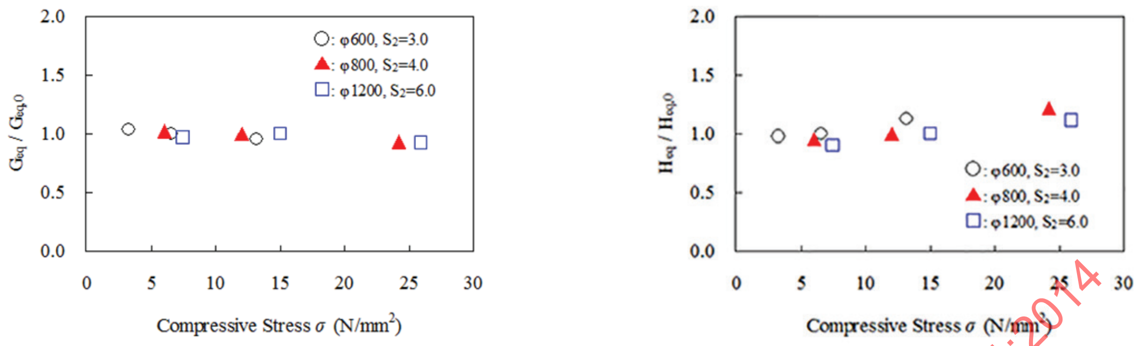
Test conditions are given below:

— shear strain amplitude: γ = 100 (%);

— reference cycle: 3rd (cycle).

b) Test results

Test results are shown in Table 19, Figures 6 a) and b).



a) compressive stress dependency on shear modulus G_{eq}

b) compressive stress dependency on equivalent damping ratio H_{eq}

Figure 6 — Compressive stress dependency

Table 19 — Change in horizontal characteristics with respect to values at compressive stress, σ_S

Outer diameter (mm)	Characteristics	Effect of compressive stress	
		$\sigma = 0{,}5\sigma_S$	$\sigma = 2\sigma_S$
600 (15)	K_{eq}	3,89 %	−4,39 %
	H_{eq}	−2,30 %	12,6 %
800 (20)	K_{eq}	2,13 %	−6,81 %
	H_{eq}	−4,76 %	21,5 %
1 200 (55)	K_{eq}	−3,06 %	−8,47 %
	H_{eq}	−10,5 %	11,6 %

6.5.5.3 Frequency dependency

Example for 6.5.5.3 of ISO 22762-3 on frequency dependency is given.

6.5.5.3.1 In case of HDR

a) Test piece and test conditions

Test piece is shown in Table 20. Shear block specimen can be used for the test.

Table 20 — Test isolators (scaled isolator)

Type	Outer diameter (mm)	First shape factor	Second shape factor	Compressive stress (N/mm²)	Number of test isolator
HDR	225	35,2	5,0	15,0	2

Test conditions are given below:

— test vibration frequency: 0,01 Hz, 0,03 Hz, 0,1 Hz and 0,33 Hz, sinusoidal wave;

— shear strain amplitude: $\gamma = \pm 100$ %;

— loading cycles: 3 cycles, respectively;

— reference cycle: 3rd cycle;

— test results were corrected to the corresponding value of the property at 23 °C by the specified method in ISO 22762-3, 6.5.5.5.

b) Test results

Test results are plotted in Figure 7.

