

Testing of resin and polymer/cement compositions for use in construction —

**Part 12: Methods for measurement of
unrestrained linear shrinkage and
coefficient of thermal expansion**

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Technical Committee B/517, Concrete, to Subcommittee B/517/8, Protection and repair of concrete structures, upon which the following bodies were represented:

- British Adhesives and Sealants Association
- British Cement Association
- British Railways Board
- Building Employers Confederation
- Cement Admixtures Association
- Concrete Repair Association
- Concrete Society
- County Surveyors' Society
- Department of the Environment (Building Research Establishment)
- Department of Transport
- Department of Transport (Transport Research Laboratory)
- Federation of Civil Engineering Contractors
- FeRFA
- Institution of Highways and Transportation
- Institution of Structural Engineers
- Plastics and Rubber Institute
- Sprayed Concrete Association

This British Standard, having been prepared under the direction of the Technical Committee B/517, was published under the authority of the Standards Board and comes into effect on 15 October 1992

© BSI 08-1999

The following BSI references relate to the work on this standard:
Committee reference B/517/8
Draft for comment 90/17981 DC

ISBN 0 580 21123 1

Amendments issued since publication

Amd. No.	Date	Comments

Contents

	Page
Committees responsible	Inside front cover
Foreword	ii
1 Scope	1
2 References	1
3 Definitions	1
4 Principles	1
5 Apparatus	1
6 Test specimens	3
7 Measurement of shrinkage	3
8 Calculation of shrinkage	3
9 Test report for shrinkage	4
10 Measurement of the coefficient of thermal expansion	4
11 Calculation of the coefficient of thermal expansion	4
12 Test report for the coefficient of thermal expansion	5
Figure 1 — General arrangement of steel mould and transducers for measuring displacements and typical cross sections	2
List of references	Inside back cover

Foreword

This Part of BS 6319 has been prepared under the direction of Technical Committee B/517, Concrete. This Part describes a method for measuring the unrestrained dimensional changes of a thin layer of freshly cast polymer mortar or polymer/cement mortar over the first 24 h after placing. The dimensional changes depend on the formulation of the mortar and can be due to any combination of water loss, heat loss subsequent to exothermic reaction and molecular rearrangement of the polymer. The measured shrinkage or expansion strains can indicate how the material would behave when used for patch repairs or surfacing to hardened concrete.

This Part of BS 6319 also describes how the mortar specimen after hardening can be used to measure its thermal expansion. If this measurement is made at early ages, raising the temperature may affect the polymer giving rise to post-cure shrinkage. The effects of temperature on these materials are described in Appendix A of BS 6319-10:1987.

The apparatus used for these tests on polymer mortars may also be used to measure the unrestrained shrinkage and coefficient of thermal expansion of cement mortars when modified by fitting suitable disposable lines to the sliding ends.

This Part of BS 6319 should be read in conjunction with BS 6319-1 which provides general information and describes a method for preparing test specimens.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations. In particular, attention is drawn to the Health and Safety at Work etc. Act 1974 [1].

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 6, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Part of BS 6319 describes the methods for the measurement of linear shrinkage from initial gel and of the coefficient of thermal expansion of hardened polymer and polymer/cement mortars in the form of unrestrained thin strips (less than 20 mm in thickness).

The methods are suitable for materials that do not contain aggregates larger than 3 mm used in thin layers for patch repairs and surfacing applications.

2 References

2.1 Normative reference

This Part of BS 6319 incorporates, by reference, provisions from a specific edition of another publication. This normative reference is cited at the appropriate points in the text and the publication is given on the inside back cover. A subsequent amendment to, or revision of, this publication applies to this Part of BS 6319 only when incorporated in it by updating or revision.

2.2 Informative reference

This Part, of BS 6319 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest edition.

3 Definitions

For the purposes of this Part of BS 6319 the definitions given in BS 6319-1:1983 apply.

4 Principles

4.1 Shrinkage test

A freshly mixed sample of polymer mortar or polymer/cement mortar is placed in a shallow steel trough shaped mould with sliding ends, the inside of which has been treated to prevent adhesion by the mortar. The trough has sliding ends which bond to the mortar and are free to move as the mortar expands or contracts. Linear displacement transducers attached to the ends enable the shrinkage to be measured. A temperature sensor attached to the mould enables its temperature and so that of the mortar to be measured.

4.2 Coefficient of thermal expansion test

Samples of hardened polymer mortar or polymer/cement mortar, prepared as for the shrinkage test, are subjected to a number of temperature cycles while movements of the ends and changes in temperature of the mortar are monitored. Correction is made for changes in the length of the mould.

