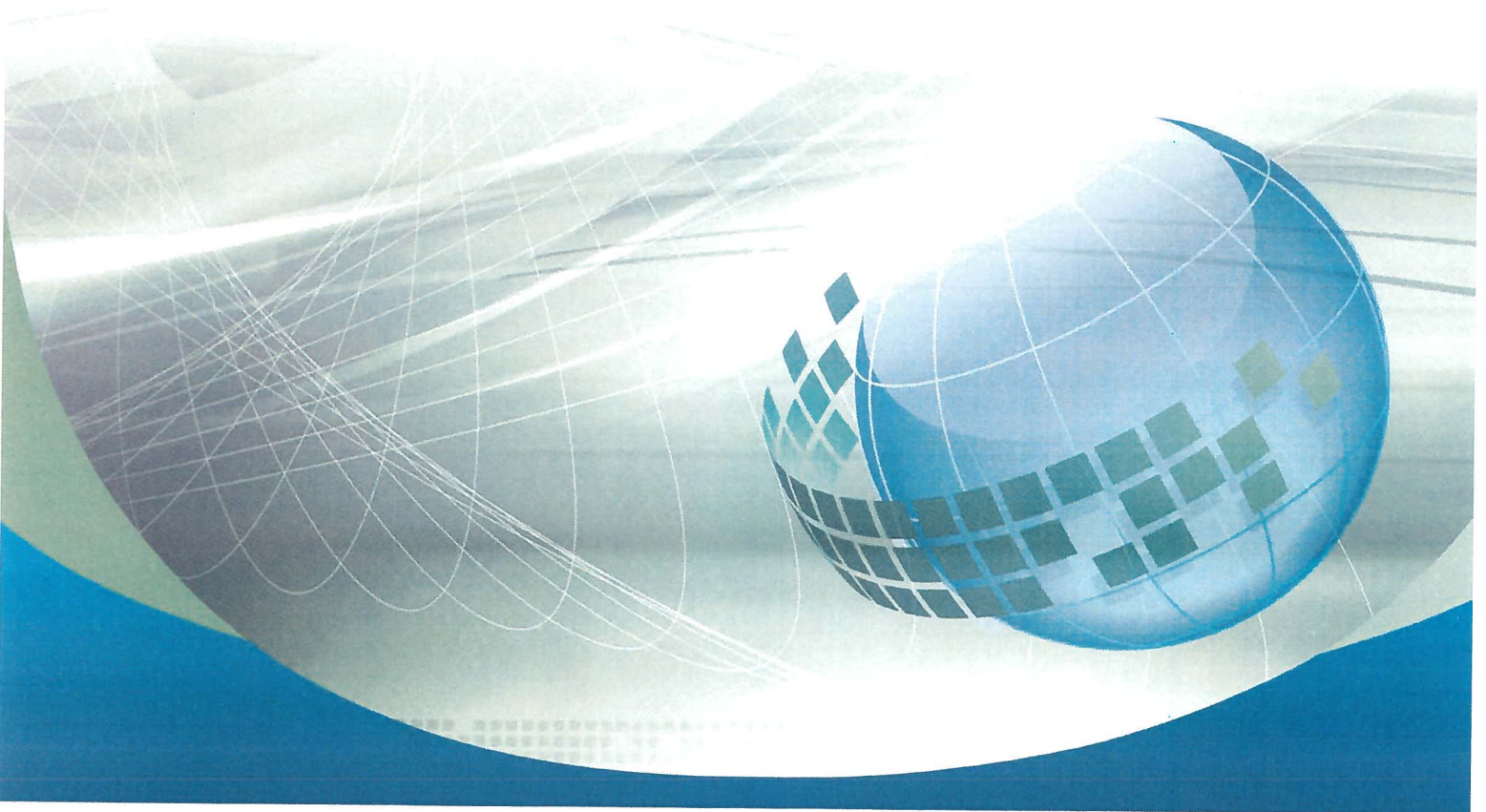




A23.1-14/A23.2-14

Concrete materials and methods of concrete construction/Test methods and standard practices for concrete



4.4.6.3.2

When the frequency of testing stipulated in [Clause 4.4.6.3.1](#) will provide fewer than three strength tests results for a given class of concrete, the strength tests results shall be made from at least three randomly selected batches on a single project.

Note: When the total quantities of concrete produced from the same mix design are less than 50 m³, the strength tests may be waived by the owner if, in the owner's judgment, adequate evidence of satisfactory strength is provided.

4.4.6.4 Standard, accelerated, and in-place strength tests

4.4.6.4.1 General

For a strength determination, a minimum of two test cylinders shall be tested.

4.4.6.4.2 Standard strength tests

Cylinders shall be tested at an age of 28 d unless otherwise specified.

Note: When structural requirements permit, the specified compressive strength requirements for mass concrete, high-strength concrete, high-performance concrete, high volume supplementary cementing materials concrete, and concrete subjected to sulphate attack may be evaluated at a later age (56 d or 91 d), as specified by the owner.

4.4.6.4.3 Accelerated strength tests

When the accelerated strength test is used as an alternative to the standard cylinder test for the acceptance of concrete on the basis of strength, the owner shall be satisfied that adequate correlation data for the standard 28 d compressive strength test are available. The owner shall specify in the contract documents if this alternative is to be used and state the basis for acceptance.

4.4.6.4.4 In-place strength tests

For in-place tests, a statistically valid number of tests shall be made.

Note: The number of tests will vary according to the test method used, the age at which tests are made, and the size of the placement that they represent. See [ACI 228.2R](#) or [Annex A of CSA A23.2](#) for guidance.

4.4.6.4.5 In-place strength

4.4.6.4.5.1 Test procedures

Unless otherwise specified by the owner, the in-place strength shall be determined in accordance with [CSA A23.2-14C](#), [CSA A23.2-15C](#) or [ASTM C1074](#) for the purposes of determining:

- (a) when forms shall be removed or when prestressing or post-tensioning shall be applied;
- (b) when curing shall be terminated; and
- (c) when re-shores shall be removed.

For in-place strength tests see [Clause 4.4.6.4.4](#).

4.4.6.5 Standard test procedures

4.4.6.5.1 Standard cured cylinders

4.4.6.5.1.1 General

Standard tests shall be carried out in accordance with [CSA A23.2-9C](#).

4.4.6.5.1.2 Test procedure

Specimens used as a basis for acceptance of concrete shall be made and cured in accordance with [CSA A23.2-3C](#).

4.4.6.5.1.3 Storage and curing facilities

To facilitate testing, the contractor shall provide and maintain, for the sole use of the testing agency, adequate facilities for safe storage and proper curing of concrete test specimens on the project site for the

initial curing period. Adequate facilities shall include a protected and temperature-controlled designated area to comply with CSA A23.2-3C.