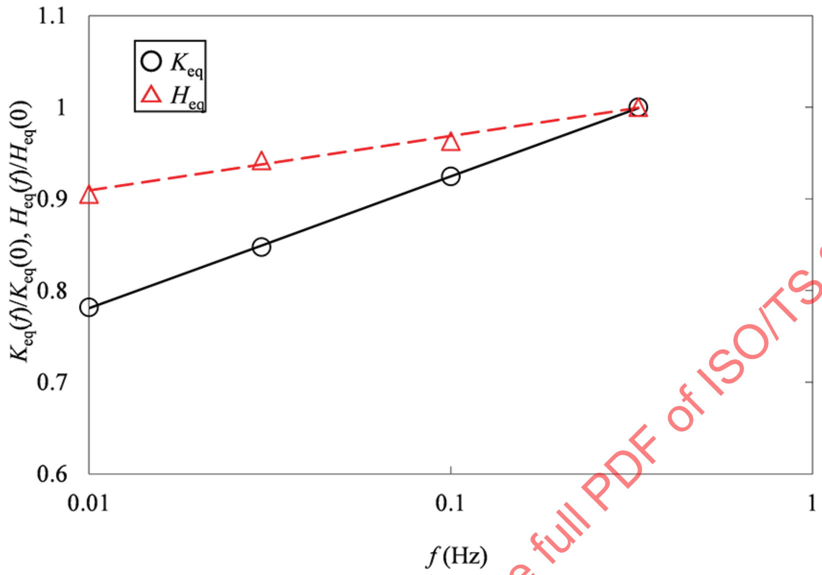


Figure 7 — An example of frequency dependency test results of HDR

The test result for each frequency is normalized by the result for the isolation frequency. By curve-fitting the results, correction factors that convert shear property values obtained at the testing frequency to values at the isolation frequency can be determined. Correction factors for loading frequency, f, can be derived as follows:

For shear stiffness:

$$\alpha_{\kappa} = \frac{1}{a_{\kappa} \log(f) + b_{\kappa}} \tag{1}$$

For equivalent damping ratio:

$$\alpha_{h} = \frac{1}{a_{h} \log(f) + b_{h}} \tag{2}$$

where

α_k is the correction factor for shear stiffness, K_{eq};

α_h is the equivalent damping ratio, H_{eq};

f is the loading frequency.

The values for a_k, b_k, a_h, and b_h, which are obtained from test results on a scaled model specimen are shown in Table 21 for one type of HDR.

Table 21 — An example of frequency correction factor

Isolation frequency	a_k	b_k	a_h	b_h
0,33 Hz	0,144	1,07	0,059 4	1,010

The test results are corrected for frequency by multiplying the results of the shear property test by α_k and α_h.

For shear stiffness:

$$K_{eq}(0{,}33\,\text{Hz}) = K_{eq}\,(f\text{:test frequency})\cdot\alpha_k \quad (3)$$

For equivalent damping ratio:

$$H_{eq}\,(0{,}33\ \text{Hz}) = H_{eq}\,(f\text{:test frequency})\cdot\alpha_h \quad (4)$$

6.5.5.3.2 In case of LRB

a) Test piece and test conditions

Test piece are shown in Table 22. Shear block specimen is also available for this test.

Table 22 — Test isolators (scaled isolator)

Type	Outer diameter (mm)	Lead plug diameter (mm)	First shape factor	Second shape factor	Compressive stress (N/mm^2)	Number of test isolator
LRB	208	41,6	28,9	4,8	7,8	2

Test conditions are given below:

— test vibration frequency: 0,01 Hz, 0,03 Hz, 0,1 Hz, and 0,33 Hz, sinusoidal wave;

— shear strain amplitude: $\gamma = \pm 100$ %;

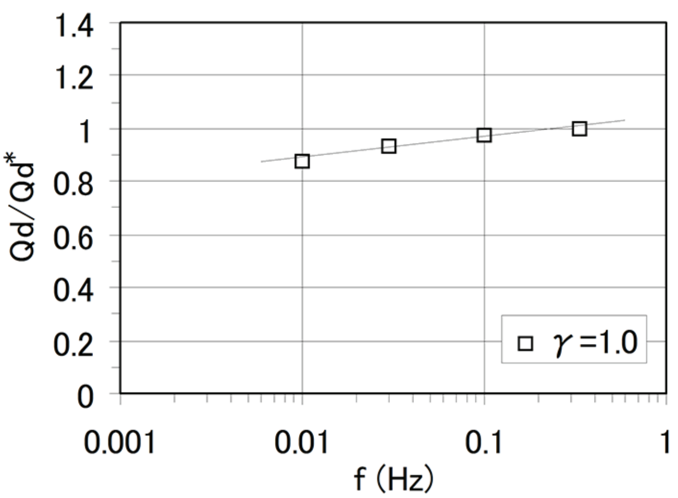
— loading cycles: 3 cycles, respectively;

— reference cycle: 3rd cycle;

— test results were corrected to the corresponding value of the property at 23 °C by the specified method in ISO 22762-3, 6.5.5.5.

b) Test results

The results for one type of LRB are plotted in Figure 8.