5 Apparatus

5.1 Mould, comprising a 400 mm long pressed steel trough supported on an insulating base and fitted with sliding ends, as shown in Figure 1. The tolerances on the dimensions of the trough shall conform to clause 3 of BS 6319-1:1983. The ends shall fit the cross section of the trough with a clearance of 0.1 mm. The inside of the trough is coated with polytetrafluoroethylene (PTFE). Disposable linings which have surfaces prepared to enable the mortar samples to adhere to them are attached to the inner faces of the sliding ends.

NOTE A bond-fin or mechanical linkage may be needed for some mortars.

The probes of linear displacement transducers (5.2) are attached to the outer faces of the sliding ends. A thermocouple (5.4) is attached at the centre of the underside of the mould

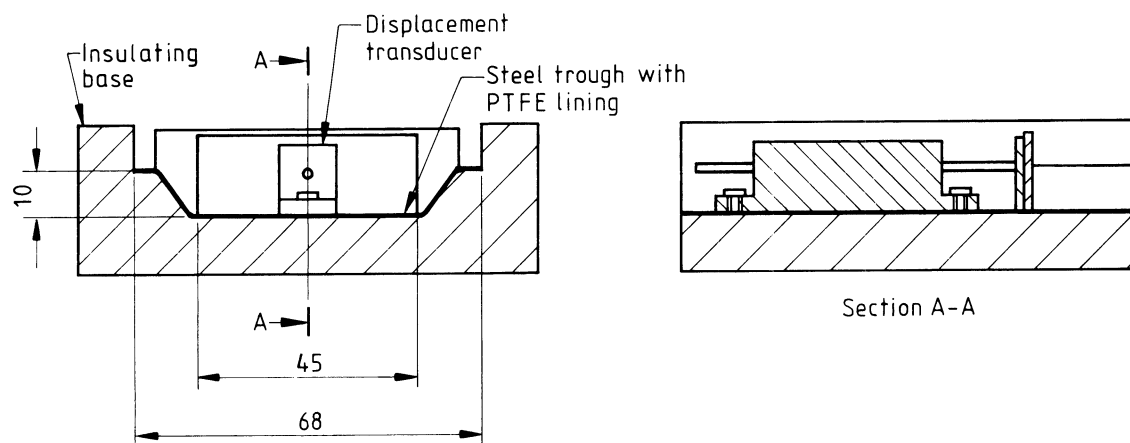
5.2 Linear displacement transducers, capable of measuring to an accuracy of 0.01 mm over a range of at least 5 mm and producing an output that can be recorded automatically.

NOTE These should be linear variable differential transformers that remain stable during fluctuations in temperature and humidity. The force required to move the probe should not exceed 8 g.

5.3 Environmental chamber, large enough to contain the mould (5.1) in a horizontal position. Air shall be able to circulate freely around the mould. The chamber shall be capable of maintaining a temperature to within $\pm 1^\circ\text{C}$ over the range -25°C to $+50^\circ\text{C}$. A thermocouple (5.4) is used to record the air temperature inside the chamber.

NOTE The relative humidity of the room in which the environmental chamber is used should be not less than 50 % r.h.

5.4 Thermocouples, connected into a signal conditioning unit, with automatic cold junction compensation, that gives a linear output proportional to temperature that can be monitored automatically.



Dimensions are in millimetres.

Figure 1 — General arrangement of steel mould and transducers for measuring displacements and typical cross sections

6 Test specimens

6.1 General

Any pre-conditioning of the constituents used in preparation of the specimens shall be declared in the test report.

Each specimen shall be representative of the polymer or polymer/cement mortar being assessed. Where more than one specimen is to be tested, the specimens shall be taken from the same batch of mortar made from the same batch of constituent materials.

6.2 Preparation of specimens

Carry out the preparation of specimens, including sampling, conditioning, proportioning and mixing of constituents, the conditioning and filling of moulds and curing as described in BS 6319-1:1983 unless the specification for a particular material requires otherwise. Any variations shall be declared in the test reports.

7 Measurement of shrinkage

7.1 Specimens

Test a minimum of three specimens at each prescribed test temperature.

NOTE The specimens may all be tested sequentially or at the same time depending on the availability of apparatus.