4.4.6.6 Compressive strength acceptance

4.4.6.6.1 Standard-cured cylinders

4.4.6.6.1.1 General

The strength level of concrete shall be considered satisfactory if for a given strength-class the following two criteria are met for concrete produced from a single mix design:

- (a) each individual strength test equals or exceeds the acceptable test result (ATR), where $ATR = \text{specified strength} - 3.5 \text{ MPa}$ when the specified compressive strength is 35 MPa or less; or where $ATR = 0.90 \times \text{specified strength}$ when the specified compressive strength is above 35 MPa; and
- (b) the moving average of three consecutive strength tests in the same concrete equals or exceeds the specified strength.

These requirements shall not apply to field-cured specimens.

Notes:

- (1) *With the standard deviation, designated "s", these criteria can be expected to be met with a high probability if the concrete is proportioned to produce an average strength as follows:*
 - (a) *1.4 times the standard deviation (1.4 s) above the specified strength when the standard deviation(s) is not more than 3.5 MPa; and*
 - (b) *2.4 times the standard deviation minus 3.5 MPa (2.4 s – 3.5 MPa) above the specified strength when the standard deviation(s) is more than 3.5 MPa.*
- (2) *The standard deviation used in Note (1) should be based on at least 30 consecutive strength tests, representing concrete made from a single mix design.*
- (3) *Individual tests from concrete meeting these requirements can be expected to be below specified strength about 10% of the time.*
- (4) *For more detail about statistical analysis of the compressive strength of concrete, see ACI 318 and ACI 214.*

4.4.6.6.1.2 Failure of standard-cured cylinder test results to meet requirements

The strength test result shall be the average of the strength of the specimens tested at the same age for concrete of a single mix design produced on the same day as per [Clause 4.4.1.3](#). If any test specimen shows distinct evidence of improper sampling, moulding, handling, curing, or testing, the test specimen shall be disregarded. The average strength of the remaining test cylinder(s) shall be considered the test result. However, if there are indications that there may have been a disruption to concrete quality control measures, the owner may wish to make a distinction between specimens for testing.

4.4.6.6.1.3

If the results of tests indicate that the concrete is not of the specified strength, the owner shall have the right to require one or more of the following:

- (a) changes in the mix proportions for the remainder of the work;
- (b) additional curing on those portions of the structure represented by the test specimens that failed to meet specified requirements;
- (c) nondestructive testing (see [Clause 4.4.6.6.5](#) and [Annex A](#) of CSA A23.2);
- (d) that cores be drilled from the portions of the structure in question and tested in accordance with [Clause 4.4.6.6.2](#). Interpretation of the core test results shall take into consideration the placing and curing conditions and the age of the concrete;
- (e) load testing of the structure or structural elements in accordance with the requirements of CSA A23.3; and
- (f) such other tests as the owner might specify.

Notes:

- (1) *Cores should not be drilled from the tension zone of a structural member because the presence of cracks can adversely affect the measured compressive strength.*
- (2) *Additional information is contained in ACI 214.4R.*

4.4.6.6.1.4

If, after carrying out the appropriate requirements of [Clause 4.4.6.6.1](#) and [4.4.6.6.2](#), the elements are found not to comply with the requirements of the standard, the owner shall require strengthening or replacement of those portions deemed to be non-compliant.

4.4.6.6.2 Cores from existing structures

4.4.6.6.2.1 Test procedure

Drilled cores shall be sampled and tested in accordance with CSA A23.2-14C.

Note: *If the cored specimen is to be used for determination of compressive strength at a given age, the specimen should be removed at that age.*

4.4.6.6.2.2 Acceptance of cores drilled from a structure

The compressive strength of the concrete in the area of the structure represented by the core tests shall be considered adequate if

- (a) the average of each set of three cores from the portion of the structure in question is equal to at least 85% of the specified strength; and
- (b) no single core is less than 75% of the specified strength.

Notes:

- (1) *The figures of 85% and 75% in Items (a) and (b) are derived from Bloem, 1965.*
- (2) *For high-strength concrete, the compressive strength values of Items (a) and (b) should be 90% and 80%, respectively, of the specified strength unless other values are determined by pre-construction trials.*
- (3) *See Annex I for further information regarding high-strength concrete.*
- (4) *Additional information can be obtained from ACI 214.4R.*

4.4.6.6.3 Field-cured specimens — Test procedure

When tests are required on specimens cured to simulate field conditions, additional specimens shall be made in accordance with CSA A23.2-3C. The test results of the field-cured specimens shall not be used as a basis for acceptance or rejection of the concrete.

Note: *Field-cured cylinders are subject to many types of variation and might not represent the strength of the structural element. In-place testing using CSA A23.2-15C is the preferred alternative when it is difficult to cure the specimens in conditions similar to the structure they represent.*

4.4.6.6.4 Accelerated tests

4.4.6.6.4.1 Test procedure

When accelerated tests are specified, they shall be made in accordance with CSA A23.2-10C and standard cured 28 d compressive strength tests shall be made for at least every other accelerated test.

Notes:

- (1) *The standard cured 28 d compressive strength results can be predicted with reasonable accuracy using an accelerated test procedure. Such a procedure can be useful for quality control purposes, since it allows early adjustment to be made to the concrete mix proportions if required.*
- (2) *These tests do not indicate the strength gain of concrete under field conditions.*
- (3) *Three accelerated curing tests are currently in use in Canada (see CSA A23.2-10C for procedures). They are*
 - (a) *the modified boiling test;*
 - (b) *the autogenous curing test; and*
 - (c) *the warm water curing test.*
- (4) *Accelerated tests should only be used on projects in which there is a high degree of control of materials.*

4.4.6.6.4.2 Acceptance using accelerated cured cylinders

The strength level of each class of concrete shall be considered satisfactory if the 28 d strength predicted from the accelerated tests meets the criteria in [Clause 4.4.6.6.1](#).

4.4.6.6.5 Non-destructive in-place tests

4.4.6.6.5.1 Test procedure

Where in-place tests are specified, they shall be made in accordance with the appropriate test methods, as follows:

- (a) CSA A23.2-15C;
- (b) ASTM C597;
- (c) ASTM C803;
- (d) ASTM C805;
- (e) ASTM C873; and
- (f) ASTM C1074.

Note: Testing programs to assess the strength of concrete in situ and interpretation of the results of non-destructive tests should follow the guidelines and recommendations provided in ACI 228.1R.

4.4.6.6.5.2 Acceptance using non-destructive in-place tests

The strength level to be reached for each class of concrete before form removal, post-tensioning, cessation of curing, or removal of reshores shall be specified by the owner.

4.4.6.6.6

If, after carrying out the appropriate requirements of Clause 4.4.6.6.1, the elements are found not to comply with the requirements of this Standard, the owner shall require strengthening or replacement of those portions deemed to be non-compliant.

4.4.7 Density

4.4.7.1 Test procedure

For normal-density and high-density concrete, the density of plastic concrete shall be measured in accordance with CSA A23.2-6C. When tests are required on low-density and semi-low-density concrete, the air-dry density shall be measured in accordance with CSA A23.2-11C.