Key

Qd sine wave

Qd* sine wave, f =0,33 Hz

Figure 8 — An example of frequency dependency test results of LRB

The correction factor for frequency, f, can be derived using Formula (5).

For characteristic strength, Q_d:

$$\alpha_{Qd} = \frac{1}{a_Q \log_{10}(f) + b_Q} \tag{5}$$

where

α_{Qd} is the correction factor for characteristic strength, Q_d;

f is the loading frequency.

The values for a_Q and b_Q, which are obtained from test results on a scaled model specimen are shown in Table 23 for one type of LRB.

Table 23 — An example of frequency correction factor

Isolation frequency	a_{Qd}	b_{Qd}
0,33 Hz	0,0829	1,049

The test results are corrected for frequency by multiplying the results of the shear property test by α_{Qd}.

For characteristic strength, Q_d:

$$Q_d\,(0{,}33\ \text{Hz}) = Q_d\,(f\text{:test frequency}) \cdot \alpha_k \tag{6}$$

6.5.5.3.3 In case of LNR

a) Test piece and test conditions

Test piece is shown in Table 24.

Shear block specimen can be used for the test.

Table 24 — Test isolators (scaled isolator)

Type	Outer diameter (mm)	Inner diameter (mm)	First shape factor	Second shape factor	Compressive stress (N/mm2)	Number of test isolator
LNR	253	29	20,0	7,0	10,0	2

Test conditions are given below:

— test vibration frequency: 0,01 Hz, 0,25 Hz, 0,5 Hz, and 1,0 Hz, sinusoidal wave;

— shear strain amplitude: γ = ±100 %;

— loading cycles: 3 cycles, respectively;

— reference cycle: 3rd cycle;

— test results were corrected to the corresponding value of the property at 23 °C by the specified method in ISO 22762-3, 6.5.5.5.

b) Test results

The results for one type of LNR are plotted in Figure 9.

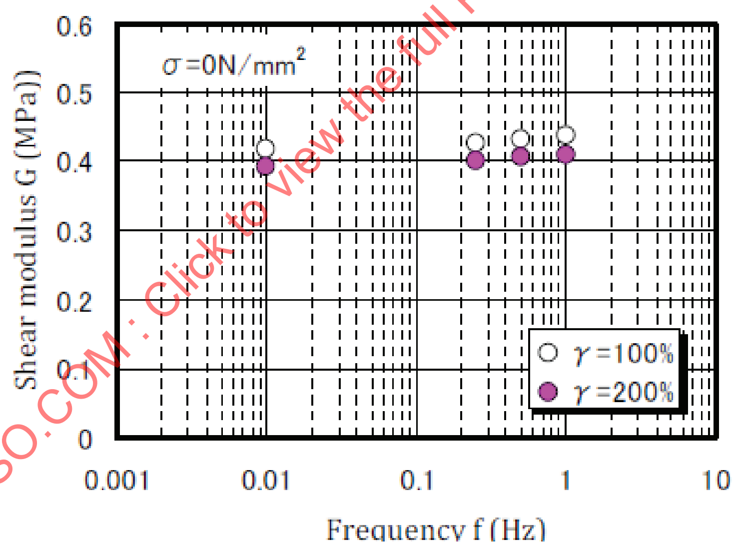


Figure 9 — An example of frequency dependency test results of LNR

Frequency dependency of LNR is negligible. Generally, no correction for frequency is required.

6.5.5.4 Repeated loading dependency

Example for 6.5.5.4 of ISO 22762-3 on repeated loading dependency is given.

6.5.5.4.1 In case of HDR

a) Test piece and test conditions

Test piece is shown in Table 25.

