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Indian Standard
**METHODS OF TESTS FOR
STRENGTH OF CONCRETE**

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(Incorporating Amendment No 1 and Including Amendment No 2)

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Indian Standard

METHODS OF TESTS FOR STRENGTH OF CONCRETE

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 10 November 1959, after the draft finalized by the Cement and Concrete Sectional Committee had been approved by the Building Division Council.

0.2 Testing plays an important role in controlling the quality of cement concrete work. Systematic testing of the raw materials, the fresh concrete and the hardened concrete is an inseparable part of any quality control programme for concrete which helps to achieve higher efficiency of the materials used and greater assurance of the performance of the concrete in regard to both strength and durability. The test methods used should be simple, direct and convenient to apply. This standard has been prepared with this object in view and provides a guide to the determination of compressive strength, flexural strength and modulus of elasticity of concrete. Sampling and analysis of concrete have been covered separately in IS: 1199-1959 Methods of Sampling and Analysis of Concrete.

0.3 The Sectional Committee responsible for the preparation of this standard has taken into consideration the views of concrete specialists, testing authorities, consumers and technologists and has related the standard to the practices followed in the country in this field. The need for international co-ordination between standards prevailing in different countries of the world has also been recognized. These considerations led the Sectional Committee to derive assistance from the published standards and publications of the following organizations:

BRITISH STANDARDS INSTITUTION
AMERICAN SOCIETY FOR TESTING MATERIALS
AMERICAN CONCRETE INSTITUTE
CANADIAN ENGINEERING STANDARDS ASSOCIATION
RESEARCH, DESIGN & STANDARDIZATION ORGANIZATION, MINISTRY
OF RAILWAYS, GOVERNMENT OF INDIA
THE CONCRETE ASSOCIATION OF INDIA

0.4 The Indian Standard Methods of Sampling and Analysis of Concrete (IS: 1199-1959) is a necessary adjunct to this standard. Besides, this standard requires reference to the following Indian Standards:

*IS: 269-1958 SPECIFICATION FOR ORDINARY, RAPID-HARDENING AND
LOW HEAT PORTLAND CEMENT (*Revised*)

*Since revised.

*IS : 383-1952 SPECIFICATION FOR COARSE AND FINE AGGREGATES FROM NATURAL SOURCES FOR CONCRETE

†IS : 455-1953 SPECIFICATION FOR PORTLAND BLASTFURNACE SLAG CEMENT

‡IS : 456-1957 CODE OF PRACTICE FOR PLAIN AND REINFORCED CONCRETE FOR GENERAL BUILDING CONSTRUCTION (*Revised*)

•IS : 460-1953 SPECIFICATION FOR TEST SIEVES

0.4.1 Wherever a reference to any standard mentioned in 0.4, except IS: 460-1953, appears in this standard, it shall be taken as a reference to the latest version of the standard.

0.5 In pursuance of the decision of the Government of India to introduce a uniform system of weights and measures throughout the country based on the metric system, in this standard, all dimensions and values have been given in metric units only. It is hoped that this step will facilitate the change-over to the metric system by the industry more expeditiously.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with*IS: 2-1949 Rules for Rounding Off Numerical Values. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

0.7 This standard is intended chiefly to cover the technical provisions relating to the testing of concrete, and it does not include all the necessary provisions of a contract.

1. SCOPE

1.1 This standard covers tests for the determination of compressive strength, flexural strength and modulus of elasticity of cement concrete.

2. MAKING AND CURING COMPRESSION TEST SPECIMENS IN THE LABORATORY

2.1 This clause specifies the procedure for making and curing compression test specimens of concrete in the laboratory where accurate control of the quantities of materials and test conditions are possible and where the maximum nominal size of aggregate does not exceed 38 mm. The method is specially applicable to the making of preliminary compression tests to ascertain the suitability of the available materials or to determine suitable mix proportions.

2.2 Sampling of Materials - Representative samples of the materials of concrete for use in the particular concrete construction work shall be

*Since revised.

† Second revision issued in 1967.

‡ Second revision issued in 1964.

obtained by careful sampling. Test samples of cement shall be made up of a small portion taken from each of a number of bags on the site. Test samples of aggregate shall be taken from larger lots by quartering.

2.3 Preparation of Materials - All materials shall be brought to room temperature, preferably $27 \pm 3^\circ\text{C}$ before commencing the tests.

The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material, care being taken to avoid the intrusion of foreign matter. The cement shall then be stored in a dry place, preferably in air-tight metal containers.

Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. In general, the aggregate shall be separated into fine and coarse fractions and recombined for each concrete batch in such a manner as to produce the desired grading. IS Sieve 480 shall be normally used for separating the fine and coarse fractions, but where special gradings are being investigated, both fine and coarse fractions shall be further separated into different sizes.

2.4 Proportioning -- The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work. Where the proportions of the ingredients of the concrete as used on the site are to be specified by volume, they shall be calculated from the proportions by weight used in the test cubes and the unit weights of the materials.

