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Rubber, vulcanized or thermoplastic — Determination of compression stress-strain properties

Caoutchouc vulcanisé ou thermoplastique — Détermination des propriétés de contrainte/déformation en compression

Reference number
ISO 7743 : 1989 (E)

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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 7743 was prepared by Technical Committee ISO/TC 45, *Rubber and rubber products.*

Annex A of this International Standard is for information only.

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Rubber, vulcanized or thermoplastic — Determination of compression stress-strain properties

1 Scope

This International Standard specifies a method for the determination of the compression stress-strain properties of vulcanized or thermoplastic rubber, using a specified test piece. Two procedures are given:

— A: With the metal plates, through which the compressive force is applied, lubricated.

— B: With the metal plates, through which the compressive force is applied, bonded to the test piece.

The two procedures do not give the same results. With lubricated test pieces, the results are dependent only on the modulus of the rubber and are independent of the test piece shape, provided that complete slip conditions are achieved. Effective lubrication is sometimes difficult to achieve and it is prudent to inspect the variance in the test results from replicate test pieces for indications of erratic slip conditions. With bonded test pieces, the results are dependent on both the modulus of the rubber and the test piece shape. The dependence on test piece shape is strong and consequently the results will be markedly different from those obtained with lubricated test pieces.

Provision is made for the use of test pieces of different size and/or shape from the specified test piece but extrapolation of the results obtained to other sizes and shapes may not be possible.

Guidance on the effect of size and shape of test piece and of bonding or lubricating is given in annex A.

The method is not suitable for materials that exhibit high set.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 468 : 1982, *Surface roughness — Parameters, their values and general rules for specifying requirements.*

ISO 471 : 1983, *Rubber — Standard temperatures, humidities and times for the conditioning and testing of test pieces.*

ISO 1826 : 1981, *Rubber, vulcanized — Time-interval between vulcanization and testing — Specification.*

ISO 3383 : 1985, *Rubber — General directions for achieving elevated or subnormal temperatures for test purposes.*

ISO 4648 : 1978, *Rubber, vulcanized — Determination of dimensions of test pieces and products for test purposes.*

ISO 4661-1 : 1986, *Rubber, vulcanized — Preparation of samples and test pieces — Part 1: Physical tests.*

ISO 5893 : 1985, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Description.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 compression stress: A stress applied so as to cause a deformation of the test piece in the direction of the applied stress, expressed as the force divided by the original area of cross-section perpendicular to the direction of application of the force.

3.2 compression strain: The deformation of the test piece in the direction of the applied stress divided by the original dimension in that direction. The compression strain is commonly expressed as a percentage of the original dimension of the test piece.

3.3 compression modulus (secant modulus): The applied stress calculated on the original area of cross-section divided by the resultant strain in the direction of application of the stress.

4 Principle

A test piece (lubricated or bonded) is compressed at a constant speed between the compression plates until a pre-determined strain is reached.

5 Apparatus and materials

5.1 Flat metal plates, of uniform thickness and having lateral dimensions greater than or equal to those of test pieces for bonding or at least 20 mm greater than those of test pieces for lubrication. For method A, one surface of each plate shall be highly polished to a surface finish with an arithmetical mean deviation R_a, determined in accordance with ISO 468, not greater than 0,4 µm. For method B, one surface of each plate shall be suitably prepared for the bonding system to be used.

5.2 Dies and **cutters** (if required), for preparing test pieces, complying with the relevant requirements of ISO 4661-1.

5.3 Thickness gauge, complying with the relevant requirements of ISO 4648.

5.4 Compression testing machine, complying with the requirements of ISO 5893, equipped with means of autographic recording of the force-deflection relationship to an accuracy corresponding to grade B in respect of both measurements. The machine shall be fitted with parallel compression platens at least as large as the metal plates, and shall be capable of operating at a nominal speed of 10 mm/min.

NOTES

1 Machines with *y*-time recorders may give erroneous results because of

a) inertia effects;

b) deflection because of compliance in the load cell or machine frame.

Machines with *x-y* recorders are therefore preferred.

2 When testing lubricated test pieces, a suitable guard should be provided to avoid damage or injury should the rubber be ejected when strained.

5.5 Lubricant, having no significant effect on the rubber under test, for method A. For most purposes a silicone or fluorosilicone fluid having a kinematic viscosity of 0,01 m²/s is suitable.