Table 25 — Test isolators (scaled isolator)

Type	Outer diameter (mm)	Inner diameter (mm)	First shape factor	Second shape factor	Compressive stress (N/mm²)	Number of test isolator
HDR	700	15	36,4	5,0	12,0	1

Test conditions are given below:

— test vibration frequency: 0,008 Hz, triangle wave;

— shear strain amplitude: γ = ±100 %;

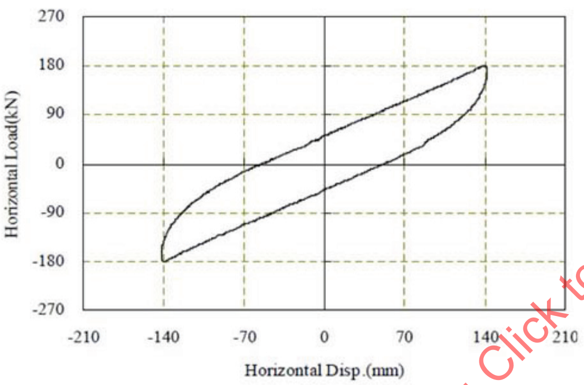
— loading cycles: 50 cycles;

— reference cycle: 3rd cycle;

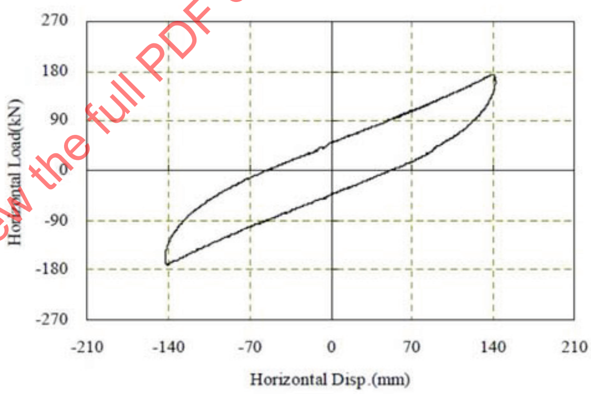
— test results were corrected to the corresponding value of the property at 23 °C by a specified method.

b) Test results

The results are given in Figure 10 and Table 26.



a) **Hysteresis loop (3rd cycle)**



b) **Hysteresis loop (30th cycle)**

Figure 10 — Repeated loading dependency of shear characteristics

Table 26 — Effect of repeated cycling [values normalized by corresponding value after third cycle (same correction as other part)]

Number of cycles	K_{eq}	H_{eq}
3	1,000	1,000
5	0,99	0,99
10	0,98	0,97
30	0,95	0,95
50	0,94	0,92

6.5.5.5 Temperature dependency

Example for 6.5.5.5 of ISO 22762-3 on temperature dependency is given.

6.5.5.5.1 In case of HDR

a) Test piece and test conditions

Test piece is shown in Table 27. Shear block specimen can be used for the test.

Table 27 — Test isolators (scaled isolator)

Type	Outer diameter (mm)	First shape factor	Second shape factor	Compressive stress (N/mm^2)	Number of test isolator
HDR	225	35,2	5,0	15,0	3

Test conditions are given below:

— test vibration frequency: 0,33 Hz, sinusoidal wave;

— test temperature: −10 °C, 0 °C, 23 °C, 30 °C, and 40 °C;

— shear strain amplitude: γ = ±100 %;

— loading cycles: 3 cycles, respectively;

— reference cycle: 3rd cycle.

b) Test results

The results for one type of HDR are plotted in Figure 11.