2.5 Weighing -- The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.

2.6 Mixing Concrete -- The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.

2.6.1 Machine Mixing -- When the mixing drum is charged by a power loader, all the mixing water shall be introduced into the drum before the solid materials; the skip shall be loaded with about one-half of the coarse aggregate, then with the fine aggregate, then with the cement and finally with the remaining coarse aggregate on top. (If all-in-aggregate is used, the skip shall be loaded first with about one-half of the aggregate then with the cement and finally with the remaining aggregate on top.) Where the mixing drum is hand-loaded it shall be charged with the dry materials in a similar manner, and the water shall be added immediately before the rotation of the drum is started. The period of mixing shall

be not less than 2 minutes after all the materials are in the drum, and shall continue till the resulting concrete is uniform in appearance. When using pan mixers, the concrete shall be heaped together before sampling.

2.6.2 Hand Mixing -- The concrete batch shall be mixed on a water-tight, non-absorbent platform with a shovel, trowel or similar suitable implement, using the following procedure:

- a) The cement and fine aggregate shall be mixed dry until the mixture is thoroughly blended and is uniform in colour,
- b) The coarse aggregate shall then be added and mixed with the cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch, and
- c) The water shall then be added and the entire batch mixed until the concrete appears to be homogeneous and has the desired consistency. If repeated mixing is necessary, because of the addition of water in increments while adjusting the consistency, the batch shall be discarded and a fresh batch made without interrupting the mixing to make trial consistency tests.

2.7 Workability -- Each batch of concrete shall be tested for consistency immediately after mixing, by one of the methods described in IS: 1199-1959. Provided that care is taken to ensure that no water or other material is lost, the concrete used for the consistency tests may be re-mixed with the remainder of batch before making the test specimens. The period of re-mixing shall be as short as possible yet sufficient to produce a homogeneous mass.

2.8 Size of Test Specimens -- Test specimens cubical in shape shall be $15 \times 15 \times 15$ cm. If the largest nominal size of the aggregate does not exceed 2 cm, 10 cm cubes may be used as an alternative. Cylindrical test specimens shall have a length equal to twice the diameter. They shall be 15 cm in diameter and 30 cm long. Smaller test specimens shall have a ratio of diameter of specimen to maximum size of aggregate of not less than 3 to 1, except that the diameter of the specimen shall be not less than 7.5 cm for mixtures containing aggregate more than 5 percent of which is retained on IS Sieve 480.

2.9 Moulds

2.9.1 Cube Moulds -- The mould shall be of metal, preferably steel or cast iron, and stout enough to prevent distortion. It shall be constructed in such a manner as to facilitate the removal of the moulded specimen without damage, and shall be so machined that, when it is assembled ready for use, the dimensions and internal faces shall be accurate within the following limits:

The height of the mould and the distance between opposite faces shall be the specified size ± 0.2 mm. The angle between adjacent

internal faces and between internal faces and top and bottom planes of the mould shall be $90^\circ \pm 0.5^\circ$. The interior faces of the mould shall be plane surfaces with a permissible variation of 0.03 mm. Each mould shall be provided with a metal base plate having a plane surface. The base plate shall be of such dimensions as to support the mould during the filling without leakage and it shall be preferably attached to the mould by springs or screws. The parts of the mould when assembled shall be positively and rigidly held together, and suitable methods of ensuring this, both during the filling and on subsequent handling of the filled mould, shall be provided.

2.9.1.1 In assembling the mould for use, the joints between the sections of mould shall be thinly coated with mould oil and a similar coating of mould oil shall be applied between the contact surfaces of the bottom of the mould and the base plate in order to ensure that no water escapes during the filling. The interior surfaces of the assembled mould shall be thinly coated with mould oil to prevent adhesion of the concrete

2.9.2 Cylinders — The cylindrical mould shall be of metal which shall be not less than 3 mm thick. Each mould shall be capable of being opened longitudinally to facilitate removal of the specimen and shall be provided with a means of keeping it closed while in use. The ends shall not depart from a plane surface, perpendicular to the axis of the mould, by more than 0.05 mm. When assembled ready for use, the mean internal diameter of the mould shall be $15.0 \text{ cm} \pm 0.2 \text{ mm}$ and in no direction shall the internal diameter be less than 14.95 cm or more than 15.05 cm. The height shall be $30.0 \text{ cm} \pm 0.1 \text{ cm}$. Each mould shall be provided with a metal base plate, and with a capping plate of glass or other suitable material. The base plate and the capping plate shall be at least 6.5 mm thick, and such that they do not depart from a plane surface by more than 0.02 mm. The base plate shall support the mould during filling without leakage and shall be rigidly attached to the mould. The mould and base plate shall be coated with a thin film of mould oil before use, in order to prevent adhesion of the concrete.

2.9.3 Tamping Bar — The tamping bar shall be a steel bar 16 mm in diameter, 0.6 m long and bullet pointed at the lower end.

