BRITISH STANDARD

Method for

Physical testing
of rubber

Part A4. Determination of compression stress-strain properties

STANDARDS

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Rubber Standards Policy Committee (RUM/-) to Technical Committee RUM/36, upon which the following bodies were represented:

British Railways Board
British Rubber Manufacturers' Association
ERA Technology Ltd.
GAMBICA (BEAMA Ltd.)
Institution of Mechanical Engineers
Institution of Water Engineers and Scientists
Malaysian Rubber Producers' Research Association
Ministry of Defence
National College of Rubber Technology
Rubber and Plastics Research Association of Great Britain
SATRA Footwear Technology Centre

This British Standard, having been prepared under the direction of the Rubber Standards Policy Committee, was published under the authority of the Board of BSI and comes into effect on 27 July 1990

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The following BSI references relate to the work on this standard:
Committee reference RUM/36
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Amd. No.	Date	Text affected

Contents

National foreword

This Part of BS 903, which has been prepared under the direction of the Rubber Standards Policy Committee, is identical with ISO 7743 : 1989 'Rubber, vulcanized or thermoplastic - Determination of compression stress-strain properties' including Technical Corrigendum No. 1 published by the International Organization for Standardization (ISO).

Cross-references

International standard	Corresponding British Standard
	BS 903 Methods of testing vulcanized rubber
ISO 471 : 1983	Part A35 : 1985 Temperatures, humidities and times for conditioning and testing of test pieces (Identical)
ISO 3383 : 1985	Part A32 : 1988 General directions for achieving elevated or subnormal temperatures for test purposes (Identical)
ISO 4648 : 1978	Part A38 : 1978 Determination of dimensions of test pieces and products for test purposes (Identical)
ISO 4661/1 : 1986	Part A36 : 1988 Preparation of samples and test pieces (Identical)
ISO 5893 : 1985	BS 5214 Specification for testing machines for rubbers and plastics Part 1 : 1975 Constant rate of traverse machines (Technically equivalent)

The Technical Committee has reviewed the provisions of ISO 468 and ISO 1826, and has decided that they are acceptable for use in conjunction with this standard. A related British Standard to ISO 468 is BS 1134 'Assessment of surface texture' Part 1 : 1988 'Methods and instrumentation' and Part 2 : 1972 'General information and guidance'. A related British Standard to ISO 1826 is BS 903 'Methods of testing vulcanized rubber' Part A19 : 1986 'Heat resistance and accelerated ageing tests'.

Additional information. In the UK, the 'standard temperature' (see clauses **9** and **10**) is 23 ± 2 °C.

NOTE. The 'standard temperature' is commonly referred to as the 'standard laboratory temperature'.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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INTERNATIONAL STANDARD

ISO 7743 : 1989 (E)

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.

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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.

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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