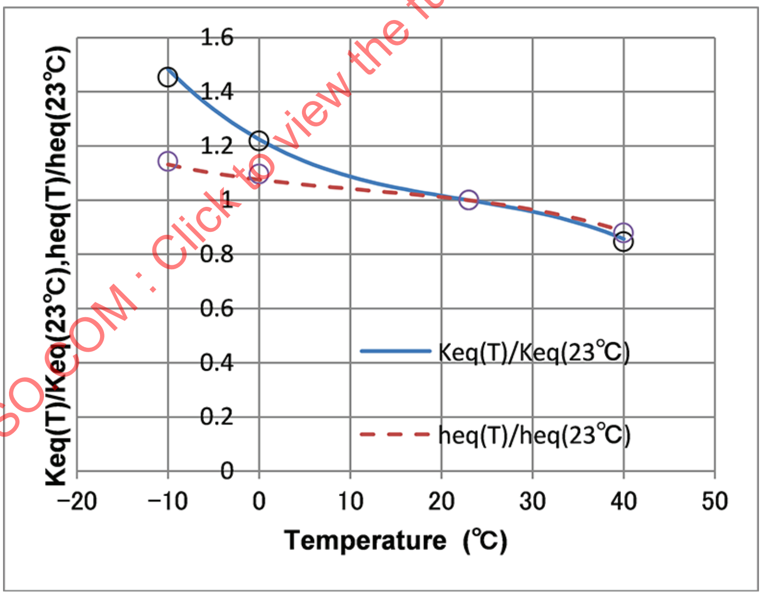


Figure 11 — An example of temperature dependency test results of HDR

The result at each temperature is normalized by the result for 23 °C.

Curve-fitting of the data gives a function expressing the dependence of the shear property on the temperature, T °C. Hence, a factor converting the value obtained at T °C to that, at 23 °C, can be derived as follows:

For shear modulus:

$$\beta_{\mathrm{k}} = \frac{1}{a + bT + cT^2 + dT^3} \tag{7}$$

For equivalent damping ratio:

$$\beta_{\mathrm{h}} = \frac{1}{e + fT + gT^2 + hT^3} \tag{8}$$

The values for *a, b, c, d, e, f, g*, and *h* for one type of HDR are shown in Table 28.

Table 28 — An example of temperature correction factor

a	*B*	*c*	*d*
1,224	$-1{,}892 \times 10^{-2}$	$6{,}087 \times 10^{-4}$	$-9{,}135 \times 10^{-6}$
e	*F*	*g*	*h*
1,076	$-4{,}175 \times 10^{-3}$	$1{,}107 \times 10^{-4}$	$-3{,}133 \times 10^{-6}$

The test results can be corrected for temperature by multiplying the results of the shear property test by β_{k} and β_{h}.

For shear stiffness:

$$K_{\mathrm{eq}}(23\ ^\circ\mathrm{C}) = K_{\mathrm{eq}}(T\text{:test temperature}) \cdot \beta_{\mathrm{k}} \tag{9}$$

For equivalent damping ratio:

$$H_{\mathrm{eq}}(23\ ^\circ\mathrm{C}) = H_{\mathrm{eq}}(T\text{:test temperature}) \cdot \beta_{\mathrm{h}} \tag{10}$$

6.5.5.5.2 In case of LRB

a) Test piece and test conditions

Test specimen is shown in Table 29.

Table 29 — Test isolators (scaled isolator)

Type	Outer diameter (mm)	Lead plug diameter (mm)	First shape factor	Second shape factor	Compressive stress (N/mm²)	Number of test isolator
LRB	250	38	41,7	4,8	6,2	2

Test conditions are given below:

— test vibration frequency: 0,33 Hz, sinusoidal wave;

— test temperature: −10 °C, 0 °C, 23 °C, 30 °C, 40 °C;

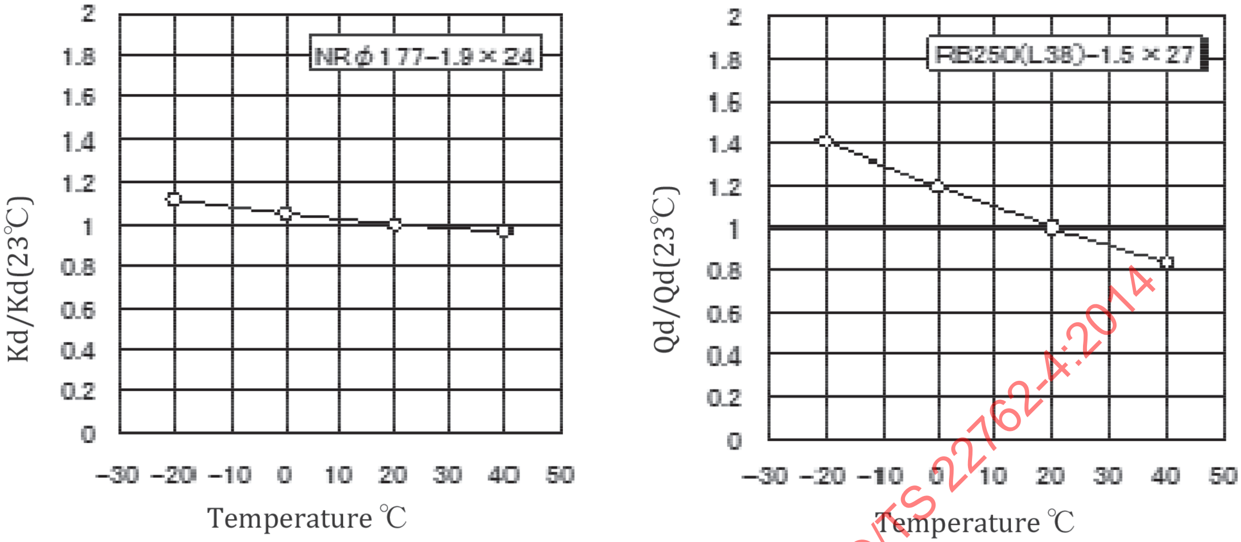
— shear strain amplitude: γ = ±100 %;

