(Reaffirmed 0)

भारतीय मानक
Indian Standard

IS 516 (Part 4) : 2018

दृढ़ीकृत कंक्रीट — परीक्षण पद्धतियाँ

भाग 4 कंक्रीट कोर के नमूने लेना, तैयार करना और परीक्षण करना

(पहला पुनरीक्षण)

Hardened Concrete — Methods of Test

Part 4 Sampling, Preparing and Testing of Concrete Cores

(First Revision)

ICS 91.100.30

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली-110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002
www.bis.org.in www.standardsbis.in

December 2018 **Price Group 7**

Indian Standard

HARDENED CONCRETE — METHODS OF TEST

PART 4 SAMPLING, PREPARING AND TESTING OF CONCRETE CORES

(First Revision)

1 SCOPE

This standard (Part 4) specifies a method for taking cores from hardened concrete, their examination, preparation for testing and determination of compressive strength.

NOTE — Extracting other types of specimens from structures and pavements, like beam specimens and slab removal are given in Annex A.

2 REFERENCES

The standards listed below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
460 (Part 1) : 1985	Test sieves: Part 1 Wire cloth test sieves
456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
516	Hardened concrete — Methods of test:
(Part 2/Sec 1) : 2018	Properties of hardened concrete other than strength, Section 1 Density of hardened concrete and depth of water penetration under pressure (*first revision*)
(Part 5/Sec 1) : 2018	Non-destructive testing of hardened concrete, Section 1 Ultrasonic pulse velocity testing (*first revision*)
4031 (Part 8) : 1988	Methods of physical tests for hydraulic cement: Part 8 Determination of transverse and compressive strength of plastic mortar using prism
14858 : 2000	Requirements for compression testing machine used for testing of concrete and mortar

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

3.1 Concrete Core — Cylindrical specimen of hardened concrete obtained by drilling from hardened concrete.

3.2 Corrected Compressive Strength of Core — Strength of core obtained by applying the correction factor for diameter to the measured compressive strength as per **8.4.1**.

3.3 Corrected Cylinder Strength of Core — Equivalent strength of cylinder having *l*/*d* ratio of 2 as per **8.4.2**.

3.4 Equivalent Cube Strength — Cube strength of concrete obtained as per **8.4.2**.

3.5 Measured Compressive Strength of Core — Compressive strength obtained by dividing the maximum load applied by the cross-sectional area as per **8.4**.

4 APPARATUS

4.1 Core Drill, shall be capable of extracting cores from the hardened concrete to the dimensions specified in **5.5** to **5.7** with the tolerances specified in **7.5**.

4.2 Compression Testing Machine (CTM), shall be conforming to IS 14858, of sufficient capacity for the tests and capable of applying the load at the rate specified in **8.2**. The accuracy of the testing machine shall be as per IS 14858. The testing machine shall be equipped with two steel bearing platens with hardened faces. One of the platens (preferably the one that normally will bear on the upper surface of the core specimen) shall be fitted with a ball seating in the form of a portion of a sphere, the centre of which coincides with the central point of the face of the platen. The other compression platen shall be plain rigid bearing block. The bearing faces of both platens shall be at least as large as, and preferably larger, than the nominal size of the core specimen to which the load is applied. The bearing surface of the platens, when new, shall not depart from a plane by more than 0.01 mm at any point, and they shall be maintained with a permissible variation limit of 0.02 mm. The movable portion of the spherically seated compression platen shall be held on the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted through small angles in any direction.

4.3 Balance or Scale, shall be capable of determining the mass of the core, as tested, to an accuracy of 0.1 percent of the mass.

4.4 Callipers and/or Ruler, shall be capable of measuring the dimensions of the core and the steel reinforcement to a tolerance of ± 0.01mm.

4.5 Gauge, shall be capable of establishing that the relevant flatness of the specimen is within the requirements as specified in **7.5**.

5 EXTRACTION OF CORES

5.1 Age of Concrete

Core to be tested for strength shall not be removed from the structure until the concrete has become hard enough to permit its removal without disturbing the bond between the mortar and the coarse aggregate. As a general guideline, for grades of concrete up to M25, the concrete shall be at least 14 days old before the cores are taken. For higher grades, cores may be taken at an earlier age.

5.2 Location

The location from where the core is extracted shall be specified by the Engineer-in-Charge on the basis of the purpose of the core extraction and the possible structural implications resulting from taking the core from the location.

Cores shall preferably be taken at points not near or at the edges of the concrete joints and reinforcement shall be avoided as far as possible.