7.2 Conditioning

First spray the mould (5.1) using a silicone aerosol. Then condition the mould and mortar constituents in the chamber (5.3) at the prescribed temperature $\pm 2^\circ\text{C}$. Monitor the temperature of the chamber using a thermocouple (5.4). Conditioning is completed when the thermocouple in the chamber and the thermocouple attached to the mould correspond within 1°C . Set the transducers (5.2) at mid-stroke and clamp the sliding ends in this position during casting.

7.3 Casting

Immediately prior to casting, place a small fillet of silicone wax at the junction of the sliding ends and the trough to prevent escape of polymer. Mix the mortar, place and compact it to form a layer not more than 20 mm deep in the mould set up on a level surface in the door opening of the chamber (5.3). Level the top surface of the mortar. Minimize the period for which the chamber door is open. As soon as casting has been completed, free the ends and place the mould in the chamber. Take the initial reading of the transducers and thermocouples immediately the chamber door has been closed.

7.4 Duration of test

Record the readings for sliding end displacement and mould temperature at 5 min intervals until 1 h after gelling of the mortar has taken place (gelling can normally be detected by monitoring inward movements of the ends).

Record further readings at 15 min intervals during the next 23 h and at hourly intervals during the subsequent 24 h. On completion of the test, measure and record the length of the hardened specimen, L_s , at ambient temperature and the length of the mould between the centre lines of the transducer bases, L_m , to the nearest 0.1 mm.

NOTE Owing to the exothermic reaction, the temperature will rise to a maximum and the trough will expand, thus exaggerating the degree of shrinkage at this stage. Corrections can be made for this expansion but are not usually required as the trough returns to ambient temperature by the time maximum shrinkage has occurred.

8 Calculation of shrinkage

Calculate the change in length of each specimen, ΔL_s , from the equation

$$\Delta L_s = \delta_1 + \delta_2 - \delta_3 \quad (1)$$

where

δ_1 and δ_2 are the transducer readings (in mm) (positive towards the centre of the specimen);

δ_3 is the thermal expansion of the mould given by

$$\delta_3 = L_m \Delta T \alpha_s \quad (2)$$

where

L_m is the length of the mould (in mm);

ΔT is the change in temperature of the mould from ambient to the prescribed temperature (in K) (values less than 5 K can be ignored);

α_s is the coefficient of thermal expansion of steel (11×10^{-6} m/m K).

Then calculate the shrinkage strain, s_m , as a percentage, from the equation

$$s_m = \frac{\Delta L_s}{L_s} \times 100 \quad (3)$$

where

L_s is the effective length of the hardened mortar specimen at ambient temperature (in mm).

9 Test report for shrinkage

The following information shall be included in the test report:

- identification of all the constituents of the mortar including manufacturer's name, code numbers if applicable, type description and date of production;
- temperature and duration of pre-conditioning of the constituents and any variations from the procedure for specimen preparation described in BS 6319-1:1983;
- date and location of mortar specimen preparation and test;
- the prescribed temperature for the test (environmental chamber temperature);
- the apparatus reference number and details of the monitoring system(s) used;
- the effective lengths of the specimens to the nearest millimetre;
- tabulation of the results of shrinkage against time, specifying whether or not temperature correction has been applied, and natural log scale graphs of these results;
- the calculated maximum value of shrinkage strain and the time to reach this value from completion of mixing the constituents for each specimen and their mean values;
- the time intervals from completion of mixing the constituents to identification of initial gel.

10 Measurement of the coefficient of thermal expansion

10.1 Specimens

Prepare and cast specimens for measuring the coefficient of thermal expansion as described in clause 7. The casting temperature shall be 15 °C unless a different temperature is stated in the specification for a particular material.

Record the casting, curing and storage conditions and age at test. Ensure that the specimen is bonded to the linings of the sliding ends and that these linings are firmly attached to the ends.

NOTE Specimens made for shrinkage measurements can be used for determining the coefficient of thermal expansion without removing them from the mould.

10.2 Procedure

Place the mould containing the specimen into the chamber (5.3) locating the chamber thermocouple immediately adjacent to the specimen. Set the chamber to the initial temperature T_1 which shall be not higher than the casting temperature for the specimen under test.

Condition the mould and specimen at T_1 until the mould and chamber temperatures correspond within 1 °C and are stable for at least 1 h.

Record the mean of the two thermocouple readings as T_1 . Then subject the specimen to the following cycles.