— loading cycles: 3 cycles, respectively;

— reference cycle: 3rd cycle.

b) Test results

The results for one type of LRB are plotted in Figure 12.



a) b)

Figure 12 — An example of temperature dependency test results of LRB

The result at each temperature is normalized by the result for 23 °C.

Curve-fitting the data gives a function expressing the dependence of the shear property on the temperature, T °C. Hence, a factor converting the value obtained at T °C to that, at 23 °C, can be derived as follows:

For shear modulus of post-yielding stiffness:

$$\beta_{\mathrm{kd}} = \frac{1}{a + bT + cT^2} \tag{11}$$

For characteristic strength:

$$\beta_{\mathrm{Qd}} = \frac{1}{d + eT + fT^2} \tag{12}$$

The values for a, b, c, d, e, f, g, and h for one type of HDR are shown in Table 30.

Table 30 — An example of temperature correction factor

a	b	c
1,052	$-2{,}955 \times 10^{-3}$	$1{,}895 \times 10^{-5}$
d	e	f
1,192	$-1{,}017 \times 10^{-2}$	$2{,}722 \times 10^{-5}$

The test results can be corrected for temperature by multiplying the results of the shear property test by β_{k} and β_{h}.

For post-yielding stiffness:

$$K_d(23\ °C) = K_d(T\text{:test temperature}) \cdot \beta_{kd} \tag{13}$$

For characteristic strength:

$$Q_d(23\ °C) = Q_d(T\text{:test temperature}) \cdot \beta_h \tag{14}$$

6.5.5.5.3 In case of LNR

a) Test piece and test conditions

Test piece is shown in Table 31.

Table 31 — Test piece

Type	Outer diameter (mm)	First shape factor	Second shape factor	Compressive stress (N/mm^2)	Number of test isolator
HDR	225	35,2	5,0	15,0	1

Test conditions are given below:

— test vibration frequency: 0,33 Hz, sinusoidal wave;

— test temperature: −10 °C, 0 °C, 23 °C, 30 °C, 40 °C;

— shear strain amplitude: γ = ±100 %;

— loading cycles: 3 cycles, respectively;

— reference cycle: 3rd cycle.

b) Test results

The results for one type of LNR are plotted in Figure 13.

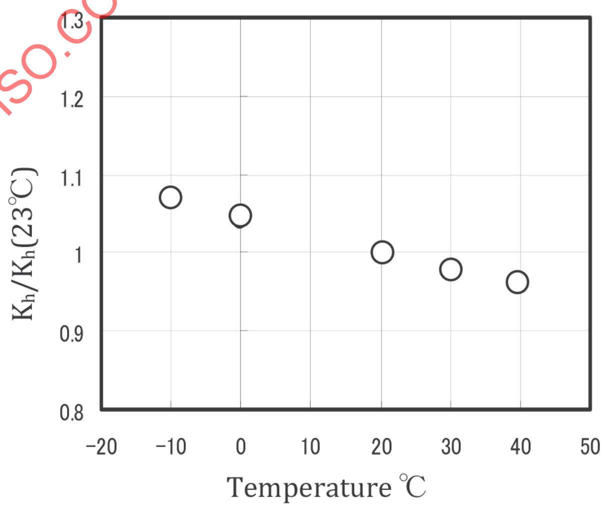


Figure 13 — An example of temperature dependency test results of LNR

The result at each temperature is normalized by the result for 23 °C.