Cores shall be taken preferably from the middle part of the member leaving top and bottom parts where variation can be more. While taking cores vertically from top, like from slab or from foundation top, the test length of core shall not contain concrete from top 15 percent to 20 percent depth as top part of the core may not contain uniform distribution of aggregates (maximum up to 60 mm). In case of cores which are not across full depth of member, about 10 percent to 15 percent portion of the bottom side of core may be trimmed off as the portion near to the broken end may contain some micro cracks/fractures.

Locations where there can be micro-cracks due to tension shall be avoided and cores shall preferably be taken from compression zone.

5.3 Drilling

Unless otherwise specified, the cores shall be drilled perpendicular to the surface in such a manner as not to damage the cores. The drilling of the core shall be carried out by an experienced operator using a diamond-impregnated bit attached to the core barrel. The drilling apparatus shall be rigidly anchored to the member to avoid bit wobble, which may result in a specimen with a variable cross-section. The drill bit shall be lubricated with water and shall be resurfaced periodically. Cores that show abnormal defects or that have been damaged in removal shall not be used.

The cores may be extracted preferably from a location where there is no interference of reinforcement

NOTE — In case of cores to be taken from the removed slab, a sufficiently large portion of the slab shall be removed so that the desired test specimens may be secured without the inclusion of any concrete which has been cracked, spalled, undercut, or otherwise damaged.

5.4 Number of Cores

The points from which cores are to be taken and the number of cores required shall be at the discretion of the Engineer-in-Charge and shall be representative of the whole of concrete concerned. In no case, however, shall fewer than three cores be tested.

5.5 Diameter of Cores

The diameter of the cores to be taken shall be specified, before testing.

The ratio of diameter to the nominal maximum size of aggregate shall be greater than 3. The core diameter shall generally be 100 mm to 150 mm (± 10 mm), with the preferred diameter being 100 mm for nominal maximum aggregate size up to 20 mm.

Other smaller diameters (not less than 3 times the nominal maximum aggregate size), which may make drilling easier and reduce the damage to the element, may be used, if the effect of the diameter on the accuracy of the result is also considered, as per **8.4**.

5.6 Length of Cores

The total length of core to be extracted and the length of the core sample to be used for testing, shall be specified by the Engineer-in-Charge.

The length of the core sample shall be decided based on,

a) the diameter of the core; and
b) whether comparison will be made with cube strength or cylinder strength (*see* **5.7** for preferred length/diameter ratios).

5.7 Length/Diameter (*l*/*d*) Ratio

The preferred *l*/*d* ratio shall be 2, however, *l*/*d* values from 1 to 2 may also be permitted (the length includes the capping material also).

In the case of using a specimen with a length-to-diameter ratio smaller than 2.0, the test value of the compressive strength should be corrected

corresponding to a value of *l/d* of 2.0, as per **8.4.2**.

5.8 Marking and Identification

Immediately after drilling, mark each core clearly and indelibly. Record its location and orientation within the element from which it was drilled. If a core is subsequently cut to produce a number of specimens, mark each specimen to indicate its position and orientation within the original core.

5.9 Reinforcement

Drilling through reinforcement shall be avoided. The core shall not contain any reinforcement bars along or near its longitudinal axis. Cores containing cross reinforcement shall be trimmed off to obtain core free from reinforcement. The reinforcement detector (cover meter) can be used for selecting the drilling location free of reinforcement.

6 EXAMINATION

6.1 Visual Inspection

Carry out visual examination of the cored specimen to identify abnormalities.

6.2 Measurements and Calculations of Drilled Core Specimens

Take the following measurements:

a) *Core diameter* — Take three pairs of measurements at right angles, at the half and quarter points of the length of the core to an accuracy of ±0.01 mm. Determine the average diameter (d_m).

b) *Core length* — Measure the maximum and minimum lengths after completion of the end preparation in accordance with 7 (excluding capping material) to an accuracy of ± 0.01 mm. Determine the average length.

c) *Mass* — Each specimen shall be weighed as received and/or saturated, as specified. The mass shall be recorded to the nearest 0.1 percentage of the mass of the specimen.

d) *Density* — The density of each specimen shall be determined as received and/or saturated, as specified, in accordance with IS 516 (Part 2/Sec 1).

7 PREPARATION OF CORES

7.1 General

The size of the specimen shall be adjusted, whenever necessary. The specimen shall be sawn perpendicular to its longitudinal axis. The intended load-bearing surfaces shall be prepared either by grinding or by capping to improve the contact with the loading machine. Cutting and grinding shall be carried out in such a way that structural changes of the test specimen are avoided. Various preparation methods including capping materials suitable for different maximum compressive strengths are given in Table 1.