$$\frac{F}{A} \text{ by } \frac{F}{A \cdot \varepsilon}$$

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

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

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.
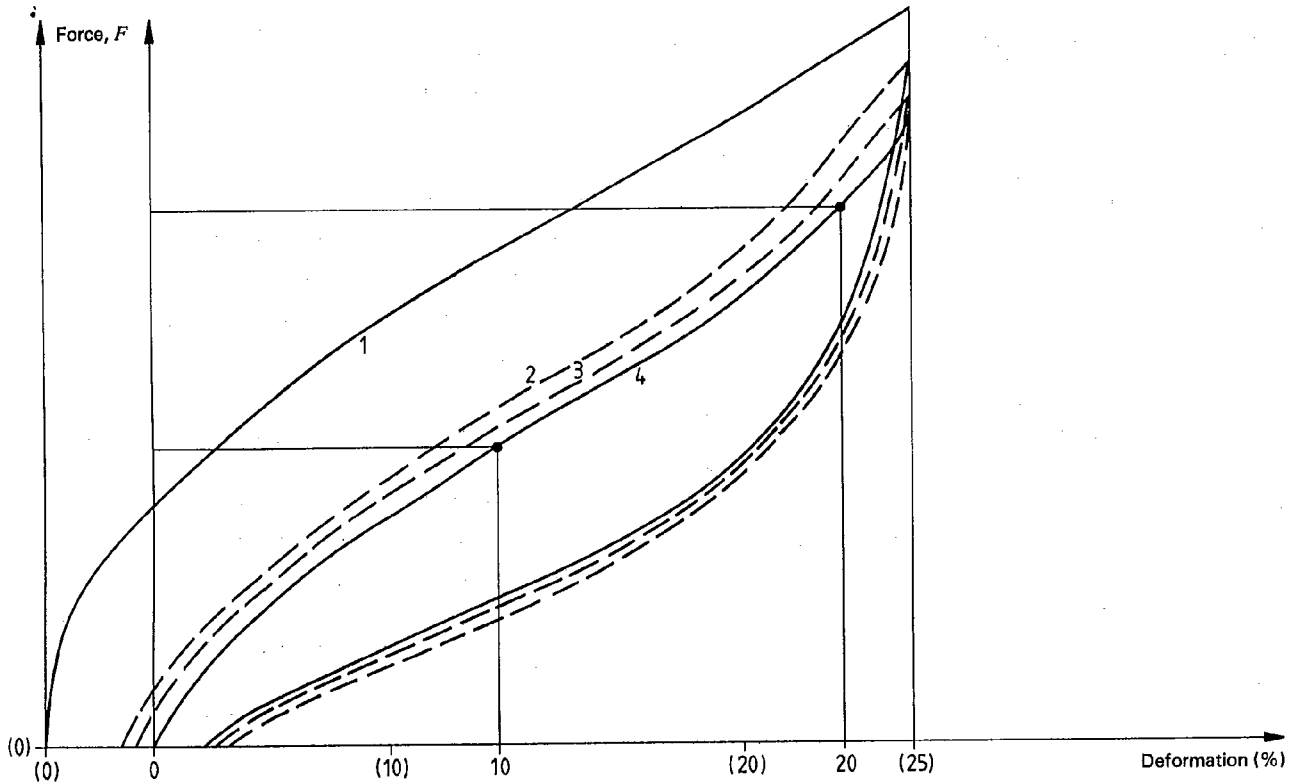
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Figure 1 — Calculation of compression modulus

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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

$$E_o = 3\,G$$

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

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

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

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

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

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

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

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

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.

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

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

$$A = 1 \text{ and } B = 2\,k$$

For rectangles

$$1{,}0 < A < 1{,}3$$

$$1{,}3 < B < 2{,}2$$

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:

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

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[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.

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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

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

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

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

From these equations, Young's modulus is given by

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

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

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

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Publications referred to

See national foreword.

BS 903 :
Part A4 : 1990
ISO 7743 : 1989

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published and effective from 30 September 1991
to BS 903 : Part A4 : 1990

Method for physical testing of rubber
Part A4. Determination of compression
stress-strain properties

AMD 6741

*Technical Corrigendum
No. 1 to
ISO 7743 : 1989*

NOTE. This Amendment implements Technical Corrigendum No. 1
to ISO 7743 : 1989 published on 15 December 1990.

Revised text

AMD 6741
September 1991

National foreword

In paragraph 1, line 4, after 'properties' insert 'including Technical Corrigendum No. 1'.

AMD 6741
September 1991

Clause 12. Expression of results

Replace the existing formulae by the following:

$$\frac{F}{A} \text{ by } \frac{F}{A \cdot \varepsilon}$$

$$\frac{F}{A_{\varepsilon_{0,1}}} \text{ by } \frac{F}{A \cdot \varepsilon_{0,1}}$$

$$\frac{F}{A_{\varepsilon_{0,2}}} \text{ by } \frac{F}{A \cdot \varepsilon_{0,2}}$$

9109—0—0.8k—B

PRM/22