2.10 Compacting — The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance. The concrete shall be filled into the mould in layers approximately 5 cm deep. In placing each scoopful of concrete, the scoop shall be moved around the top edge of the mould as the concrete slides from it, in order to ensure a symmetrical distribution of the concrete within the mould. Each layer shall be compacted either by hand or by vibration as described below (see 2.10.1 and 2.10.2). After the top layer has been compacted, the

Clause 2.9.2 is replaced with: The Cylindrical moulds shall be of 150 mm diameter and 300 mm height conforming to IS 10086: 1982 - Specification for moulds for use in tests of cement and concrete

Clause 2.9.3 is replaced with: Tamping Bar - It should conform to 6.1 (a) of IS 10086: 1982 - Specification for moulds for use in tests of cement and concrete

surface of the concrete shall be finished level with the top of the mould, using a trowel, and covered with a glass or metal plate to prevent evaporation.

2.10.1 Compacting by Hand — When compacting by hand, the standard tamping bar shall be used and the strokes of the bar shall be distributed in a uniform manner over the cross-section of the mould. The number of strokes per layer required to produce specified conditions will vary according to the type of concrete. For cubical specimens, in no case shall the concrete be subjected to less than 35 strokes per layer for 15 cm cubes or 25 strokes per layer for 10 cm cubes. For cylindrical specimens, the number of strokes shall not be less than thirty per layer. The strokes shall penetrate into the underlying layer and the bottom layer shall be rodded throughout its depth. Where voids are left by the tamping bar, the sides of the mould shall be tapped to close the voids.

2.10.2 Compacting by Vibration — When compacting by vibration, each layer shall be vibrated by means of an electric or pneumatic hammer or vibrator or by means of a suitable vibrating table until the specified condition is attained.

NOTE — The mode and quantum of vibration of the laboratory specimen shall be as nearly the same as those adopted in actual concreting operations.

2.11 Capping Specimens — The ends of all cylindrical test specimens that are not plane within 0.05 mm shall be capped. Capped surfaces shall not depart from a plane by more than 0.05 mm and shall be approximately at right angles to the axis of the specimens. The planeness of the cap shall be checked by means of a straight edge and feeler gauge, making a minimum of three measurements on different diameters. Caps shall be made as thin as practicable and shall not flow or fracture when the specimen is tested. Capping shall be carried out according to one of the following methods.

2.11.1 Neat Cement — Test cylinders may be capped with a thin layer of stiff, neat Portland cement paste after the concrete has ceased settling in the moulds, generally for two to four hours or more after moulding. The cap shall be formed by means of glass plate not less than 6.5 mm in thickness or a machined metal plate not less than 13 mm in thickness and having a minimum surface dimension at least 25 mm larger than the diameter of the mould. It shall be worked on the cement paste until its lower surface rests on the top of the mould. The cement for capping shall be mixed to a stiff paste for about two to four hours before it is to be used in order to avoid the tendency of the cap to shrink. Adhesion of paste to the capping plate may be avoided by coating the plate with a thin coat of oil or grease.

2.11.2 Sulphur — Just prior to testing, the cylindrical specimens may be capped with a sulphur mixture consisting of 2 or 3 parts sulphur to 1 part of inert filler, such as fire-clay. The specimens shall be securely held in a

special jig so that the caps formed have true plane surfaces. Care shall be taken to ensure that the sulphur compound is not over-heated as it will not then develop the required compressive strength. Sulphur caps shall be allowed to harden for at least 2 hours before applying the load.

2.11.3 Hard Plaster — Just prior to testing, specimens may be capped with hard plaster having a compressive strength of at least 420 kg/sq cm in one hour. Such plasters are generally available as proprietary material. The cap shall be formed by means of a glass plate not less than 13 mm in thickness, having a minimum surface dimension at least 25 mm larger than the diameter of the mould. The glass plate shall be lightly coated with oil to avoid sticking.

NOTE Ordinary plaster of paris will not serve the purpose of the capping material due to its low compressive strength.

2.11.4 As soon as possible after the concrete is mixed, a mortar shall be gauged using a cement similar to that used in the concrete and sand which passes IS Sieve 30 but is retained on IS Sieve 15. The mortar shall have a water/cement ratio not higher than that of the concrete of which the specimen is made, and shall be of a stiff consistence. If an excessively wet mix of concrete is being tested, any free water which has collected on the surface of the specimen shall be removed with a sponge, blotting paper or other suitable absorbent material before the cap is formed. The mortar shall then be applied firmly and compacted with a trowel to a slightly convex surface above the edges of the mould, after which the capping plate shall be pressed down on the cap with a rotary motion until it makes complete contact with the rim of the mould. The plate shall be left in position until the specimen is removed from the mould.

2.12 Curing — The test specimens shall be stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of $27^{\circ} \pm 2^{\circ}\text{C}$ for 24 hours $\pm \frac{1}{2}$ hour from the time of addition of water to the dry ingredients. After this period, the specimens shall be marked and removed from the moulds and, unless required for test within 24 hours, immediately submerged in clean, fresh water or saturated lime solution and kept there until taken out just prior to test. The water or solution in which the specimens are submerged shall be renewed every seven days and shall be maintained at a temperature of $27^{\circ} \pm 2^{\circ}\text{C}$. The specimens shall not be allowed to become dry at any time until they have been tested.

3. MAKING AND CURING COMPRESSION TEST SPECIMEN IN THE FIELD

3.1 This clause deals with the procedure for making and curing compression test specimens of concrete sampled during the progress of construction where the nominal maximum size of the aggregate does not exceed 38 mm.