Table 1 Suitable Methods of Preparation of Load Bearing Surfaces of Specimens
(*Clause* 7.1)

Sl No.	Anticipated Strength of Concrete	Preparation Method
(1)	(2)	(3)
i)	For any value of strength	Grinding
ii)	Up to 50 MPa	Capping with calcium aluminate cement mortar[1)] Capping with sulphur mixture
iii)	Up to 100 MPa	Capping with high strength sulphur mixture

[1)] Other cements may be used provided that, at the time of test, the mortar has a strength at least equal to the anticipated strength of the concrete.

NOTE — Other capping materials may also be used provided that, at the time of testing, it has a strength at least equal to the anticipated strength of concrete.

The details of the preparation methods for load bearing surfaces of specimens mentioned in Table 1 are given below.

7.2 Grinding

Specimens cured in water shall be removed from the water for grinding for not more than 1h at a time and re-immersed in water for at least 1 h before further grinding or testing. The ends of the specimen shall be ground to the tolerances as given in **7.5**.

7.3 Capping — Calcium Aluminate Cement Mortar

7.3.1 *General*

Before capping, ensure that the surface of the core specimen is in a wet condition, clean and free from all loose particles. The caps shall be as thin as possible and shall not, on average, be greater than 5 mm thick, small local deviations are permissible.

7.3.2 *Capping with Calcium Aluminate Cement Mortar*

The capping material shall consist of a mortar containing three parts by mass of calcium aluminate cement to one part by mass of fine sand in a saturated surface dry condition [most of which passes a 300µm wire cloth sieve conforming to IS 460 Part (1)]. The water-cement ratio shall not exceed 0.35.

The soaked core specimen shall be placed with one end on a horizontal metal plate. A steel collar of correct dimensions and having a machined upper edge shall be rigidly clamped to the upper end of the core specimen

to be capped in such a way that the upper edge is horizontal and just extends beyond the highest part of the concrete surface.

The capping material shall be filled into the collar until it is the form of a convex surface above the edge of the collar. The glass capping plate, coated with a thin film of mould oil shall be pressed down on to the capping material with a rotary motion until it makes complete contact with the edge of the collar. The core specimen with collar and plate in position shall immediately be placed in moist air of at least 90 percent relative humidity and at a temperature of 27± 2°C. The plate and collar shall be removed when the mortar is hard enough to resist handling damage.

7.4 Capping — Sulphur Mixture Method (Normal and High Strength)

7.4.1 *General*

Before capping, ensure that the surface of the core specimen is in a dry condition, is clean and free from all loose particles. The caps shall be as thin as possible and should not, on average, be greater than 5 mm thick. Small local deviations are permissible.

7.4.2 *Capping Material*

Sulphur mixtures shall be of normal strength or of high strength, and as follows:

a) *Normal strength (for concrete up to 50 MPa)* — The capping material shall comprise equal mass fractions of sulphur and fine siliceous sand (most of which passes a 250 µm wire cloth sieve conforming to IS 460 (Part 1) and is retained on a 125 µm wire cloth sieve). A small proportion, up to 2 percent, of carbon black may be added. The strength of the mixture tested in accordance with **7.4.4** shall be as follows:

   Compressive strength: At least the anticipated compressive strength of the concrete.

b) *High strength (for concrete from 50 to 100 MPa*) — The capping material shall consist of a blend of sulphur and suitable additions passing a 0.5 mm sieve. The strength of the mixture tested in accordance with **7.4.4** shall be as follows:

   1) *Flexure strength* : At least 6.5 MPa; and
   2) *Compressive strength* : At least the anticipated compressive strength of the concrete.

7.4.3 *Procedure*

Lower one end of the core specimen, which is held vertically, into a pool of molten sulphur mixture on a horizontal plate/mould. Allow specimen to harden before repeating the procedure for the other end. Use a capping frame that will ensure that both capped surfaces are parallel. Mineral oil shall be used as a release agent for plates/moulds. Where necessary, trim surplus capping material from the edges of the core specimen.

The level of the mixture in the melting pot shall never be allowed to fall too low, as there will be an increased risk of the production of sulphur vapour, which could ignite.

The core specimen shall be checked to ensure that the capping material has adhered to both ends of the core specimen. If a capping layer sounds hollow, it shall be removed and the capping operation repeated. The cap shall not fail or fracture before the concrete fails when the core specimen is tested. The compression test on the test core specimen shall not be carried out until at least 30 min have elapsed since the last capping operation.

NOTES

1 Stir the mixture continuously to ensure its homogeneity and to avoid sediment forming at the bottom of the melting pot.

2 If capping operations are carried out repeatedly, it is advisable to use two thermostatically controlled melting pots.

3 A fume extraction system shall be operating during the whole melting process to ensure full extraction of the sulphur vapour, which is heavier than air. Care shall be taken to ensure that the temperature of the mixture is maintained within the specified range to reduce the risk of pollution.