Curve-fitting the data gives a function expressing the dependence of the shear property on the temperature, T °C. Hence, a factor converting the value obtained at T °C to that, at 23 °C, can be derived as follows:

For shear modulus of shear stiffness:

$$\beta_\mathrm{k} = \frac{1}{a + bT + cT^2} \tag{15}$$

The values for a, b, and c for one type of LNR are shown in Table 32.

Table 32 — An example of temperature correction factor

a	b	c
1,052	$-2,955 \times 10^{-3}$	$1,895 \times 10^{-5}$

The test results can be corrected for temperature by multiplying the results of the shear property test by β_k and β_h.

For stiffness:

$$K_\mathrm{h}(23\ °\mathrm{C}) = K_\mathrm{h}(T\text{:test temperature}) \cdot \beta_\mathrm{k} \tag{16}$$

For characteristic strength:

$$Q_\mathrm{d}(23\ °\mathrm{C}) = Q_\mathrm{d}(T\text{:test temperature}) \cdot \beta_\mathrm{h} \tag{17}$$

6.5.6 Dependencies of compressive properties

No guidance is given.

6.5.7 Shear displacement capacity

Example for 6.5.7 of ISO 22762-3 on shear displacement capacity is given.

6.5.7.1 In case of HDR

a) Test piece and test conditions

Test pieces for ramp loading test are shown in Table 33.

Table 33 — Test piece

Type	Outer diameter (mm)	Inner diameter (mm)	First shape factor	Second shape factor	Compressive stress (N/mm^2)	Number of isolators
HDR	800	20	36,1	4,0	12,1	2

Test conditions are given below:

— test wave: triangular wave (V = 18 mm/sec);

— loading cycles: 1 cycle, respectively.

b) Test results

The Figure 14 and Table 34 show the test results.

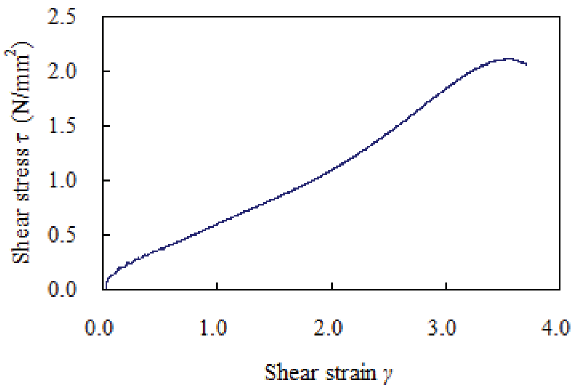


Figure 14 — Horizontal deformation capacity of HDR 800 mm diameter under ramp loading

Table 34 — Test results

Compressive stress (N/mm^2)	Test shear strain (%)	Test results
12,1	357	No failure

6.5.8 Durability

Example for 6.5.8 of ISO 22762-3 on durability is given.

6.5.8.1 Change in properties on aging

a) Test piece and test conditions

Test piece is shown in Table 35.

Table 35 — Test specimen

Type	Outer diameter (mm)	First shape factor	Second shape factor	Compressive stress (N/mm^2)1	Number of isolators	Remark
HDR	160	35	5,0	0,0	2	Initial
				0,0	1	30 years
				15,0	1	30 years
				0,0	1	60 years
				15,0	1	60 years

Accelerated aging condition for expected life under 23 °C is determined according to ISO 22762-1, Annex A as shown in Table 36.

Table 36 — Accelerated ageing condition

Activation energy	Condition: 23 °C × 60 y Eq.
$9,13 \times 10^4$ J/mol	90 °C × 16 d

b) Test results

Test results for property changes in shear properties and ultimate properties are shown in Tables 37 and 38. Ultimate property test results are plotted in Figure 15.