3.2 Size of test specimen, apparatus to be used and procedure to prepare specimens shall be the same as specified in 2.

3.3 Curing — The test specimens shall be stored on the site at a place free from vibration, under damp matting, sacks or other similar material for 24 hours $\pm \frac{1}{2}$ hour from the time of adding the water to the other ingredients. The temperature of the place of storage shall be within the range of 22° to 32°C. After the period of 24 hours, they shall be marked for later identification, removed from the moulds and, unless required for testing within 24 hours, stored in clean water at a temperature of 24° to 30°C until they are transported to the testing laboratory. They shall be sent to the testing laboratory well packed in damp sand, damp sacks, or other suitable material so as to arrive there in a damp condition not less than 24 hours before the time of test. On arrival at the testing laboratory, the specimens shall be stored in water at a temperature of 27° $\pm$ 2°C until the time of test. Records of the daily maximum and minimum temperature shall be kept both during the period of the specimens remain on the site and in the laboratory.

4. SECURING AND PREPARING SPECIMENS OF HARDENED CONCRETE FOR COMPRESSION TEST

4.1 This clause deals with the procedure for securing and preparing compression test specimens obtained from hardened concrete after the concrete has been laid in position.

4.2 The test specimens shall be procured from hardened concrete according to the method described in 4 of IS: 1199-1959.*

4.3 Cores to be tested for compression strength shall have ends that are reasonably even, perpendicular to the axis and of the same diameter as the body of the specimen. A core which, before capping, has a maximum height of less than 95 percent of the diameter, or after capping, a height less than its diameter shall not be used.

4.4 Capping — The ends of the specimen shall be capped before testing. The material used for the capping shall be such that its compressive strength is greater than that of the concrete in the core. Caps shall be made as thin as practicable and shall not flow or fracture before the concrete fails when the specimen is tested. The capped surfaces shall be at right angles to the axis of the specimen and shall not depart from a plane by more than 0.05 mm. The capping of specimens shall be carried out as described in 2.11.

4.5 After checking for irregularities, the core shall be placed in water at a temperature of 24° to 30°C for 48 hours before testing. The overall height of the specimens, with capping shall be measured to the nearest millimetre.

*Since revised.

5. TEST FOR COMPRESSIVE STRENGTH OF CONCRETE SPECIMEN

5.1 This clause deals with the procedure for determining the compressive strength of concrete specimens.

5.2 Apparatus

5.2.1 Testing Machine — The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified in 5.5. The permissible error shall be not greater than ± 2 percent of the maximum load. 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 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 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.

5.3 Age at Test — Tests shall be made at recognized ages of the test specimens, the most usual being 7 and 28 days. Ages of 13 weeks and one year are recommended if tests at greater ages are required. Where it may be necessary to obtain the early strengths, tests may be made at the ages of 24 hours $\pm \frac{1}{2}$ hour and 72 hours ± 2 hours. The ages shall be calculated from the time of the addition of water to the dry ingredients.

5.4 Number of Specimens — At least three specimens, preferably from different batches, shall be made for testing at each selected age.

NOTE — When a full investigation is being carried out, it is advisable for three separate batches to be made for each given variable. An equal number of specimens for each variable should be made.

5.5 Procedure — Specimens stored in water shall be tested immediately on removal from the water and while they are still in the wet condition. Surface water and grit shall be wiped off the specimens and any projecting fins removed. Specimens when received dry shall be kept in water for 24 hours before they are taken for testing. The dimensions of the specimens to the nearest 0.2 mm and their weight shall be noted before testing.

5.5.1 Placing the Specimen in the Testing Machine — The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the specimen which are to be in

contact with the compression platens. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine. As the spherically seated block is brought to bear on the 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 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

5.6 Calculation — The measured compressive strength of the 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 (*see also 4.5.1 of IS: 1199-1959*) and shall be expressed to the nearest kg per sq cm. Average of three values shall be taken as the representative of the batch provided the individual variation is not more than ± 15 percent of the average. Otherwise repeat tests shall be made.

5.6.1 A correction factor according to the height/diameter ratio of specimen after capping shall be obtained from the curve shown in Fig. 1. The product of this correction factor and the measured compressive strength shall be known as the corrected compressive 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

5.6.2 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,
- d) curing conditions, including date of manufacture of specimen in the field,
- e) weight of specimen,
- f) dimensions of specimen,
- g) cross-sectional area,
- h) maximum load,
- i) compressive strength, and
- k) appearance of fractured faces of concrete and type of fracture, if these are unusual.