7.4.4 *Material Test for High Strength Sulphur Mixture*

7.4.4.1 *Principle*

It gives the methodology to be adopted for carrying out flexural strength and compressive strength tests to check the conformity of the capping material used for the high-strength sulphur mixture method.

7.4.4.2 *Apparatus*

a) *Prism mould*, with dimensions of 40 mm × 40 mm × 160 mm, complete with a filling frame.
b) *Melting pot*, with a thermostat to control the temperature of the mixture to 130 ± 10 °C.
c) *Ladle*, with a capacity of at least 1/3 litre.
d) *Saw*, capable of cutting the capping material when it is dry.
e) *Compression testing machine*, capable of testing mortar prisms for flexural and compressive strength in accordance with IS 4031 (Part 8).

7.4.4.3 *Procedure*

The sulphur mixture shall be heated in the melting pot to 130 ± 10°C, stirring with the ladle to make the mixture homogenous. The filling frame shall be fitted to the mould and both shall be lightly oiled using a normal mould-release oil. The liquid sulphur mixture

shall be poured into the mould, overfilling each part in turn using the filling frame to produce three specimens. Thirty minutes after casting the last specimen, the filling frame shall be removed and the three specimens demoulded. They shall then be left at ambient temperature for a further 30 min. Approximately 1 h after casting, each test specimen shall be sawn to remove the excess height and to produce three specimens with dimensions of 40 ± 1 mm × 40 ± 1 mm × 160 ± 1 mm. The actual dimensions shall be measured and recorded. Approximately 2 h after casting, the specimens shall be tested for flexural and compressive strength.

7.4.4.4 *Test result*

The flexural and the compressive strength of each beam specimen made shall be determined using the actual dimensions recorded, not the nominal dimensions. The test procedures are as described in IS 4031 (Part 8). The compressive strength of the sulphur mixture shall be taken as the mean of the results of the tests on the three specimens.

7.5 Tolerances

Prepare the core specimen as per methods mentioned in **7** within the following tolerances:

a) *Flatness* (*see* Fig. 1A) — The tolerance on flatness of the prepared end surfaces shall be ± 0.05 mm.

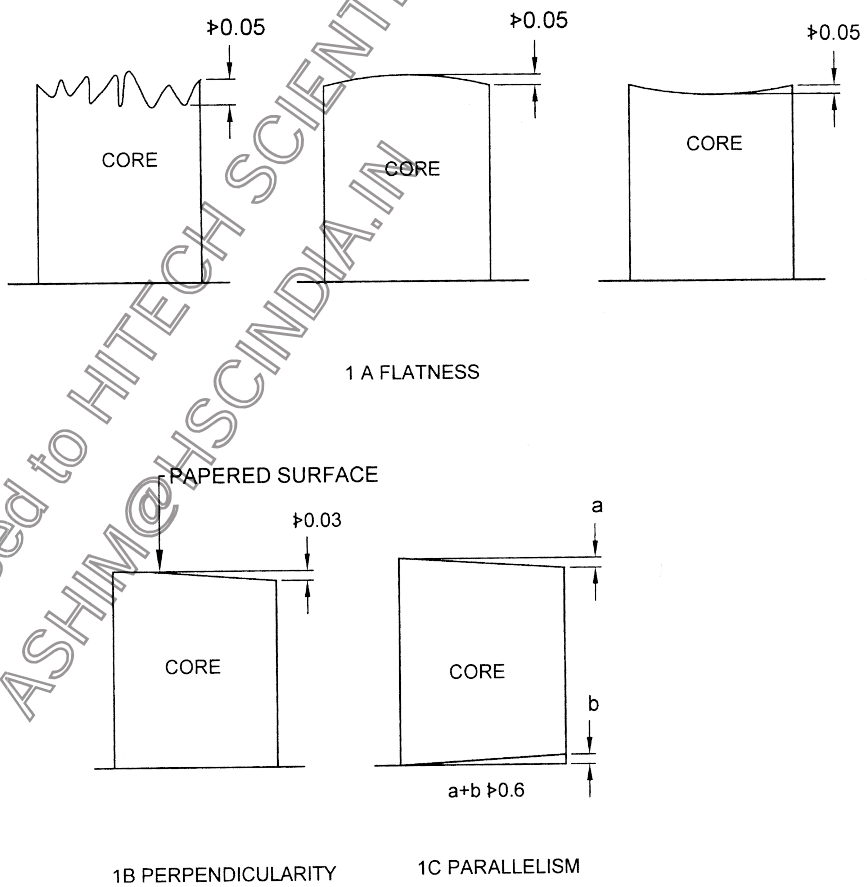
b) *Perpendicularity* (*see* Fig. 1B) — The tolerance on perpendicularity of the prepared end, with respect to the axis of the specimen as datum, shall be ± 0.03 mm.

c) *Parallelism* (*see* Fig. 1C) — The tolerance on parallelism of the prepared top surface, with respect to the bottom surface of the specimen as datum, shall be ± 0.6 mm.

d) *Straightness* — The tolerance on straightness of any surface parallel to the centre line of the core shall be ± 3 percent of the average core diameter (d_m).