6 Test pieces

The standard test piece for both methods A and B is a cylinder of diameter 29 mm ± 0,5 mm and height 12,5 mm ± 0,5 mm. Test pieces may be cut or moulded. Cut test pieces shall be prepared in accordance with ISO 4661-1.

Other test pieces may be used but extrapolation of the results may not be possible (see annex A).

For method B, test pieces may be directly moulded to the metal plates using a suitable mould and bonding system or adhered to the plates using suitable non-solvent adhesive systems.

It is essential to have test pieces with flat and parallel surfaces. Moreover, the height shall be measured accurately to ± 0,01 mm in order that the strain can be estimated accurately to ± 1 %.

7 Number of test pieces

At least three test pieces shall be tested.

8 Time-lapse between vulcanization and testing

Unless otherwise specified for technical reasons, the following requirements shall be observed (see ISO 1826).

For all test purposes, the minimum time between vulcanization and testing shall be 16 h.

For non-product tests, the maximum time between vulcanization and testing shall be 4 weeks and for evaluations intended to be comparable, the tests, as far as possible, shall be carried out after the same time-interval.

For product tests, whenever possible, the time between vulcanization and testing shall not exceed 3 months. In other cases, tests shall be made within 2 months of the date of receipt of the product by the customer.

9 Conditioning

Samples and test pieces shall be protected from light as completely as possible during the interval between vulcanization and testing.

Samples, after any necessary preparation, shall be conditioned at standard temperature (see ISO 471) for at least 3 h before the test pieces are cut. The test pieces may be marked, if necessary, and measured and tested immediately. If not tested immediately, they shall be kept at the standard temperature until tested. If the preparation involves buffing, the interval between buffing and testing shall not exceed 72 h.

Moulded test pieces shall be conditioned at standard temperature for at least 3 h immediately before being measured and tested.

If the test is to be carried out at a temperature other than standard temperature, the test pieces shall be conditioned at the test temperature, immediately prior to testing, for a period sufficient to ensure that they have reached the test temperature (see ISO 3383).

10 Temperature of test

The test shall normally be carried out at standard temperature (see ISO 471). If another temperature is used, it should preferably be one of the following:

> −75 °C, −55 °C, −40 °C, −25 °C, −10 °C, 0 °C, 40 °C, 55 °C, 70 °C, 85 °C, 100 °C, 125 °C, 150 °C, 175 °C, 200 °C or 225 °C,

with a tolerance of ± 2 °C up to 150 °C and ± 3 °C at higher temperatures.

11 Procedure

11.1 Measurement of test pieces

Determine the dimensions of the test pieces by the appropriate methods specified in ISO 4648. For test pieces bonded by vulcanization, measure the thickness of the bonded assembly and determine the thickness of rubber by subtraction of the sum of the thicknesses of the metal plates.

11.2 Determination of stress-strain properties

For lubricated test pieces, lightly coat the polished surfaces of the metal plates with a film of the lubricant.

Insert the assembly (lubricated or bonded) centrally in the compression machine and operate the machine at a speed of 10 mm/min until a strain of 25 % is reached. Release the strain at the same speed of 10 mm/min and repeat the compression and release cycle three more times, the four compression cycles forming an uninterrupted sequence.

12 Expression of results

The results shall be derived from the recorded force-deformation diagrams (see figure 1) and shall be expressed in megapascals as the compression moduli at 10 % and 20 % strain, the strain being measured from the point at which the curve in the last cycle meets the strain (deformation) axis. Determine the stress-strain properties from the force-deformation measurements obtained during the compression part of the last cycle. Report the median and individual values at 10 % and 20 % compression strain for all the test pieces.

The compression modulus is given, in megapascals, by the formula

$$\frac{F}{A}$$

$$= \frac{F}{A_{\varepsilon_{0,1}}} \text{ for compression modulus at 10 \% strain}$$

$$= \frac{F}{A_{\varepsilon_{0,2}}} \text{ for compression modulus at 20 \% strain}$$

where

F is the force, in newtons, applied to cause the compression strain;

A is the original cross-sectional area, in square millimetres, of the test piece;

ε is the compression strain, expressed as a percentage of the height of the test piece.