4.4.8 Flexural strength

4.4.8.1 Test procedure

When tests are required, the flexural strength of concrete shall be measured in accordance with CSA A23.2-8C.

4.4.9 Splitting tensile strength

4.4.9.1 Test procedure

When tests are required, the splitting tensile strength of concrete shall be measured in accordance with CSA A23.2-13C from tests performed on 150 mm × 300 mm cylinders.

4.4.10 Salt scaling

The owner shall specify the method to be used for evaluation of salt scaling resistance of concrete and the criteria to be met.

Note: The following tests may be used to evaluate the resistance of concrete to salt-induced scaling:

- (a) CSA A23.2-22C *Scaling resistance of concrete surfaces exposed to deicing chemicals using mass loss.*
- (b) BNQ NQ 2621-905/2012, *Annex B, Article 7.6;* or
- (c) LS-412, "Method of Test for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals", *Ontario Ministry of Transportation (MTO) Laboratory Testing Manual.*

6.8.5.4.2

The placing of concrete shall be in accordance with Clause 7.4.

6.8.5.4.3

When concrete is placed, reinforcement, tendons, vent pipes, sheaths, and ducts shall not be displaced.

6.8.5.4.4

The concrete shall be vibrated with particular care at each post-tensioning anchorage location to ensure adequate consolidation in the anchorage zone.

6.8.5.4.5

Before stressing, the concrete strength, determined in accordance with CSA A23.2-14C or A23.2-15C, shall be not less than the specified transfer strength. The conditioning of the cores in the Test Method specified in CSA A23.2-14C for either dry condition or wet condition is not required when measuring for transfer strength. Cores shall be tested as they are received and results shall be recorded accordingly.

6.8.5.5 Jointing segmental sections

6.8.5.5.1

The joints of match-cast elements shall be coated with an approved adhesive before the separate elements are connected.

6.8.5.5.2

Joints 10 mm to 70 mm wide shall be filled with a sand/cement mortar.

6.8.5.5.3

Joints over 70 mm wide shall be filled with concrete.

6.8.5.5.4

The strength of the mortar or concrete used in joints shall be at least equal to the parent concrete, unless a lower strength is specified in the project documents.

6.8.5.5.5

To obtain the desired strength and durability, joints shall be protected so that the adhesive, mortar, or concrete is properly cured.

6.8.6 Application and measurement of prestressing force

6.8.6.1

The required tendon elongation and jacking force shall be computed based on the required prestressing force and consideration of the stressing procedures and losses due to effects such as jack friction and anchorage set as well as strand friction, strand wobble.

6.8.6.2

Tendons shall be tensioned in sequence, as specified in the approved drawings.

6.8.6.3

A specified initial load shall be applied to the tendon to take up slack and to provide a starting point for elongation measurements before the final load is applied, as specified in the stressing procedure.

Notes:

(1) *The initial load is usually 10% to 20% of the full load.*

- (f) communication protocol for inspection and testing non-conformances; and
- (g) report distribution and transmission method(s).

J.8 Summary

The adoption of a performance approach to supplying concrete and building a structure is an obvious departure from the traditional approach. Recent experience has demonstrated that success is achieved when the owner has confidence in the ability of the contractors and suppliers to meet the performance criteria, and the contractors and suppliers embrace the concept of quality control to the point where the quality control process not only identifies and corrects deficiencies, but provides persuasive evidence to the owner that the required performance will be met.

Table J.1
Potential tests for concrete and approximate test duration
(required lead time)
 (See Clauses J.7.1.1 and J.7.1.4.)

Property	Test method or procedure*	Time required to complete testing
Materials requirements (beyond physical tests)		
Alkali-aggregate reactivity of aggregates	CSA A23.2-14A and 25A	12 months (concrete) and 16 days (mortar)
Fresh concrete properties		
Slump or slump flow	CSA A23.2-5C or -19C	Same day
Air content on fresh concrete	CSA A23.2-4C or 7C	Same day
Passability	CSA A23.2-20C	Same day
Set time	ASTM C403	Same day
Plastic shrinkage	ASTM C1579	Same day
Water content of fresh concrete	CSA A23.2-18C	Same day
Density of fresh concrete	CSA A23.2-6C	Same day
Temperature	CSA A23.2-17C	Same day
Structural properties		
Compressive strength on cylinders	CSA A23.2-9C	1 to 91 days
Compressive strength on cores	CSA A23.2-14C	2 days
Flexural strength	CSA A23.2-8C	7 to 91 days
Splitting tensile strength	CSA A23.2-13C	7 to 91 days
Pull out strength	CSA A23.2-15C	1 to 91 days
Modulus of elasticity and Poisson's ratio	ASTM C 469	7 to 91 days
Direct tensile strength	CSA A23.2-6B or CRD-C164	7 to 90 days

(Continued)

9.3.3 Demoulding time of test specimens

Remove the specimens from the moulds at the end of 28 h \pm 8 h if the test specimens were made for checking the adequacy of the laboratory mixture proportions for strength or as the basis for acceptance. Store the test specimens in accordance with Clause 9.3.2.2.

Demoulding time may be extended to a maximum of 76 h for cylinders representing concrete having a specified strength of less than 35 MPa, provided that the specimens are stored in an environmentally controlled facility at the project site that maintains the temperature between 15 °C and 25 °C immediately adjacent to the specimens and prevents loss of moisture from the specimens. Record the maximum and minimum temperatures when the initial curing period is extended beyond 24 h.

Determine the mass of each test specimen, expressed to the nearest gram (g), immediately upon demoulding.

9.3.4 Specimens for determining when forms are removed or when a structure is put into service

Store the test specimens in or on the structure as near to the point of use as possible when the test specimens are made for determining when forms can be removed or when a structure can be put into service. Provide the test specimens, insofar as practicable, the same protection from the elements on all surfaces as is given to the portions of the structure that they represent. Test the specimens in the moisture condition resulting from the specified curing treatment. Remove the specimens from the moulds at the time of removing the formwork when the specimens are made for the purpose of determining when a structure can be put in service.

In-place testing using CSA A23.2-15C is the preferred alternative when it is difficult to cure the specimens in conditions similar to those of the structure they represent.

Notes:

- (1) *The requirements of this Clause also apply to specimens representing concrete subjected to accelerated curing, such as steam curing. See Clause 17.5 of CAN/CSA-A23.4.*
- (2) *Determination of the correlation of the maturity of the specimens and the concrete in the forms is recommended, using thermocouples embedded in the specimens and into the structure. See ASTM C1074 for information determining maturity.*

9.4 Transportation of concrete test samples during curing period

Transport the test specimens from the field to the laboratory only after curing for a minimum of 20 h under the curing condition required by Clause 9.3.2.1. Protect the test specimens during transportation, from any shocks or exposure to adverse conditions. State the curing conditions and the date received in the laboratory in the test report.