- Stage 1.* Record the chamber control setting for the initial temperature accurately and also the transducer settings. Adjust the chamber control to produce a reduction in temperature of between 20 °C and 25 °C. Maintain this setting until both thermocouples indicate the same temperature within 1 °C for at least 1 h and record their mean as T_2 . Then return the chamber control to the initial temperature setting and repeat this temperature cycle twice.
- Stage 2.* Set the chamber control to the initial temperature. When stability has been reached, adjust the chamber control to give a rise in temperature of between 20 °C and 25 °C. Maintain this setting until both thermocouples indicate the same temperature within 1 °C for at least 1 h and record their mean as T_3 . Repeat the procedure as for stage 1 but complete five temperature cycles.

11 Calculation of the coefficient of thermal expansion

11.1 Stage 1

Calculate the coefficient of thermal expansion, α_m , in m/m K as the mean of the six numerical values of α'_m , ignoring their sign, determined for each temperature change between T_1 and T_2 from the equation

$$\alpha'_m = \frac{\delta_4 + \delta_5 + \delta_6}{L_s(T_1 - T_2)} \quad (4)$$

where

δ_4 and δ_5 are the transducer readings (in mm) (positive towards the centre of the specimen);

δ_6 is the change in length of the mould (in mm) (shortening positive, lengthening negative) given by

$$\delta_6 = L_m(T_1 - T_2)\alpha_s \quad (5)$$

where

α_s is the coefficient of thermal expansion of steel (11×10^{-6} m/m K);

L_s is the effective length of the specimen at ambient temperature (in mm);

L_m is the length of the mould between the centre lines of the transducer bases (in mm).

11.2 Stage 2

Calculate the coefficient of thermal expansion, α_m , as the mean value of α'_m for each temperature change between T_1 and T_3 in the third, fourth and fifth cycles from the equation

$$\alpha'_m = \frac{\delta_7 + \delta_8 + \delta_9}{L_s(T_3 - T_1)} \quad (6)$$

where

δ_7 and δ_8 are the transducer readings (in mm) (positive towards the centre of the specimen);

δ_9 is the change in length of the mould (in mm) (shortening positive, lengthening negative) given by

$$\delta_9 = L_m(T_3 - T_1)\alpha_s \quad (7)$$

NOTE Significant differences in the values of transducer readings for the rising and falling temperatures in cycles one and two may occur due to post-cure shrinkage.

12 Test report for the coefficient of thermal expansion

The following information shall be included in the test report:

- a) identification of all the constituents in the mortar mix including manufacturer's name, code numbers if applicable, type description and date of production;
- b) temperature and duration of pre-conditioning of the constituents and any variation from the procedure described in BS 6319-1:1983;
- c) date and location of mortar specimen preparation and test;
- d) the temperature of casting the specimen;
- e) the cure and storage history of the specimen prior to test;
- f) the apparatus reference number and details of the monitoring system(s) used;
- g) the effective length of the specimen to the nearest millimetre;
- h) tabulation of the results obtained, giving for each temperature cycle the initial temperature, the temperature difference in the cycle, sliding end movements, change in length of the mould and α'_m ;
- i) the mean values for α_m in stage 1 and stage 2;
- j) the amount of any post-cure shrinkage observed.

List of references (see clause 2)

Normative references

BSI standards publications

BRITISH STANDARDS INSTITUTION, London

BS 6319, *Testing of resin and polymer/cement compositions for use in construction.*

BS 6319-1:1983, *Method for preparation of test specimens.*

Informative references

BSI standards publications

BRITISH STANDARDS INSTITUTION, London

BS 6319, *Testing of resin and polymer/cement compositions for use in construction.*

BS 6319-10:1987, *Method for measurement of temperature of deflection under a bending stress.*

Other references

[1] GREAT BRITAIN. Health and Safety at Work etc. Act 1974. London: HMSO.

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: 020 8996 9000. Fax: 020 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: 020 8996 9001. Fax: 020 8996 7001.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre. Tel: 020 8996 7111. Fax: 020 8996 7048.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: 020 8996 7002. Fax: 020 8996 7001.

Copyright

Copyright subsists in all BSI publications. BSI also holds the copyright, in the UK, of the publications of the international standardization bodies. Except as permitted under the Copyright, Designs and Patents Act 1988 no extract may be reproduced, stored in a retrieval system or transmitted in any form or by any means – electronic, photocopying, recording or otherwise – without prior written permission from BSI.

This does not preclude the free use, in the course of implementing the standard, of necessary details such as symbols, and size, type or grade designations. If these details are to be used for any other purpose than implementation then the prior written permission of BSI must be obtained.

If permission is granted, the terms may include royalty payments or a licensing agreement. Details and advice can be obtained from the Copyright Manager. Tel: 020 8996 7070.