13 Test report

The test report shall include the following:

a) identification of the sample;

b) a reference to this International Standard;

c) the method used (A or B);

d) the number of test pieces used;

e) the dimensions of the test pieces, if different from those specified;

f) the method of preparation of the test pieces;

g) the type of lubricating or bonding agent;

h) the temperature of test;

i) the median and individual values, expressed in megapascals, of the compression moduli at 10 % and 20 % strain;

j) any deviation from the procedure specified.

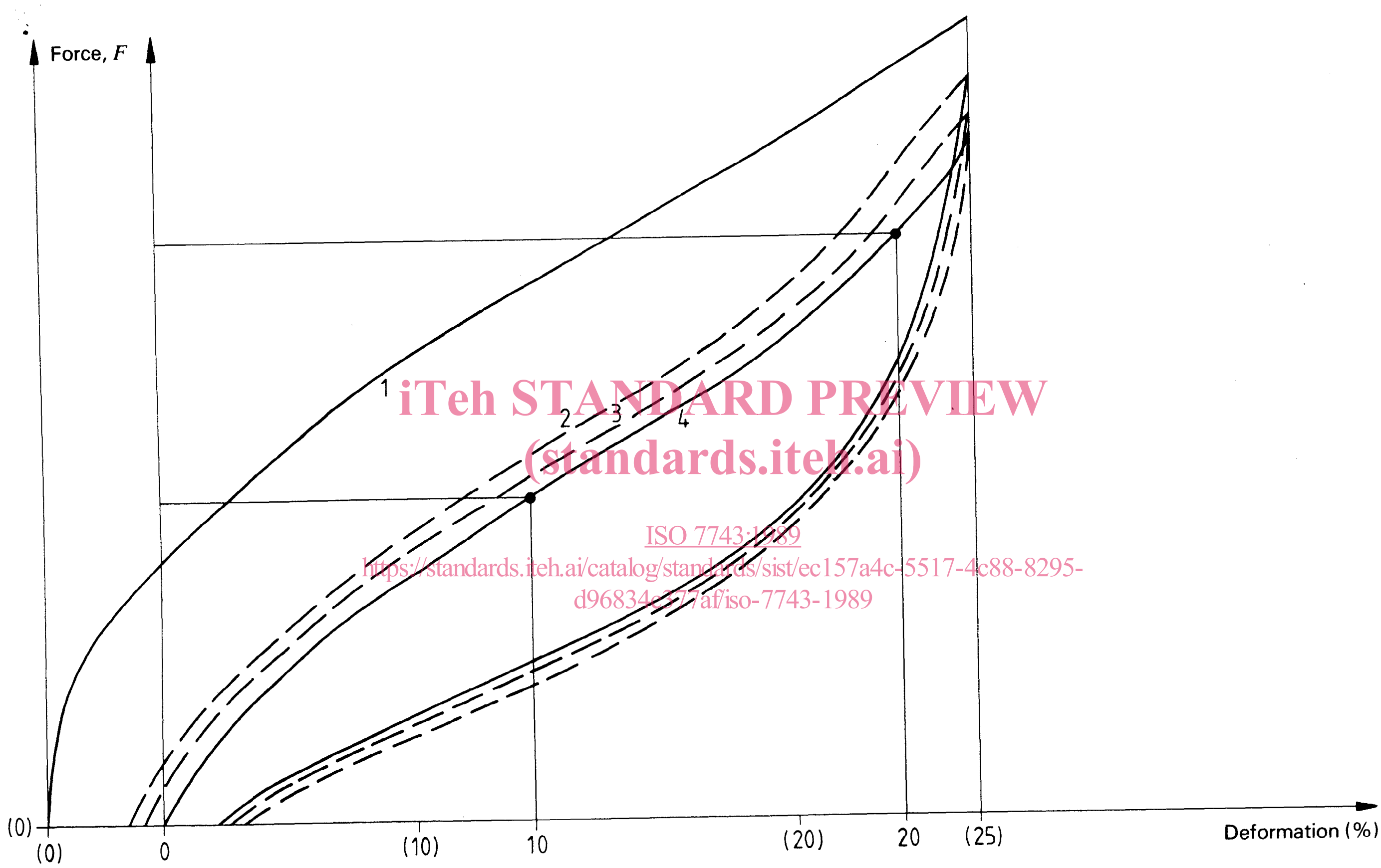

Figure 1 — Calculation of compression modulus

Annex A
(informative)

Extrapolation of results to non-standard test pieces

The effects of shape factor and degree of slip at the compressed faces on the compression stress-strain properties of rubber are very complex and normally test results should be regarded as uniquely applicable to the specific shape of test piece and conditions used in the test.