*Since revised

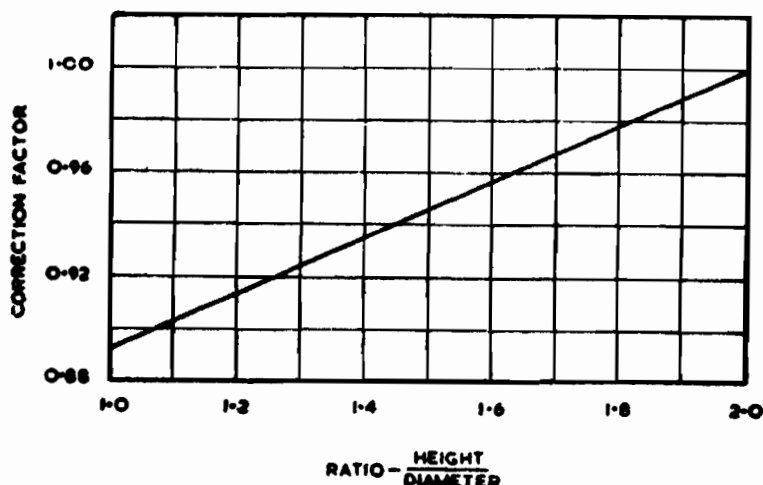


FIG 1 CORRECTION FACTOR FOR HEIGHT/DIAMETER RATIO OF A CORR

6. DETERMINATION OF COMPRESSIVE STRENGTH OF CONCRETE USING PORTIONS OF BEAMS BROKEN IN FLEXURE (" EQUIVALENT CUBE " METHOD)

6.1 This clause specifies the procedure for determining the compressive strength of concrete using portions of beams broken in flexure as the test specimens. The results obtained from this test are approximately equal to, and on the average may be up to 5 percent greater than those obtained by the test specified in 5.

NOTE — For method of making and testing flexure test specimens, see 7.

6.2 Apparatus

6.2.1 *Compression Testing Machine* — The testing machine shall comply in all respects with the requirements of 5.2.1.

6.2.2 *Bearing Plates* — Two metal bearing plates not less than 6.5 mm or more than 19 mm thick shall be provided. The plates shall be 10 cm square for the beams 10 cm in depth and 15 cm square for the beams 15 cm in depth with the surfaces machined to a permissible variation not exceeding 0.02 mm. The distance between the opposite edges shall be the specified size ± 0.02 mm and the angle between the edges shall be $90^\circ \pm 0.5^\circ$.

6.3 Test Specimens — The length of the broken portions of the beams selected for the compression test shall be at least 5 cm greater than the depth of the beam and the broken portions shall be free from cracks, chipped surfaces or other obvious defects within the length to be tested.

6.4 Procedure — During the interval between testing the specimens as beams and testing the broken portions as cubes, the specimens shall be stored in water at a temperature of 24° to 30°C and shall be tested immediately on removal from the water and while still in the wet condition.

6.4.1 Placing the Specimen in the Testing Machine — The bearing surfaces of the testing machine and the bearing plates shall be wiped clean and any loose sand or other material shall be removed from the surfaces of the specimen which are to be in contact with the bearing plates. The specimen shall be placed between the bearing plates in such a manner that the upper bearing plate is directly over the lower plate and the bearing plates extend at least 25 mm from each end of the specimen. A device which ensures the proper location of the upper plate with reference to the lower plate is shown in Fig. 2. No packing shall be used between the faces of the specimen and the bearing plates. The specimens shall be tested with the moulded sides in contact with the plates. The load shall

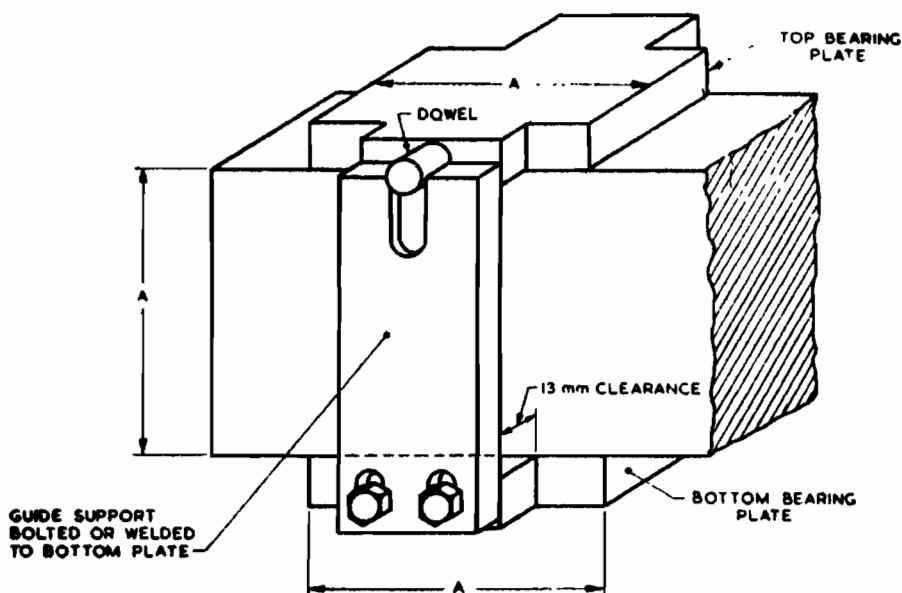


FIG 2 DEVICE FOR ALIGNING BEARING PLATES

be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

6.5 Calculation — The equivalent cube strength of the specimen shall be calculated by dividing the maximum load by the area of contact of the bearing plates and shall be expressed to the nearest kg/sq cm.

6.6 Report — The following information shall be included in the report on each specimen:

- a) identification mark,
- b) date of test,
- c) age of specimen,
- d) curing conditions,
- e) nominal size of specimen,
- f) maximum load,
- g) equivalent cube strength, and
- h) appearance of the concrete and type of fracture, if these are unusual.

