

Testing concrete —

Part 201: Guide to the use of non-destructive methods of test for hardened concrete

UDC 666.972.017:691.32:620.1

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- Association of Metropolitan Authorities
- British Aggregate Construction Materials Industries
- British Precast Concrete Federation
- British Ready Mixed Concrete Association
- Building Employers' Confederation
- Cement Admixtures Association
- Cement and Concrete Association
- Cement Makers' Federation
- Concrete Society
- County Surveyor's Society
- Department of the Environment (Building Research Establishment)
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- Royal Institute of British Architects
- Royal Institution of Chartered Surveyors
- Sand and Gravel Association
- Society of Chemical Industry

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- British Civil Engineering Test Equipment Manufacturers' Association
- British Nuclear Fuels Limited
- United Kingdom Atomic Energy Authority

This British Standard, having been prepared under the direction of the Cement, Gypsum, Aggregates and Quarry Products Standards Committee, was published under the authority of the Board of BSI and comes into effect on 28 February 1986

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The following BSI references relate to the work on this standard:
Committee reference CAB/4
Draft for comment 84/10723 DC

ISBN 0 580 14767 3

Amendments issued since publication

Amd. No.	Date of issue	Comments

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Foreword

This Part of BS 1881 has been prepared under the direction of the Cement, Gypsum, Aggregates and Quarry Products Standards Committee. All aspects of testing concrete are being included as parts of BS 1881 and this Part forms a general introduction to those on non-destructive testing.

Non-destructive testing of a body of hardened concrete as cast, whether in a structure or as a component, offers advantages of speed, cost and lack of damage in comparison with test methods which require the removal of a sample. The range of properties that can be measured in this way is considerable, and much valuable information may be obtained if the available methods are used with an under-standing of what they can, and cannot, achieve.

This guide presents information on test methods of this type which will assist with the planning of investigations and the selection of methods which are most appropriate to the circumstances. It summarizes the principal features of currently available techniques together with their advantages, limitations and most reliable applications. Many of the methods will be described in detail in other Parts of BS 1881-202 onwards¹⁾, while other techniques which are not yet so well established are also included with appropriate references. Additional guidance is given concerning the value of combinations of test methods.

The use of tests to assess strength is covered in greater detail in BS 6089. Strain gauges suitable for monitoring the behaviour of concrete structures in service, or under test load conditions, will be dealt with in Part 206¹⁾ of this standard. For details of methods which are not covered in these British Standards, reference should be made to specialist literature as indicated.

It is hoped that the guidance given in this Part will encourage the wider use of non-destructive testing in a worthwhile and economical manner; it is not intended to supplant engineering judgement or to inhibit the development and use of other test methods.

NOTE The numbers in parentheses in the text of this Part refer to the numbered bibliographic references given in Appendix A.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 22, 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⁾ In preparation.

Section 1. General

1.1 Scope

This Part of BS 1881 gives guidance on the tests that are available for non-destructive testing of hardened concrete which forms a laboratory specimen or part of a structure, structural component or other type of engineering construction. Some tests cause varying degrees of localized damage or defacement and may therefore be considered partially destructive; these methods are all defined as non-destructive. All the tests can be performed on the concrete as cast and do not require the removal of samples for subsequent analysis or testing.

Methods of testing hardened concrete which require sample extraction are either dealt with in other Parts of BS 1881 or elsewhere (1,2).

NOTE 1 Damage caused by the extraction of small-diameter cores may not be significantly greater than that due to some of the near-to-surface methods included here, provided that reinforcement is not cut during extraction. In cases where strength determination is required they may offer similar or better accuracy with fewer calibration problems (3).

NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

1.2 Definitions

For the purposes of this Part of BS 1881, the definitions given in BS 2787 and BS 6100-6 apply, together with the following.