Note: *When concrete specimens are to be transported under curing conditions other than those of Clause 9.3.2.1, the transportation should be delayed as long as possible to minimize the effect of adverse transportation conditions.*

10 Flexural test specimens

10.1 Size of specimens

Use rectangular beams with a length at least 50 mm greater than three times their depth formed with their long axes horizontal. The ratio of width to depth, as moulded, shall not exceed 1.5. The cross-section shall be not less than 150 mm \times 150 mm or three times the maximum size of aggregate, whichever is larger.

10.2 Placing and consolidation

10.2.1 Placing the concrete

Place the concrete in the moulds using a scoop or shovel. Fill moulds 200 mm or less in depth in two approximately equal layers. Fill moulds more than 200 mm in depth in three approximately equal layers. Distribute the concrete symmetrically within the mould.

Note: *The concrete may be distributed by means of the tamping rod prior to the start of consolidation.*

A23.2-15C

Evaluation of concrete strength in place using the pullout test

1 Scope

This Test Method describes the evaluation of the in-place hardened concrete compressive strength of a structural element using the pullout test. Pullout strength is obtained through the measurement of the force required to pull a metal insert, previously inserted in a mass of fresh concrete. The force measured is correlated to an equivalent compressive strength of the concrete on standard cylinders, through a correlation curve. This Test Method is applicable to concrete with a nominal maximum aggregate size of 40 mm or less.

2 Reference publications

In addition to the references in CSA A23.1, this Test Method refers to the following publications, and where such reference is made, it shall be to the editions listed below, including all amendments published thereto:

CSA Group

A23.1-14

Concrete materials and methods of concrete construction

A23.2-1C-14

Sampling plastic concrete

A23.2-3C-14

Making and curing concrete compression and flexural test specimens

A23.2-9C-14

Compressive strength of cylindrical concrete specimens

A23.2-1D-14

Moulds for forming vertical concrete test cylinders

ACI (American Concrete Institute)

228.1R (14)-03

In-Place Methods to Estimate Concrete Strength

ASTM International (American Society for Testing and Materials)

C900-13

Standard Test Method for Pullout Strength of Hardened Concrete

E4-13

Standard Practices for Force Verification of Testing Machines

E74-13a

Standard Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines

Other publications

Bickley, J.A. 1982. The Variability of Pullout Test and In-place Concrete Strength. *Concrete International: Design and Construction* 4 (4): 44–51.

Krenchel, H., and Petersen, C.G. 1984. In-Situ Pullout Testing with Loktest: Ten Years' Experience. *International Conference on In-situ/Non Destructive Testing of Concrete. Proceedings.*

Stone, W.C., Carino, N.J., and Reeve, C.P. 1986. Statistical Methods for In-Place Strength Predictions by the Pullout Test. *ACI Journal Proceedings* 83: 745–756.

3 Summary**3.1**

An insert is cast in fresh concrete. When the concrete has hardened, pullout strength is measured by the maximum force required to pull out the insert from the surrounding concrete mass.

3.2

An alternative is to apply a predetermined force to the insert, without causing the failure of the adjacent concrete, to verify whether a minimum level of in-place strength has been attained.

Notes:

- (1) *The configuration of the insert and of the bearing surface of the loading apparatus influences the shape of the fractured concrete cone in the concrete mass and the corresponding pullout strength. Accordingly, the dimensions of the insert and the bearing surface are fixed in this Test Method.*
- (2) *Pullout strength is correlated to compressive strength of standard cylinders.*
- (3) *For a given configuration of insert, bearing system, and depth of the insert, there is a correlation between pullout strength and standard cylinder's compressive strength.**
*See Stone, Carino, and Reeve (1986), Krenchel and Petersen (1984), and Bickley (1982).
- (4) *When a correlation curve is established for a specific concrete mix, the correlation curve should cover the range of strength to be evaluated. The following provides for a typical set of correlation data points. Figure 1 provides an example of a calibration curve plot for the following data points:*

Compressive strength vs. pullout strength

Set of data	Pullout strength, kN					Compressive strength of cylinders, MPa		
	1	2	3	4	mean	1	2	mean
1	9	10	11	10	10	8.0	10.0	9.0
2	15	17	19	16	17	13.8	13.8	14.1
3	24	22	16	18	20	22.2	22.2	21.8
4	24	21	29	30	26	24.5	24.2	24.0

4 Significance and use**4.1**

Pullout tests are used to evaluate in-place compressive strength. The following are examples of such applications:

- (a) evaluation of the earliest age to authorize removal of forms or loading of a structural element;
- (b) evaluation of the earliest age to release prestressed cables or to apply post-tensioning;
- (c) evaluation of the earliest age to stop curing or cold weather protection;

- (d) optimization of the use of high-early strength concrete in order to accelerate construction; and
- (e) evaluation of the in-place strength of structural element at a given age (e.g., 7 d, 28 d, 91 d) in order to verify in-place concrete strength.

Note: Evaluation of in-place strength should not be a substitute for the standard strength test.

4.2

This Test Method can be used for any type of concrete construction, including structural slabs, slabs on ground, walls, columns, tunnels, precast elements, prestressed and post-tensioned elements, and bridge deck repairs.

5 Apparatus

5.1 Standard insert

5.1.1

Figure 2 shows a standard insert. The standard insert shall consist of a steel cylindrical head and a shaft. The diameter of the cylindrical head shall be 25 mm. The thickness of cylindrical head and elastic limit of the material shall be sufficient not to reach failure during testing. The shaft shall be conical or cylindrical and perpendicular to the cylindrical head. The diameter of the shaft at the level of the head shall be 7.5 mm. The length of the shaft shall be such that the distance from the cylindrical head to the concrete surface shall be 25 mm.

5.1.2

Inserts shall be coated with a release agent to minimize bonding to concrete. When the shaft has to be removed prior to testing, the cylindrical head shall be notched on the opposite side to the direction of the load, in order to prevent its rotation in the concrete.

5.2 Load test apparatus

5.2.1

The test apparatus shall consist of a bearing surface concentric with

- (a) the insert;
- (b) a loading system;
- (c) an anchoring system providing a means to attach the apparatus to the insert; and
- (d) a gauge for the measure of the applied load.

5.2.2

The internal diameter of the bearing ring shall be 55 mm with an exterior diameter of at least 70 mm and a height of at least 70 mm. The bearing ring and anchoring system shall be made of a material rigid enough to transmit the full-applied load to the insert.

5.2.3

The loading system shall allow a uniform load increase from zero to the maximum load.

5.2.4

The gauge used to measure the pullout force shall have the least division not greater than 5% of the minimum value in the intended range use. The calibration of the loading apparatus shall be performed at least once a year and after all repairs. Calibrate the pullout apparatus using a testing machine verified in accordance with ASTM E4 or a Class A load cell as defined in ASTM E74. Calibration shall also be

performed after adjustment or repair of the apparatus or according to the requirements of the manufacturer. The indicated pullout force on the gauge based on the calibration relationship shall be within 2% of the force measured by the calibration load cell or testing machine.