7. MAKING AND CURING FLEXURE TEST SPECIMENS IN THE LABORATORY

7.1 This clause specifies the procedure for making and curing flexure test specimens of concrete in the laboratory where accurate control of the quantities of materials and test conditions is possible, provided the maximum nominal size of the aggregate does not exceed 38 mm. The method is specially applicable to the making of preliminary flexure tests to ascertain the suitability of the available material or to determine suitable mix proportions.

7.2 Sampling of Material — Preparation of materials, proportions, weighing, mixing of concrete shall be done in the same way as in the case of making compression test specimens in the laboratory (see 2).

7.3 Size of Specimens — The standard size shall be 15 × 15 × 70 cm. Alternatively, if the largest nominal size of the aggregate does not exceed 19 mm, specimens 10 × 10 × 50 cm may be used.

7.4 Apparatus

7.4.1 The mould shall be of metal, preferably steel or cast iron and the metal shall be of sufficient thickness to prevent spreading or warping. The mould shall be constructed with the longer dimension horizontal and in such a manner as to facilitate the removal of the moulded specimens

without damage. The mould shall be so machined that when assembled ready for use the dimensions shall be accurate within the following limits:

- a) The height of the mould shall be either 15.0 ± 0.005 cm or 10.0 ± 0.005 cm, and the corresponding internal width of the mould shall be 15.0 ± 0.02 cm or 10.0 ± 0.02 cm respectively. The angle between the interior faces and the top and bottom planes of the mould shall be $90^\circ \pm 0.5^\circ$. The internal surfaces of the mould shall be plane surfaces with a permissible variation of 0.02 mm in 15.0 cm and 0.1 mm overall.
- b) Each mould shall be provided with a metal base plate and two loose top plates of 4.0×0.6 cm cross-section and 5.0 cm longer than the width of the mould. The base plate and top plate shall have plane surfaces with a permissible variation of 0.05 mm. The base plate shall support the mould without leakage during the filling, and shall be rigidly attached to the mould.
- c) The parts of the mould when assembled shall be positively and rigidly held together, and suitable methods of ensuring this, both during the filling and on subsequent handling of the filled mould, shall be provided.
- d) In assembling the mould for use, the joints between the sections of the mould shall be thinly coated with mould oil and a similar coating of mould oil shall be applied between the contact surfaces of the bottom of the mould and the base plate in order to ensure that no water escapes during the filling. The interior faces of the assembled mould shall be thinly coated with mould oil to prevent adhesion of the concrete.

7.4.2 Tamping Bar — The tamping bar shall be a steel bar weighing 2 kg, 40 cm long, and shall have a ramming face 25 mm square.

7.5 Procedure, curing, age at test, number of specimens shall be the same as in 2 and 5.

8. TEST FOR FLEXURAL STRENGTH OF MOULDED FLEXURE TEST SPECIMENS

8.1 This clause deals with the procedure for determining the flexural strength of moulded concrete flexure test specimens.

8.2 Apparatus

8.2.1 The testing machine may be of any reliable type of sufficient capacity for the tests and capable of applying the load at the rate specified in 8.3. The permissible errors shall be not greater than ± 0.5 percent of the applied load where a high degree of accuracy is required and not greater than ± 1.5 percent of the applied load for commercial type of use. The bed of the testing machine shall be provided with two steel rollers,

38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15.0 cm specimens or 40 cm for 10.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span, that is, spaced at 20 or 13.3 cm centre to centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints. One suitable arrangement which complies with these requirements is indicated in Fig. 3.

8.3 Procedure — Test specimens stored in water at a temperature of 24° to 30°C for 48 hours before testing, shall be tested immediately on removal from the water whilst they are still in a wet condition. The dimensions of each specimen shall be noted before testing. No preparation of the surfaces is required.

8.3.1 Placing the Specimen in the Testing Machine — The bearing surfaces of the supporting and loading rollers shall be wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen shall then be placed in the machine in such a manner that the load shall be applied to the uppermost surface as cast in the mould, along two lines spaced 20.0 or 13.3 cm apart. The axis of the specimen shall be carefully aligned with the axis of the loading device. No packing shall be used between the bearing surfaces of the specimen and the rollers. The load shall be applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 7 kg/sq cm./min, that is, at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens. The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted.