1.2.1

non-destructive test

a test that does not impair the intended performance of the element or member under investigation

1.2.2

location

a region of concrete that is being assessed and that, for practical purposes, is assumed to be of uniform quality

1.2.3

near-to-surface test

a test that measures some property of the concrete near to, but below, the surface

1.2.4

standard cube strength

the measured compressive strength of a cube made, cured and tested in accordance with BS 1881-108, BS 1881-111 and BS 1881-116 respectively

1.2.5

estimated in situ cube strength

the strength of concrete at a location in a structural member estimated by indirect means and expressed as the compressive strength of specimens of cubic shape

1.3 Principal considerations

1.3.1 Advantages of non-destructive testing

Non-destructive testing offers significant advantages of speed, cost and lack of damage in comparison with test methods which require the removal of a sample for subsequent examination. These factors will permit more extensive testing and thus enable an investigation to be wider ranging with respect to the concrete structure under examination than would otherwise be possible. The immediate availability of results may also be an important advantage of this type of testing.

1.3.2 Properties measured

The range of properties that can be assessed using non-destructive techniques is large and includes fundamental parameters of the concrete such as density and elastic modulus in addition to strength. Other properties which can be assessed include concrete surface hardness, surface absorption and moisture condition as well as reinforcement location, cover and corrosion risk. The quality of workmanship and structural integrity may also be checked by the ability to identify and locate voids, cracking and delamination.

The required property is not measured directly by a number of the available methods and precise correlations are not always easy to achieve. In some instances estimates of the required property can only be achieved by comparative means.

1.3.3 Importance of trained staff

Skill and care by the operator will generally be necessary, while the results obtained by some methods are particularly sensitive to variations in testing procedure. It is important that tests are performed by trained and reliable staff if worthwhile results are to be achieved, and it is recommended that two persons should normally be involved during testing on site.

1.3.4 Situations in which non-destructive testing may be valuable

Non-destructive testing may be applied to both new and existing structures. For new structures, the principal applications are likely to be for quality control or resolution of doubts about the quality of materials or construction. Testing of existing structures will usually be related to an assessment of structural integrity or adequacy. In either case, a small number of tests on a large structure, for example tests on a few cores, can be misleading, while non-destructive testing is often a valuable indicator, either on its own or as a preliminary to some other form of testing.

Non-destructive tests are useful for the following purposes:

- a) quality control of precast units or construction in situ;
- b) removing uncertainties about the acceptability of the material supplied owing to apparent non-compliance with specifications;
- c) confirming or negating doubt concerning the workmanship involved in batching, mixing, placing, compacting or curing of concrete;
- d) monitoring of strength development in relation to formwork removal, cessation of curing, pre-stressing, load application or similar purposes;
- e) location and determination of the extent of cracks, voids, honeycombing and similar defects within a concrete structure;
- f) determining the position, quantities or condition of reinforcement;
- g) determining the concrete uniformity, possibly as a preliminary to core cutting, load testing or other more expensive or disruptive tests;
- h) increasing the confidence level of a smaller number of destructive tests;
- i) determining the extent of concrete variability in order to help in the selection of sample locations representative of the quality to be assessed;
- j) confirming or locating suspected deterioration of concrete resulting from such factors as
 - 1) overloading,
 - 2) fatigue,
 - 3) external or internal chemical attack or change,
 - 4) fire,
 - 5) explosion,
 - 6) environmental effects;
- k) assessing the potential durability of the concrete;
- l) monitoring long term changes in concrete properties;
- m) providing information for any proposed change of use of a structure, for insurance or for change of ownership.

1.4 Planning an investigation

1.4.1 Reasons for testing

The situations in which non-destructive testing may be useful have been indicated in 1.3.4, and the reasons for testing should be clearly established before the details of a test programme are planned. These will establish the information that is required, e.g. strength, uniformity and density, and whether this should relate to the surface, near to the surface, or to the body of a member.

1.4.2 Acceptance of test data

Before any programme commences, it is essential that there is agreement between the interested parties on the validity of the proposed testing procedures, the criteria for acceptance and the appointment of a person and/or laboratory to take responsibility for the testing and interpretation of the results.