Table 37 — Test results: Shear property changes from initial value

Outer diameter (mm)	First shape factor	Second shape factor	G_{eq}	H_{eq}
160	35	5,0	+9 %	−10 %
	35	5,0	+10 %	−5 %
	35	5,0	+7 %	−6 %

Table 38 — Test results: Ultimate property changes

Outer diameter (mm)	First shape factor	Second shape factor	Compressive stress (N/mm^2)	Ultimate shear strain		
				Initial	30 years	60 years
160	35	5,0	15	4,51	-	-
				4,47	-	-
				-	4,43	-
				-	4,40	-
				-	4,54	-
				-	-	4,47
				-	-	4,32
				-	-	4,48
Average				4,49	4,46	4,42

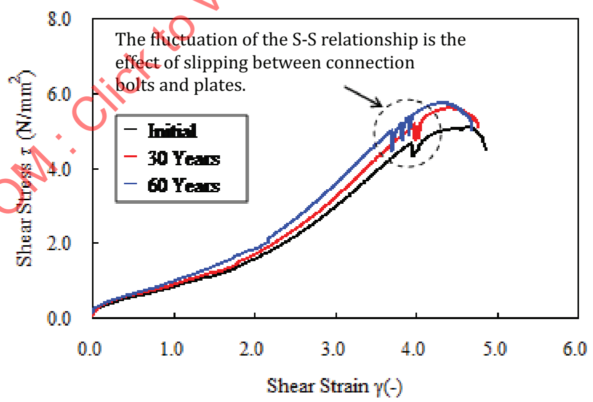


Figure 15 — Change of ultimate shear strength with ageing

6.5.8.2 Creep

a) Test piece and test conditions

Test piece is shown in Table 39.

Table 39 — Test isolators (scaled isolator)

Type	Outer diameter (mm)	First shape factor	Second shape factor	Number of isolators
HDR	160	35,9	4,0	2

Test conditions are given below:

— compressive stress: 15,0 (MPa);

— testing time: 2 000 hr.

b) Test results

Test results are shown in Figure 16 and Table 40.

The creep at 2 000 h was extrapolated to 60 years to predict creep at 60 years (Table 40).

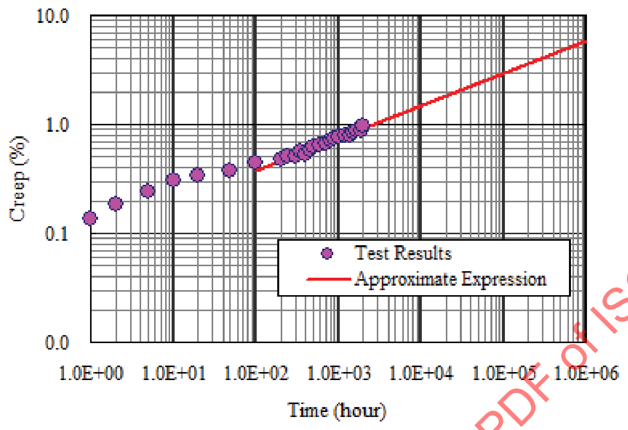


Figure 16 — Creep properties

Table 40 — Test result

Axial stress σ (N/mm²)	**Creep** ε (%)
15,0	within 9 %

7 Guidance on the use of Clause 7 of ISO 22762-3

7.1 General

Guidance is given for 7.3.1 of ISO 22762-3:2010.

7.2 Compressive stiffness

Two methods of evaluating compressive stiffness are given in Annex E of ISO 22762-3:2010. The values of E_∞ in Table E.1 of ISO 22762-3:2010, which are based on early test data obtained from compression of rubber discs, are lower than the results obtained directly from bulk compression tests (L.A. Wood et.al, 1964). A typical value of E_∞ is 2 000 MPa.

Examples for computation of isolator properties for each type (LNR, LRB, and HDR) are given below. The elastomer material constants used are only applicable to the compound chosen for the example calculation.

7.2.1 In case of LNR

7.2.1.1 Loading conditions and dimensional characteristics of isolators

— Compressive force: P = 7 520 (kN)