8.4 Calculation — The flexural strength of the specimen shall be expressed as the modulus of rupture f_b , which, if 'a' equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, shall be calculated to the nearest 0.5 kg/sq cm as follows:

$$f_b = \frac{P \times l}{b \cdot d^2}$$

when 'a' is greater than 20.0 cm for 15.0 cm specimen, or greater than 13.3 cm for a 10.0 cm specimen, or

$$f_b = \frac{3P \times a}{b \cdot d^2}$$

when 'a' is less than 20.0 cm but greater than 17.0 cm for 15.0 cm specimen, or less than 13.3 cm but greater than 11.0 cm for a 10.0 cm specimen

where

b = measured width in cm of the specimen,

d = measured depth in cm of the specimen at the point of failure,

l = length in cm of the span on which the specimen was supported, and

p = maximum load in kg applied to the specimen

If ' a ' is less than 17.0 cm for a 15.0 cm specimen, or less than 11.0 cm for a 10.0 cm specimen, the results of the test shall be discarded

8.5 Report — The following information shall be included in the report on each specimen:

- a) identification mark,
- b) date of test,
- c) age of specimen,
- d) curing conditions,
- e) size of specimen,
- f) span length,
- g) maximum load,
- h) position of fracture (value ' a '),
- j) modulus of rupture (kg per sq cm), and
- k) appearance of concrete and type of fracture if these are unusual

9. DETERMINATION OF THE MODULUS OF ELASTICITY BY MEANS OF AN EXTENSOMETER

9.1 This clause specifies the procedure for making and curing test specimens, determining the modulus of elasticity of concrete in compression by means of an extensometer where the maximum nominal size of aggregate does not exceed 38 mm.

9.2 Size of Specimens — The test specimens shall consist of concrete cylinders 15.0 cm in diameter and 30.0 cm long. Alternately, other sizes of cylinders or square prisms may be used provided that the height/diameter or height/width ratio is at least 2

9.3 Sampling, apparatus and procedure shall be as described in 2.

9.4 Preparation of Test Specimens — The test specimens shall be prepared in accordance with 2 and shall be stored in water at a temperature of 24° to 30°C for at least 48 hours before testing. At least three specimens shall be made and tested.

9.5 Age at Test — Normally test shall be made when the specimens reach the age of 28 days

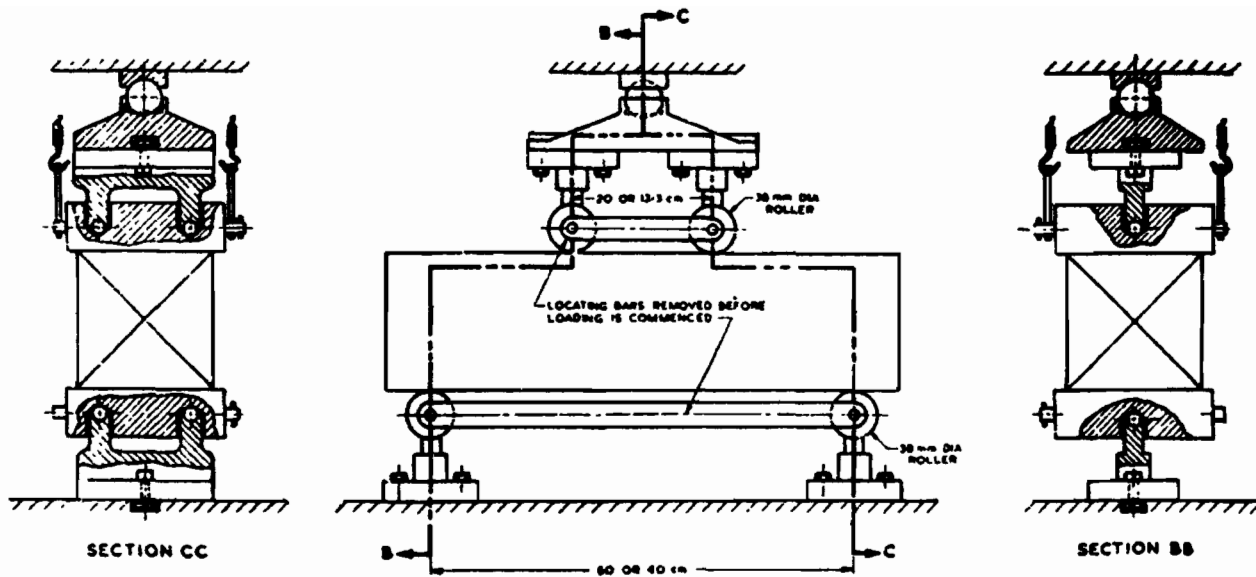


FIG. 3 ARRANGEMENT FOR LOADING OF FLEXURE TEST SPECIMEN

9.6 In order to determine the compressive strength of the concrete, three test specimens for compressive strength shall be made together with each set of cylinders or prisms in accordance with 9.2. The test specimens for compressive strength shall be made from the same sample of concrete as the cylinders or prisms and shall be cured and stored under identical conditions.

9.7 Apparatus

9.7.1 Testing Machine — The testing machine shall comply in all respects with the requirements of 5.2.1 and in addition shall be capable of maintaining the load at any desired value.

9.7.2 Extensometers — Two extensometers are required each having a gauge length of not less than 10.2 cm and not more than half the length of the specimen. They shall be capable of measuring strains to an accuracy of 2×10^{-6} . Mirror extensometers of the roller or rocker type are suitable.