However, this annex is intended to give some indication of the factors to be considered should any attempt be made to compare results obtained on different test pieces or to extrapolate from test pieces to products, and to indicate the difference in behaviour between lubricated and bonded test pieces. It must be emphasized that the relationships given are approximate and that any extrapolation of results using them should be confirmed by experimental means.

The following symbols are used throughout this annex:

- E_o Young's modulus
- E_c Effective compression modulus
- ε Compression strain, expressed as a fraction of the original dimension in the direction of strain
- G Shear modulus
- K Bulk modulus
- S Shape factor
- λ Compression ratio ($\lambda = 1 - \varepsilon$)
- σ Average compression stress
- k A factor depending on hardness[1]

Rubbers have a very high bulk modulus and for most purposes may be regarded as incompressible.

Thus

$$E_o = 3G$$

Under lubricated conditions (method A), assuming complete slip, the compression is homogeneous and the stress-strain relationship predicted by Gaussian theory is applicable:

$$\sigma = G(\lambda^{-2} - \lambda)$$

$$= \frac{E_o(\lambda^{-2} - \lambda)}{3} \qquad \text{... (A.1)}$$

For small strains, up to about 5 %, the second and higher powers of ε may be neglected to give the approximation

$$\sigma = E_o\varepsilon \qquad \text{... (A.2)}$$

For higher strains, up to about 30 %, the third and higher powers of ε may be neglected to give the approximation

$$\sigma = \frac{E_o\varepsilon}{1 - \varepsilon}$$

$$= 3G(\lambda^{-1} - 1) \qquad \text{... (A.3)}$$

In the bonded condition (method B), non-uniform distribution of shear strain arises from the constraints at the bonded surfaces and the compression strain becomes dependent upon the shape and the hardness of the material.

$$E_c = E_o(A + BS^n) \qquad \text{... (A.4)}$$

NOTE — In the case of natural rubber, $n = 2$.

S is the ratio of the area to which the force is applied to the force free area; for example for a disc:

$$S = \frac{\text{diameter}}{4 \times \text{thickness}}$$

For discs

$A = 1$ and $B = 2k$

For rectangles

$1{,}0 \leqslant A \leqslant 1{,}3$

$1{,}3 \leqslant B \leqslant 2{,}2$

depending on hardness.

The value of E_c derived from equation (A.4) may be substituted for E_o in equation (A.1), (A.2) or (A.3) as appropriate, depending on the level of strain.

At very high strains, or when S becomes large, account may need to be taken of the bulk modulus. An approximation is:

$$\frac{1}{E_c} = \frac{1}{E_o(A + BS^n)} + \frac{1}{K} \qquad \text{... (A.5)}$$

1) See FREAKLEY, P.K., and PAYNE, A.R., *Theory and practice of engineering with rubber*, published by Applied Science Publishers Ltd., 1978, pp. 113-118.

Rubber containing filler behaves non-linearly in shear and this can have a significant effect on the shape factor component of E_c; the same applies in homogeneous compression.

When neither lubrication nor bonding is used, friction will not normally entirely prevent slip and the extent to which slippage occurs will be variable, depending on surface conditions, level of strain, etc. It may also be time-dependent and be increased in the presence of vibration.

For design purposes, Young's modulus is of more value than the secant modulus. To determine Young's modulus from the experimental measurements at 10 % and 20 % strain, equation (A.3) should be used, modified if required by equation (A.4).

The secant modulus SM is then given by

$$\mathrm{SM} = \frac{\sigma}{\varepsilon}$$

$$= \frac{E_o}{1 - \varepsilon} \text{ for lubricated test pieces}$$

$$= \frac{E_o (A + BS^n)}{1 - \varepsilon} \text{ for bonded test pieces}$$

From these equations, Young's modulus is given by

$$E_o = \mathrm{SM}\,(1 - \varepsilon) \text{ for lubricated test pieces}$$

$$= \frac{\mathrm{SM}\,(1 - \varepsilon)}{A + BS^n} \text{ for bonded test pieces}$$

The value to be reported should be the median of E_o determined from the secant moduli for 10 % and 20 % strain.

UDC [678.4+.7] : 620.173.2

Descriptors : rubber, vulcanized rubber, crude rubber, tests, compressive tests, compression stress, strain, strain measurement.

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