5.3 Centering plate

The loading system shall include the necessary centering equipment to ensure that the bearing face is centered on the insert and that the load is axial and uniform over the bearing ring.

5.4 Hardware

A smooth plate, with an area larger than the exterior area of the bearing ring, shall be attached to the insert in order to provide a smooth and plane concrete surface, allowing for the proper seating of the bearing ring.

5.5 Tolerances

A tolerance of $\pm 2\%$ shall apply to pullout test inserts, the bearing ring, and embedment depth dimensions.

6 Hazards

This Test Method does not purport to address the safety problems associated with its use. It is the responsibility of the user of this Test Method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

7 Testing procedure

7.1 Placing of inserts

7.1.1 General

7.1.1.1

Placing of inserts is a critical step requiring trained personnel. Inserts may be placed on a formed or unformed surface. Figures 3, 4, 5, and 6 show the main assembly modes.

7.1.1.2

Inserts shall be attached to the forms before placing of the concrete or inserted within the concrete surface when the concrete is still plastic. The minimum free space between two inserts shall be 250 mm. The minimum free space between the centre of the insert and a free end shall be 100 mm. Inserts shall be installed in such a way that reinforcement or other embedded items are clear of the failure cone. Inserts shall be placed so that the distance from reinforcement shall be at least equal to one bar diameter or one diameter of the maximum size aggregate, whichever is greater.

Note: Inserts should usually be placed randomly in concrete, within representative locations of the quality of concrete being tested.

7.1.2 Inserts on a formed surface

Inserts shall be firmly attached to the forms with a threaded bolt, nut, and washer assembly as shown in Figure 3. The shaft of the insert shall be perpendicular to the concrete surface. A smooth metal plate shall be installed between the shaft of the insert and the form in order to produce a smooth bearing surface. This plate may be lightly lubricated in order to help removal before testing. Care shall be exercised in order to make sure that inserts are not damaged during placement of reinforcement or pouring of the plastic concrete.

7.1.3 Inserts in an unformed surface (floating)

When there is no form on the surface to be tested, inserts shall be installed in plastic concrete using typical inserts shown in Figure 3. The insert shall be installed in such a way that the cylindrical head penetrates the concrete laterally, with a circular motion. A smooth metal plate with holes, as shown in Figure 5, shall be attached at the end of the insert's shaft to allow it to "float" on the surface and to ensure a smooth bearing surface that is free of air voids. The shaft shall then be inclined about 10° from a right angle to the surface to prevent air bubbles from being trapped under the plate. An internal vibrator shall be inserted under the insert in order to achieve a good embedment of the insert. The plate shall then be cleaned of any accumulation of concrete over its surface in order to allow for easy removal at time of testing. All necessary precautions shall be taken to ensure that finishing operations do not damage inserts or the surrounding concrete.

7.2 Number of inserts

7.2.1

At each test age, at least eight inserts shall be tested for each 100 m³ of concrete placed or for each 500 m² of surface area.

Notes:

- (1) *When the initial pullout strength results are lower than the specified minimum strength requirement, a reduced number of inserts can be tested to obtain an indication of the strength level of the concrete in the structure.*
- (2) *The number of inserts and their location also depend upon the type of construction, geometry, and uniformity of exposure to temperature, humidity, drying, etc.*

7.2.2

Extra inserts shall be used if strength tests at different ages are required or to allow for retest at a later age.

7.3 Concrete maturity

No pullout testing shall be performed when the concrete temperature is below 0 °C. The location of inserts shall take into account exposure conditions creating a variability of concrete maturity within a construction in order to obtain a representative result of the most critical conditions. For example, for a structural slab heated from under the forms and exposed to cold outside conditions at its top surface, inserts should be installed preferably on top of the slab in order to sample the concrete of lower maturity.

7.4 Loading

Before loading, hardware necessary to the installation of inserts shall be removed (i.e., bolt, smooth metal plate, and shaft). The bearing surface of the concrete shall be smooth and free of loose particles and dust. The loading apparatus shall be connected to the insert by means of the appropriate mechanisms and centered on the insert in order to ensure that the load is axial and uniform over the bearing ring. The load shall be applied at a uniform rate of 500 N/s ± 20 N/s for the total time of the pullout test.

7.5 Test to failure

Loading shall be applied until failure of the concrete cone (i.e., until maximum load is reached). The maximum load shall be recorded to the nearest 0.5 kN.

Note: *In order to minimize damage to the concrete surface, the cracked cone of concrete may be left in place. In the case of doubt about a result, the concrete cone should be extracted completely in order to observe and report potential defects, such as a bad embedding of the insert or the presence of other embedded items in the failure zone of the insert.*

7.6 Testing to a predetermined strength level

The load shall be increased to the maximum predetermined force. If failure does not occur, the load shall be maintained for at least 10 s. In a case where failure occurs, the maximum load shall be recorded, in kN, and further testing shall be delayed to a later time.

7.7 Testing period

All inserts used for one strength test at a given age shall be tested within a maximum period of 90 minutes.

8 Correlation between pullout strength and compressive strength of standard cylinders

The correlation between pullout strength and compressive strength of standard cylinders can vary with aggregate type and with the specified strength of the concrete mix. Unless correlation data are available, a correlation curve shall be established for each type of concrete mix and specified level of strength.

The correlation curve is established based on tests with standard 150 mm × 300 mm cylinders in which inserts are attached to the centre of the base (see Figure 6) or 200 mm cubes in which inserts are attached to the centre of the cubes' faces. At various test ages, pullout strength tests shall be carried out until maximum load is reached (i.e., tested to failure). When cylinders are used, care shall be taken not to extract the cracked cone from the bottom of the cylinder. The tested cone area shall be slightly hammered down using an approximate 20 mm thick plywood piece with a diameter approximately equal to the cone area at the surface in order to reduce the raised surface height of the cone caused during testing. The cylinder shall then be immediately capped with an appropriate capping compound, allowing compressive strength tests to be made within 30 minutes. Concrete for fabrication of cylinder specimens shall be sampled in accordance with CSA A23.2-1C. Fabrication cylinder test specimens shall be carried out in accordance with CSA A23.2-3C. Cylinders shall be tested for compressive strength in accordance with CSA A23.2-9C.

Notes:

- (1) Tests have shown that the compressive strength of cylinders is not affected by this procedure. See ASME E4 and Stone, Carino, and Reeve (1986).
- (2) Further information on the interpretation of pullout strength and development of the calibration curve can be obtained from ACI 228-1R.

The set of results obtained for each cylinder (i.e., maximum pullout force, kN, and cylinder compressive strength, MPa) or each group of companion cylinders and cubes shall be recorded.