It is essential, despite the apparent simplicity of some test methods, that testing is performed only by skilled operators who are familiar with the methods and that the interpretation of results is entrusted to a suitably experienced engineer.

1.4.3 Selecting a test programme

1.4.3.1 General. The test programme will be determined by the objectives of the investigation coupled with the suitability of the available methods in relation to the site conditions and economic factors as outlined in 1.4.3.2 to 1.4.3.5.

The objective may be to investigate the overall quality of the fabric, in which instance a random choice of test locations will be appropriate. Where the objective is to investigate suspect material, the test locations will be selected for this purpose and the test results will only apply to this suspect material. In both cases, a sufficient number of test locations should be chosen to establish a satisfactory confidence level for the results.

Visual inspection should also be regarded as an essential preliminary to the planning of a programme of testing since observation of features such as deflection, cracking and colour may yield valuable information affecting the choice of methods and location of test points.

In some instances, calibration is necessary to relate the measured values or properties to those which are required. The availability and reliability of such calibrations are thus important.

1.4.3.2 Choice of test methods. The methods recommended in Table 1 are likely to be most suitable for the general circumstances indicated. Practical limitations may preclude the use of particular methods in some situations, while in other cases it may be appropriate or necessary to consider the use of methods other than those recommended. For example, surface treatments, such as those to reduce moisture permeability, or decorative coatings may prevent the use of some methods. The principal features of the methods, including their most important limitations and most reliable applications, are described in section 2 and summarized in Table 2.

The equipment required to perform the tests is easily portable in most cases, and all tests can be rapidly carried out, although extensive preparation may sometimes be necessary.

Important considerations affecting the choice of test method include the following.

- a) *Test locations.* Some factors to be considered are:
 - 1) the position within the member or structure;
 - 2) the variations of concrete properties through depth of lift;
 - 3) the position of reinforcement;
 - 4) the presence of local defects or influences, e.g. surface carbonation;
 - 5) the depth below the surface of the zone to which results apply.
- b) *Effect of damage.* The choice of method may be influenced by:
 - 1) the effects of testing on the surface appearance of the members;
 - 2) the possibility of structural damage resulting from the testing of small section members.
- c) *Size of member.* The size of the member may restrict the use of some test methods as a result of limitations on minimum edge distances, minimum or maximum thicknesses, or similar considerations.
- d) *Testing accuracy required.* The testing accuracy required will depend upon the purpose of the investigation. The level that can be achieved will depend on:
 - 1) the test method;
 - 2) the number and location of measurements;
 - 3) the accuracy and reliability of available calibrations.

In determining the necessary number of measurements, it should be remembered that an individual result relates only to the immediate test position and does not necessarily reflect the properties of the concrete in general.

1.4.3.3 Combination of methods. In some circumstances, the accuracy achieved may be improved by the use of two or more test methods. A combination of different test methods may be used for the following reasons.

- a) The use of one method as a preliminary to another.

The most common situations of this type are:

- 1) the location of reinforcement prior to core cutting or use of other non-destructive testing methods;
 - 2) the use of a non-destructive method to provide comparative data on concrete uniformity prior to core cutting or use of other non-destructive methods involving greater expense or damage.
- b) To obtain enhanced reliability of results on the basis of:
 - 1) the confirmation of observed patterns of concrete quality;
 - 2) the correlation of combinations of measured values with a desired property.

Suitable combinations of methods are discussed in section 3.

1.4.3.4 Site condition. The principal site conditions that should be considered include:

- a) the geographic location and ease of transport of test equipment;
- b) the accessibility of test locations;
- c) the environment;
- d) the safety of personnel and the general public during testing.

1.4.3.5 Economic and social factors. The test programme will be influenced by factors such as the value of the project and costs arising from:

- a) delays in construction, or restriction on usage or occupancy, while testing is conducted and decisions are made;
- b) remedial works that may be necessary;
- c) the features of different test methods, including time, materials and equipment, temporary works and making good;
- d) the need to select an adequate number of tests for an appropriate reliability of assessment;
- e) the need for a higher level of confidence in the assessment of structures where public safety is involved.