The above tolerances values are for 100 mm diameter core. If the cores with diameter less than the values recommended in **5.5**, the tolerances shall be reduced in proportion to the tolerances specified for 100 mm diameter core.

7.6 Calipers, rulers, carpenters arm, etc, can also be used for measuring the tolerances. Flatness can also be



All dimensions in millimetres.

FIG. 1 PERMISSIBLE TOLERANCES FOR PREPARED CORE SPECIMENS

checked by covering the surface with a thin carbon paper and an ordinary paper and checking the impression formed on the ordinary paper, while tightening the platen over the paper covered surface. The papers are to be removed before testing.

8 COMPRESSION TEST

8.1 Storage

Cores may be tested generally in saturated condition except if specifically required to be tested in air dry condition. For the saturated condition, soak in water at 27 ± 3°C for a minimum of 40 h and maximum up to 48h before testing. Core shall be removed from the water and tested while it is still wet but remove all excess surface grit and water by wiping off. If it is required to test the core specimen in air-dry conditions, store in laboratory air for a minimum of 40 h and maximum up to 48 h prior to testing, record the storage time, ambient temperature and relative humidity of the storage conditions during air-dry storage of the specimens.

8.2 Placing and Testing of Core Specimen

Before placing the core specimen in testing machine, weigh it and also determine its length. The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the core specimen which are to be in contact with the compression platens. The core specimen shall be placed in the machine in such a manner that the load shall be applied to the top and bottom prepared surfaces. The axis of the core specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. As the spherically seated block is brought to bear on the core specimen, the movable portion shall be rotated gently by hand so that uniform seating may be obtained. The load shall be applied without shock and increased continuously at a rate of approximately 14 N/mm^2/min until the the core specimen breaks down and no greater load can be sustained. The maximum load applied to the core specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

8.3 Assessment of Type of Failure

For core specimens, if the failure is satisfactory (*see* Fig. 2), this fact shall be recorded. If the failure pattern is unsatisfactory, this fact shall be recorded and the type of failure recorded using the pattern letter (a to m) as given in Fig. 3, closest to the observed failure.

8.4 Calculation

8.4.1 The measured compressive strength of the core specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area, calculated from the mean dimensions of the section and shall be expressed to the nearest N/mm^2.

The product of correction factor for core diameter (cores having diameter less than 100 mm) as given below, and the measured compressive strength shall be known as the corrected compressive strength:

Diameter of Core (No. of Cores ≥ 3) mm	*Correction Factor*
75 ± 5	1.03
< 70	1.06

8.4.2 A correction factor according to the *l/d* ratio of core specimen after capping shall be obtained from the following equation:

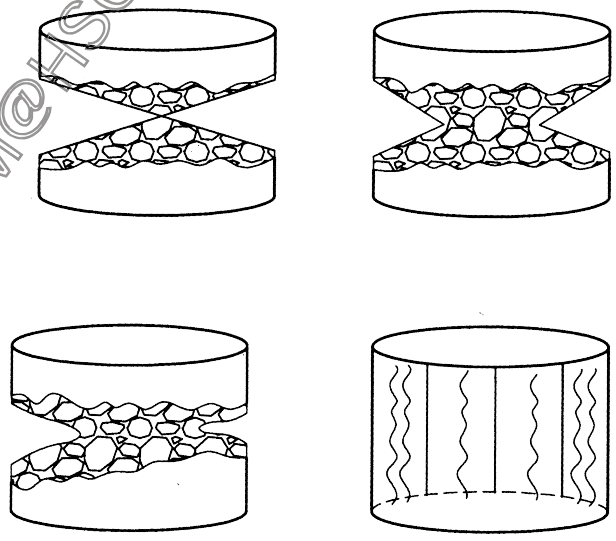


FIG. 2 SATISFACTORY FAILURE OF SPECIMEN

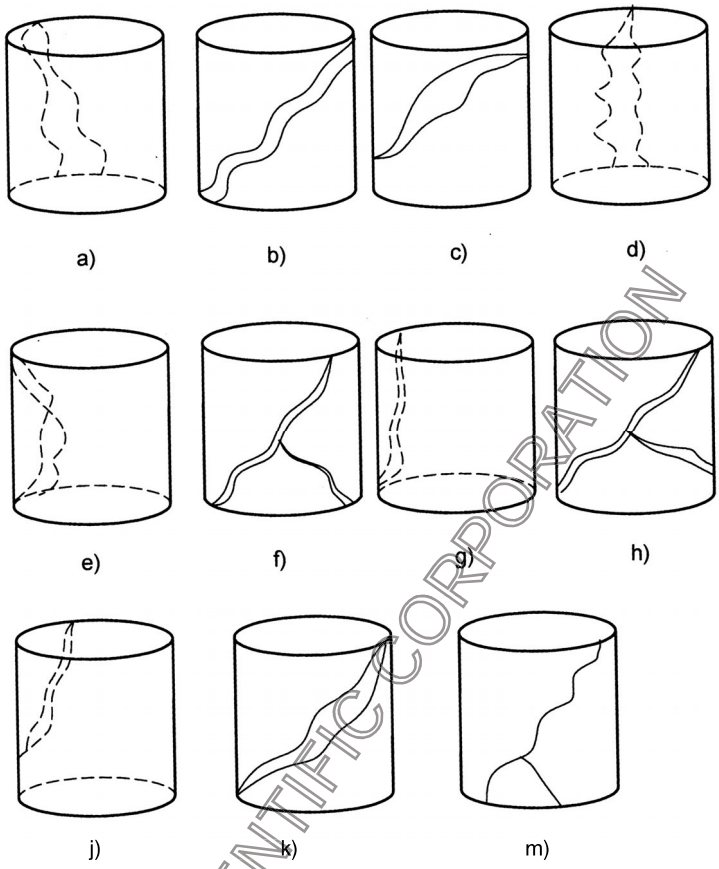


FIG. 3 UNSATISFACTORY FAILURE OF SPECIMEN

$$F = 0.11N + 0.78$$

where

F = correction factor, and

N = length /diameter ratio.

The product of this correction factor and the measured compressive strength or the corrected compressive strength for diameter as per **8.4.1** shall be known as the corrected cylinder strength, this being the equivalent strength of a cylinder having a height/diameter ratio of two. The equivalent cube strength of the concrete shall be determined by multiplying the corrected cylinder strength by 5/4.

8.4.3 *Report*

The following information shall be included in the report on each test specimen:

a) Identification mark;
b) Date of test;
c) Age of specimen (if known/supplied);
d) Maximum nominal size of aggregate (if known/supplied);
e) Curing conditions, including date of manufacture of specimen in the field (if known/ supplied);
f) Density of specimen (after end surface preparation) and dry density (prior to capping), the density of a core may be determined by weighing it and dividing it by the volume calculated from average diameter and length. Wet density to be reported, if specifically asked;
g) Method used for preparation of specimen: cutting/grinding/capping;
h) Dimensions of specimen (diameter and length (after preparation);
j) Cross-sectional area;
k) Maximum load;
m) Measured compressive strength;
n) Corrected compressive strength;
p) Corrected cylinder strength;
q) Equivalent cube strength; and
r) Appearance of fractured faces of concrete (satisfactory/unsatisfactory) and, type of fracture, if these are unusual.

Annex B, gives guidelines for interpretation of core test results based on various factors.

ANNEX A

(*Clause* 1)

SECURING AND PREPARING TEST SPECIMENS FROM HARDENED CONCRETE

A-1 This annex specifies the procedure for securing and preparing test specimens from hardened concrete in structures and pavements. A specimen to be tested for strength shall not be removed from the structure until the concrete has become hard enough to permit its removal without disturbing the bond between the mortar and the coarse aggregate. Normally, the concrete shall be 14 days old before the specimens are removed. Specimens that show abnormal defects or that have been damaged in removal shall not be used.

A-2 APPARATUS

A-2.1 Saw — A saw shall be used for securing beam specimens from the structure or pavement for flexural strength tests. The saw shall have a diamond or silicon carbide cutting edge and shall have adjustments that permit cutting of specimens conforming to the dimensions specified in **A-3.1**.

A-3 TEST SPECIMENS

A-3.1 Beam Specimen

The beam specimen for the determination of flexural strength shall normally have a cross-section of 150 × 150 mm and shall be at least 700 mm in length. If the largest size of the aggregate does not exceed 20 mm, the beam specimen shall be 100 mm × 100 mm × 500 mm.

NOTE — In many cases, particularly with prisms cut from pavement slabs, the width is governed by the size of the coarse aggregate and the depth by the thickness of the slabs.

A-4 PROCEDURE

A-4.1 Slab Removal

A sufficiently large slab shall be removed so that the desired test specimens may be secured without the inclusion of any concrete which has been cracked, spalled, undercut, or otherwise damaged.

A-4.2 Beam Sawing

The sawing operation shall be so performed that the concrete will not be weakened by shock or by heating. The sawn surfaces shall be smooth, plane, parallel and shall be free from steps, ridges and grooves. Care shall be taken in handling the sawn beam specimens to avoid chipping or cracking.