In the case of higher compressive strengths, if radial cracking of the cylinder is observed after pullout testing, results from these cylinders shall not be used for the correlation curve. When cylinder specimens are used in developing a pullout strength correlation curve and the majority of the cylinder specimens exhibit radial cracking, 200 mm cube specimens shall be used instead of the cylinder specimens.

A minimum of eight compressive strength tests and 16 pullout strength tests on cylinders or cubes shall be used to establish the correlation curve. The correlation shall cover at least a range of compressive strengths of about 5 MPa of the specified minimum strength required to allow for critical construction operations to proceed or to allow for cessation of curing. A least square linear regression shall be calculated to obtain the best fitting line relationship between the sets pullout strength and compressive strength of standard cylinders data points. The regression coefficient shall be greater than 0.90 to validate the correlation.

9 Calculations

The pullout test force measured in kilonewtons on the in-place concrete shall be converted to an equivalent compressive strength based on standard cylinders through the use of the established correlation curve for the specific concrete mix being tested.

10 Reporting

10.1 Required information

The following information shall be included in the test report, as applicable:

- (a) location of inserts;
- (b) number of inserts installed per pour placement and the corresponding amount of concrete in m³;
- (c) type of surface insert used (i.e., unformed or formed);
- (d) identification of the concrete mix under test;
- (e) equivalent compressive strength in megapascals measured on standard cylinders to the nearest 0.1 MPa, as established with the correlation curve, for each pullout test performed, along with the mean strength as determined by the pullout tests;
- (f) date and start and completion times of concrete placing
- (g) date and start and completion times of pullout tests;
- (h) type of failure of the cone, if abnormal;
- (i) other information about curing or exposure conditions of concrete that can affect in-place strength;
- (j) name of the technician who performed the test
- (k) identification of the certified laboratory performing the test (i.e., name and address);
- (l) name and signature of the person responsible for review of the test report, and
- (m) any deviations from the test procedure.

10.2 Optional information

The report may include the following information:

- (a) equation of the correlation relationship used for a given mix;
- (b) maximum pullout load in kN to the nearest 0.5 kN.

11 Precision and bias statement

Based on the data summarized in ACI 228.1 R (14) for cast-in-place pullout tests with embedment depths of about 25 mm, the average coefficient of variation for tests made on concrete with a maximum aggregate of 20 mm by a single operator using the same test device is 8%. Therefore, the range in individual test results, expressed as a percentage of the average, should not exceed the following:

Number of tests	Acceptable range, % of average
5	31
7	34
10	36

Note: The above information was extracted from ACI 228.1 R (14) and ASTM C900.

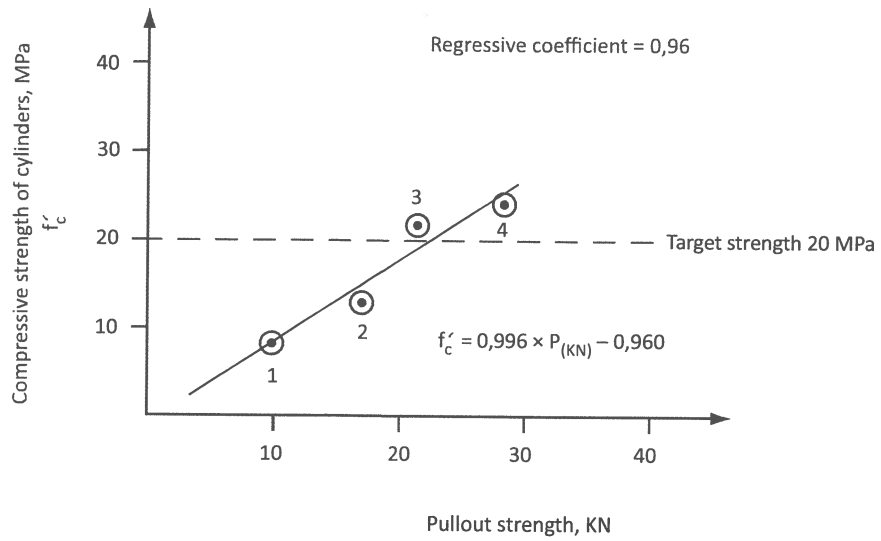


Figure 1
Typical plot of correlation data points
 (See Clause 3.2.)

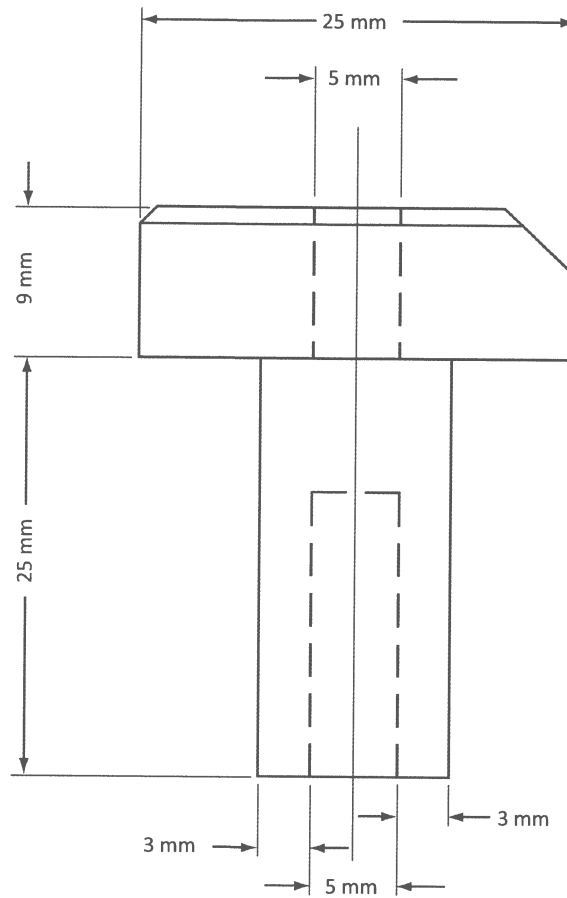
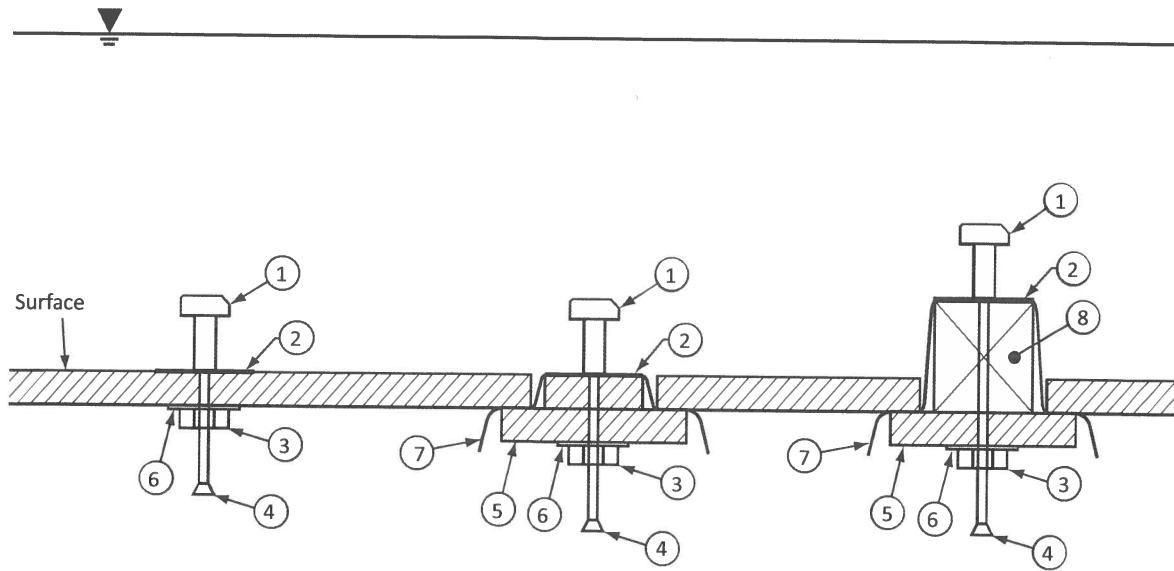