Table 1 — Suitability of non-destructive test methods

Methods ^a	Test situation					
	Quality control	Investigation of standard of workmanship	Control of formwork removal, pre-stress release or load application	Comparative survey of quality of concrete in the structure	Investigation of potential durability	Investigation of fire, frost, chemical attack or similar
Pull-out test (cast-in insert)	X		X			
Pull-out test (drilled hole)	X		X	X		X
Internal fracture	X		X	X		X
Break-off test	X		X			
Pull-off test	X		X	X		
Penetration resistance	X		X	X		
Surface hardness	X		X	X	X	
Screed test	X			X	X	
Dynamic response	X	X		X		
Ultrasonic pulse velocity measurement	X	X	X	X	X	X
Acoustic emission		X			X	
Electromagnetic cover measurement	X	X			X	
Radar		X		X		
Radiography		X				X
Radiometry	X	X		X		
Neutron moisture measurement				X	X	
Depth of carbonation				X	X	X
Initial surface absorption				X	X	
Surface permeability					X	
Resistivity measurements				X	X	
Half-cell potential measurements					X	
Strain measurements		X	X	X	X	X
Thermography					X	X
Maturity measurements			X			
Resonant frequency	X					

^a Subject to the practical limitations outlined in section 2.

Table 2 — Summary of principal test methods

Method	Clause number	Principal reference	Principal applications	Principal properties assessed	Surface damage	Type of equipment	Remarks
Pull-out test (cast-in insert)	2.18	BS 1881-207 ^a	Quality control (in situ strength)	Strength related	Moderate/minor	Mechanical	Preplanned usage, surface zone test
Pull-out test (drilled hole)	2.18	BS 1881-207 ^a	In situ strength measurement	Strength related	Moderate/minor	Mechanical	Drilling difficulties on vertical surfaces or soffits, surface zone test
Internal fracture	2.17	BS 1881-207 ^a	In situ strength measurement	Strength related	Moderate/minor	Mechanical	High test variability, surface zone test
Break-off test	2.20	BS 1881-207 ^a	In situ strength measurement	Flexural tensile strength	Substantial/moderate	Mechanical	High test variability, substantial damage
Pull-off test	2.19	BS 1881-207 ^a	In situ strength measurement	Direct tensile strength	Moderate/minor	Mechanical	Care needed with adhesive, surface zone test
Penetration resistance	2.21	BS 1881-207 ^a	In situ strength measurement	Strength related	Moderate/minor	Mechanical	Specific calibrations required, limits on minimum member size, surface zone test
Surface hardness	2.15	BS 1881-202 (supersedes BS 4408-4)	Comparative surveys	Surface hardness	Very minor	Mechanical	Greatly affected by surface texture and moisture, surface test unrepresentative on concrete more than 3 months old, strength calibration affected by mix properties
Initial surface absorption	2.8	BS 1881-208 ^a (supersedes BS 1881-5)	Surface permeability assessment	Surface absorption	Minor	Hydraulic	Difficult to standardize in situ moisture conditions and to obtain watertight seal to surface, comparative test
Surface permeability	2.9	(11)	Surface permeability assessment	Surface permeability	Minor	Hydraulic	Surface zone test, water or gas
Resistivity measurements	2.3	(6)	Durability survey	Resistivity	Minor	Electrical	Surface zone test, related to moisture content, indicates probability of reinforcement corrosion in zones of high risk
Half-cell potential measurements	2.4	(9)	Survey of reinforcement corrosion risk	Electrode potential of reinforcement	Very minor	Electro-chemical	Cannot indicate corrosion rate
Thermography	2.11	(16)	Structural integrity survey and void location	Surface temperature differences	None	Infra-red radiation detection	Extraneous temperature effects have to be excluded, temperature differentials small, shortage of data and development
Maturity measurements	2.10	(14)	In situ strength development monitoring	Maturity	Minor	Thermo-sensitive chemical or electronic	Preplanned usage, specific calibration required