ANNEX B

(*Clause* 8.4.3)

INTERPRETATION OF CORE TEST RESULTS (INFORMATIVE)

B-1 FACTORS AFFECTING STRENGTH OF CORES

The following are the factors that affect the strength of cores:

a) *Place of drilling the core* — There can be variation within the member. For example, generally the in-place strength of concrete at the top of member as cast is less than the strength at the bottom.

b) *Micro-cracking* — Micro-cracking present in the concrete may reduce the core strength. Micro-cracks can be present if the core is drilled from a region of the structure that has been subjected to stress resulting from applied load or restraint of imposed deformation. Rough handling of core sample may also cause micro cracking.

c) *Curing* — Curing period and curing temperature both affect the strength. In mass concrete, differential moisture and temperature within the member can give variation in results of cores taken from outer face and inner mass. Inner mass can have lower compressive strength due to high initial temperature. Similarly, for non-continuous curing, the

moisture gradient between surface and inner mass can result in different strengths in concrete, that is, lower strength in cores along face, due to less curing and higher strength within the inner mass due to availability of moisture for continuous curing.

d) *Compaction* — Entrapped air in the concrete due to poor compaction or bleeding can reduce the strength. As the extent of poor compaction or bleeding can vary within the member, visual inspection of cores is essential to see if there is the presence of voids or honeycombs in the core samples. The extent of non-compaction and/or bleeding can be assessed by ultrasonic pulse velocity testing, as per IS 516 (Part 5/ Sec 1).

e) *Moisture content* — Moisture condition of cores also affects the strength. Dried core samples give about 5 to 10 percent more strength than saturated samples. Therefore, for comparison with the cube test results, saturated sample testing is recommended in the test procedure of this code.

f) The overall average effect of factors mentioned at (a) to (e) and other minor factors like coring direction, etc, is that, the core test is generally 85 to 90 percent of corresponding cube strength and the same has been considered in the acceptance criteria for core given in IS 456. However, if cracks are observed in the core, the core should not be tested or if cracking is observed during testing from failure pattern or from load machine displacement curve, the core results can be discarded [*see also* note under **B-2.5.2** (b)].

The effect of diameter is considered in the correction factors at **8.4**. While there is consensus that difference between 100 mm and 150 mm diameter cores are negligible, there is less agreement concerning smaller diameter cores. The analysis of large number of cores by various investigators indicated that the strength of 50 mm diameter cores was on an average 6 percent less than the strength of 100 mm diameter cores. In other tests, the average strength of 60 mm diameter cores was less by about 7 percent (for cores with average strength of 32 N/mm^2). As the strength increases, the difference reduces. The scatter in results of 60 mm diameter cores is also found to be more. Therefore, when core diameter is less than 100 mm, more number of cores will give better assessment.

B-2 ACCEPTANCE CRITERIA OF CORE TEST RESULTS

The acceptance criteria for the core test results shall be as given hereunder.

B-2.1 As the specified compressive strength is generally cube strength, the results of cores are also expressed in terms of equivalent cube strength. Accordingly the acceptance criteria of core test results should also be correlated to acceptance criteria of cube tests.

B-2.2 Acceptance criteria of cube tests in the Indian Standards and other International Standards are based on statistical analysis technique. The confidence level considered in the Indian Standard is 95 percent (that is, 95 percent probability that 95 percent of the results will be more than f_{ck}, with minimum 30 samples).

B-2.3 In the expression, $f_{mean} = f_{ck} + z\sigma$, for 95 percent confidence level, z is 1.65 and the same is considered in target strength calculation. Therefore in IS 456, for acceptance based on average of 4 consecutive samples ($4 \times 3 = 12$ cubes).

f_{min} for avg of 4 samples = $[(f_{mean} = f_{ck} + 1.65\sigma) - 1.65 \times s]$

where $s = \sigma/4^{0.5} = \sigma/2$.

So $f_{min} = f_{ck} + 0.825 \times \sigma$, subject to $f_{min} = f_{ck} + 3$

B-2.4 For acceptance of concrete based on limited *in-situ* testing, little lower confidence level is acceptable. Generally 75 percent confidence level (75 percent probability of 95 percent results > f_{ck}) is considered. So mean core strength required is $f'_{mean \geq} (f'_{ck} + 1.48\sigma)$ where σ is the standard deviation. However, this is valid only if sufficient numbers of cores are tested.

B-2.5 Acceptance of core test results is generally required for two purposes as mentioned below, particularly for new construction. For existing structures the requirement is generally to assess the grade or strength of concrete in place,

a) acceptance for structural adequacy; and
b) contractual acceptance for conformance to specification.

(Deviations from specifications also affects durability besides strength.)