Figure 2
Standard insert
(See Clause 5.1.1.)



Legend:

- | | |
|--|-------------------------|
| (1) Insert | (5) Wood block assembly |
| (2) Smooth steel plate (no perforations) | (6) Lock washer |
| (3) Nut | (7) Plastic sheet |
| (4) Bolt | (8) Wood block assembly |

Figure 3
Typical insert installations for formed surfaces
 (See Clauses 7.1.1.1, 7.1.2, and 7.1.3.)

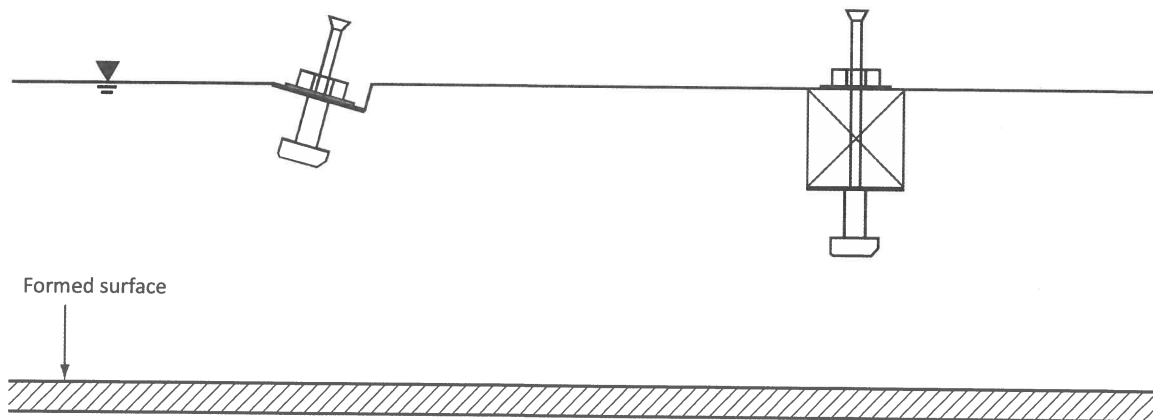


Figure 4
Typical insert installations for unformed surfaces
 (See Clause 7.1.1.1.)

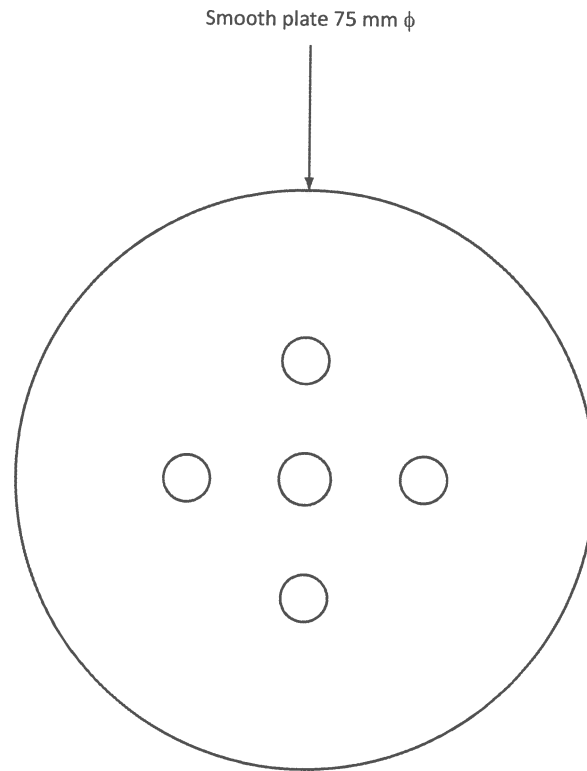


Figure 5
Smooth perforated plate
(See Clauses 7.1.1.1 and 7.1.3.)

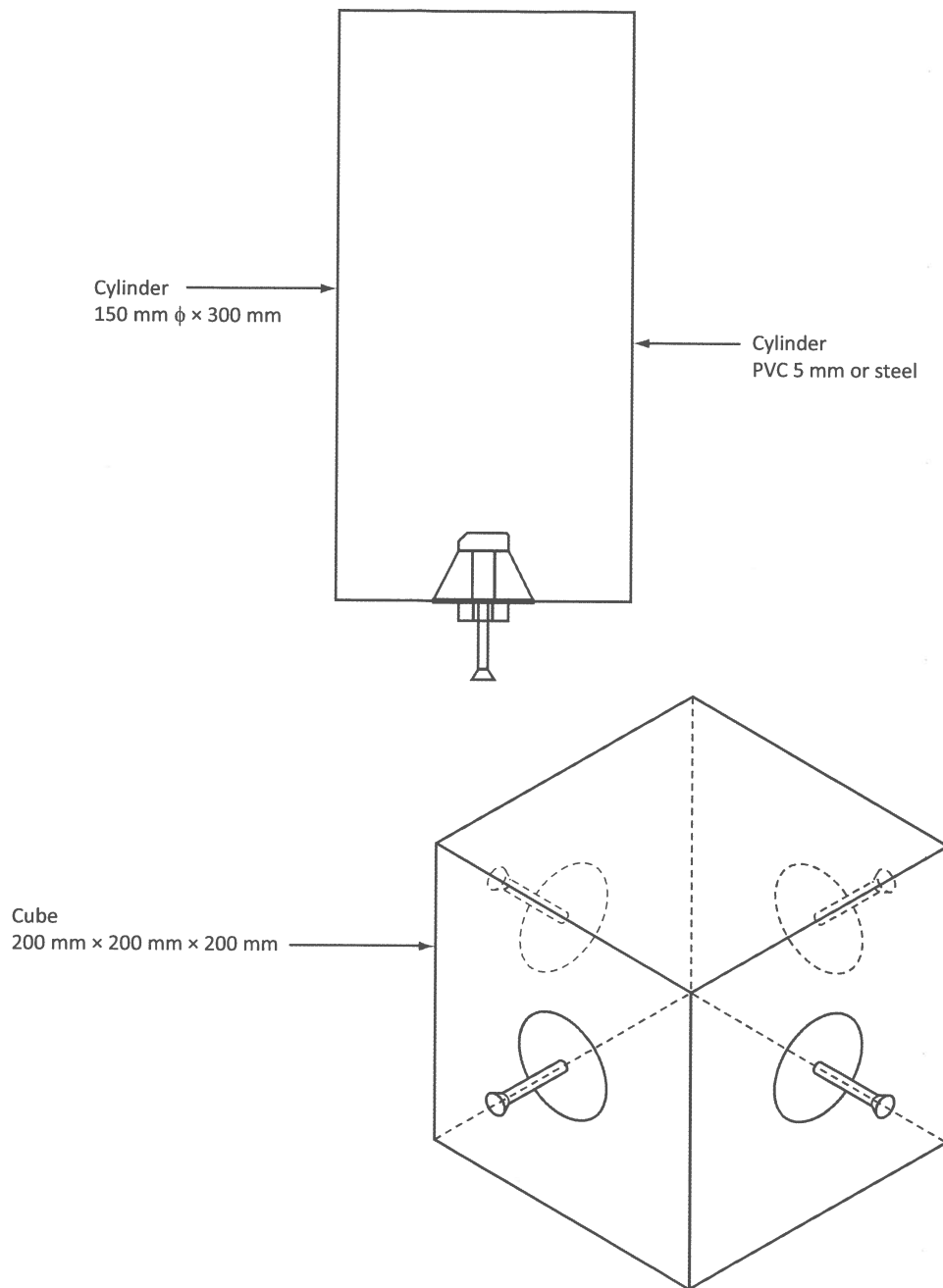


Figure 6
Typical cylinder and cube specimens insert
configuration of correlation testing
(See Clauses 7.1.1.1 and 8.)

Test Methods and standard practices

- A23.2-1A — Sampling aggregates for use in concrete 273
- A23.2-2A — Sieve analysis of fine and coarse aggregate 280
- A23.2-3A — Clay lumps in natural aggregate 286
- A23.2-4A — Low-density granular material in aggregate 290
- A23.2-5A — Amount of material finer than 80 µm in aggregate 295
- A23.2-6A — Relative density and absorption of fine aggregate 299
- A23.2-7A — Test for organic impurities in fine aggregates for concrete 306
- A23.2-8A — Measuring mortar-strength properties of fine aggregate 308
- A23.2-9A — Soundness of fine and coarse aggregate by use of magnesium sulphate 316
- A23.2-10A — Bulk density of aggregate 324
- A23.2-11A — Surface moisture in fine and coarse aggregate 329
- A23.2-12A — Relative density and absorption of coarse aggregate 336
- A23.2-13A — Flat and elongated particles in coarse aggregate 342
- A23.2-14A — Potential expansivity of aggregates (procedure for length change due to alkali-aggregate reaction in concrete prisms at 38 °C) 350
- A23.2-15A — Petrographic examination of aggregates 363
- A23.2-16A — Resistance to degradation of small-size coarse aggregate by abrasion and impact in the Los Angeles machine 394
- A23.2-17A — Resistance to degradation of large-size coarse aggregate by abrasion and impact in the Los Angeles machine 401
- A23.2-23A — Test method for the resistance of fine aggregate to degradation by abrasion in the Micro-Deval apparatus 405
- A23.2-24A — Test method for the resistance of unconfined coarse aggregate to freezing and thawing 414
- A23.2-25A — Test method for detection of alkali-silica reactive aggregate by accelerated expansion of mortar bars 425
- A23.2-26A — Determination of potential alkali-carbonate reactivity of quarried carbonate rocks by chemical composition 434
- A23.2-27A — Standard practice to identify degree of alkali-reactivity of aggregates and to identify measures to avoid deleterious expansion in concrete 439
- A23.2-28A — Standard Practice for laboratory testing to demonstrate the effectiveness of supplementary cementing materials and lithium-based admixtures to prevent alkali-silica reaction in concrete 452
- A23.2-29A — Test method for the resistance of coarse aggregate to degradation by abrasion in the Micro-Deval apparatus 458
- A23.2-1B — Testing for properties of flowable grout 465
- A23.2-2B — Determination of sulphate ion content in groundwater 471
- A23.2-3B — Determination of total or water-soluble sulphate ion content of soil 474
- A23.2-4B — Sampling and determination of water-soluble chloride ion content in hardened grout or concrete 478
- A23.2-6B — Determination of bond strength of bonded toppings and overlays and of direct tensile strength of concrete, mortar, and grout 486
- A23.2-7B — Random sampling of construction materials 494
- A23.2-8B — Determination of water-soluble sulphate ion content of recycled aggregates containing crushed concrete 501
- A23.2-1C — Sampling plastic concrete 504
- A23.2-2C — Making concrete mixes in the laboratory 508
- A23.2-3C — Making and curing concrete compression and flexural test specimens 514
- A23.2-4C — Air content of plastic concrete by the pressure method 526
- A23.2-5C — Slump of concrete 532
- A23.2-6C — Density, and yield, of plastic concrete 538
- A23.2-7C — Air content of plastic concrete by the volumetric method 543
- A23.2-8C — Flexural strength of concrete (using simple beam with third-point loading) 548

- A23.2-9C — Compressive strength of cylindrical concrete specimens 552
A23.2-10C — Accelerating the curing of concrete cylinders and determining their compressive strength 566
A23.2-11C — Water content, density, absorption, and voids in hardened concrete, grout, or mortar 573
A23.2-12C — Making, curing, and testing compression test specimens of no-slump concrete 577
A23.2-13C — Splitting tensile strength of cylindrical concrete specimens 582
A23.2-14C — Obtaining and testing drilled cores for compressive strength testing 590
A23.2-15C — Evaluation of concrete strength in place using the pullout test 594
A23.2-16C — Determination of steel or synthetic fibre content in plastic concrete 606
A23.2-17C — Temperature of freshly mixed hydraulic cement concrete 610
A23.2-18C — Determination of total water content of normal weight fresh concrete 614
A23.2-19C — Slump flow of concrete 619
A23.2-20C — Passing ability of self-consolidating concrete by J-ring and slump cone 624
A23.2-21C — Test Method for length change of hardened concrete 629
A23.2-22C — Scaling resistance of concrete surfaces exposed to deicing chemicals using mass loss 636
A23.2-23C — Electrical indication of concrete's ability to resist chloride ion penetration 644
A23.2-1D — Moulds for forming vertical concrete test cylinders 658

Annexes

- A** (informative) — Nondestructive methods for testing concrete 664
B (informative) — Form for reporting compressive strength of concrete test cylinders 668