B-2.5.1 *Procedure as per IS 456*

If average of equivalent cube strength of minimum three cores is more than 0.85 times the specified cube strength (characteristic strength, f_{ck}) and no individual core has equivalent cube strength less than 0.75 times specified cube strength (f_{ck}), the core test results are considered satisfactory.

The international approach for assessing the core strength is also similar.

B-2.5.2 Recommended procedure for acceptance of core test results:

a) The present procedure of IS 456 as mentioned before at **B-2.5.1** is simple and can be used

for assessing strength of a particular member by taking three cores or in a case where one set of cube samples (set of 4 consecutive sample) has failed. The specified strength will be considered as characteristic strength.

b) For overall assessment requirement or where large number of cube sets (each set consisting of 4 consecutive samples) have failed say 2 consecutive sets or 3 scattered sets have failed (for the same grade/class of concrete) within a batch to be assessed, minimum 10 cores will be tested and the acceptance in such case will be as under:

f' (avg) $\geq 0.85\ (f_{ck} + 3)$

f' (i) $\geq 0.75\ (f_{ck})$

where f' (avg) is average equivalent cube strength of all cores (minimum nine cores - after excluding outliers if any).

f' (i) is equivalent cube strength of individual core.

NOTE — Detecting outliers in test results: Outlier can be detected by inspection of load-machine displacement curves or using statistical tests. For statistical test, values beyond 'f(avg) ± 2s' may be treated as outliers as a guide. Out of every 10 cores tested, one core test result can be outlier.

c) Where the requirements of procedure **B-2.5.2** (a) and **B-2.5.2** (b) as the case may be, have been met, the concrete can be said to be meeting requirements of specification of IS 456. But where, 10 or more than 10 cores are taken but the results do not meet the criteria of **B-2.5.2** (b), but results of average of cores from all the individual members tested have strength more than $0.85f_{ck}$ and no individual core has strength less than $0.75f_{ck}$, the concrete in the particular batch or member may be accepted for structural adequacy and contractual acceptance/ penalties/deduction may be decided as per contract provisions by the project authorities.

NOTE — The procedure for assessment of strength of concrete by core test as given above is generally in line with international practice but modified to make it in line with present acceptance criteria given in IS 456 for acceptance of cube test results.

B-2.5.2.1 *Age factors for increase of strength with age*

Though there is normally a gain of strength beyond 28 days, the quantum of increase depends upon the grade, type of cement, curing and environmental condition. Therefore, while assessing the strength of concrete based on cores extracted at a later age, no age factor is generally considered except where considered in design or included in the contract specifications (*see also* **6.2.1** of IS 456).

1st Floor, D. No. 76-13-99/5, Beside Bhashyam Public School, Bypass Road, Joji Nagar, Bhavanipuram, Vijayawada – 520012 (Andhra Pradesh)
e-mail : aprrp.pmc@cegindia.com

Annexure-1

Table 900-5 : Age-Strength Relation of Concrete (Related to 100 percent at 28 Days)

Days	0	2	4	6	8
0	–	41.0	60.0	71.0	77.5
10	81.5	85.0	87.5	90.0	92.0
20	94.0	96.0	97.5	98.5	100.0
30	101.0	102.0	103.5	104.5	105.5
40	106.5	107.0	108.0	109.5	110.0
50	110.5	111.0	112.0	112.5	113.0
60	114.0	114.5	115.0	115.5	116.0
70	116.5	117.0	117.5	118.0	118.5
80	119.0	119.5	119.5	120.0	120.5
90	121.0	121.5	122.0	122.0	122.5
100	123.5	123.5	123.5	124.0	124.5
110	125.0	125.0	125.5	125.5	126.0
120	126.0	126.0	127.0	127.0	127.5
130	127.5	128.0	128.5	128.5	129.0
140	129.0	129.5	129.5	130.0	130.0
150	130.5	130.5	131.0	131.0	131.5
160	131.5	131.5	132.0	132.0	132.5
170	132.5	132.5	133.0	133.0	133.5
180	133.5	134.0	134.0	134.5	134.5
190	135.0	135.0	135.0	135.5	135.5
200	135.5	135.5	136.0	136.0	136.5
210	136.5	136.5	137.0	137.0	137.0
220	137.0	137.5	137.5	137.5	138.0
230	138.0	138.5	138.5	138.5	138.5
240	139.0	139.0	139.0	139.5	139.5
250	139.5	140.0	140.0	140.0	140.0
260	140.5	140.5	140.5	140.5	141.0
270	141.0	141.0	141.5	141.5	141.5
280	142.0	142.0	142.0	142.0	142.0
290	142.5	142.5	142.5	142.5	142.5
300	143.0	143.0	143.0	143.0	143.5