9.8 Procedure — The three test specimens for compressive strength shall first be tested in accordance with 5 and the average compressive strength shall be recorded. Immediately on removing the cylinder or prism from the water and while it is still in a wet condition, the extensometers shall be attached at the ends, or on opposite sides of the specimen and parallel to its axis, in such a way that the gauge points are symmetrical about the centre of the specimen and in no case are nearer to either end of the specimen than a distance equal to half the diameter or half the width of the specimen. The extensometers shall be fixed with the recording points at the same end. The specimen shall be immediately placed in the testing machine and accurately centred. The load shall be applied continuously and without shock at a rate of 140 kg/sq cm/min until an average stress of $(C + 5)$ kg/sq cm is reached, where C is one-third of the average compressive strength of the cubes calculated to the nearest 5 kg/sq cm. The load shall be maintained at this stress for at least one minute and shall then be reduced gradually to an average stress of 1.5 kg/sq cm when extensometer readings shall be taken. The load shall be applied a second time at the same rate until an average stress of $(C + 1.5)$ kg/sq cm is reached. The load shall be maintained at this figure while extensometer readings are taken. The load shall again be reduced gradually and readings again taken at 1.5 kg/sq cm. The load shall then be applied a third time and extensometer readings taken at ten approximately equal increments of stress up to an average stress of $(C + 1.5)$ kg/sq cm. Readings shall be taken at each stage of loading with as little delay as possible. If the overall strains observed on the second and third readings differ by more than 5 percent, the loading cycle shall be repeated until the difference in strain between consecutive readings at $(C + 1.5)$ kg/sq cm does not exceed 5 percent.

9.9 Calculation — The strains at the various loads in the last two cycles shall be calculated separately for each extensometer and the results shall be plotted graphically against the stress. Straight lines shall be drawn through the points for each extensometer; the slopes of these two lines shall be determined and from them the average value shall be found. If the difference between the individual values is less than 15 percent of the average value, this average value, expressed in kg/sq cm to the nearest 1 000 kg/sq cm shall be recorded as the modulus of elasticity of the concrete. If the difference is greater than 15 percent, the specimen shall be re-centred in the testing machine and the test repeated. If the difference after re-centring and testing is still greater than 15 percent of the average value, the results of the test shall be discarded.

9.10 Report — The following information shall be included in the report:

- a) identification mark;
- b) date of test;
- c) age of specimen;
- d) shape and nominal dimensions of specimen;
- e) modulus of elasticity; and
- f) remarks, such as number of loading cycles.

10. DETERMINATION OF THE MODULUS OF ELASTICITY BY ELECTRODYNAMIC METHOD

10.1 This clause specifies the procedure for determining the modulus of elasticity of concrete by an electrodynamic method, namely by measuring the natural frequency of the fundamental mode of longitudinal vibration of concrete prisms. This is a non-destructive test and therefore the same specimens may subsequently be used for the flexural strength test specified in 8.

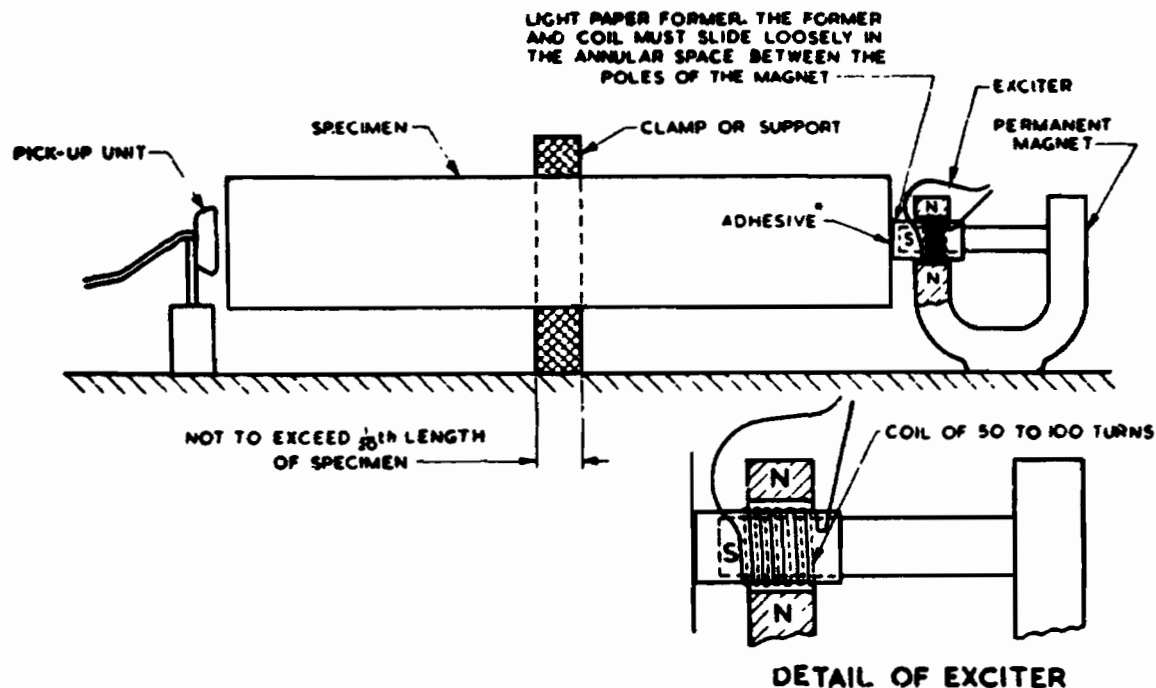
10.2 Specimens — The specimens shall in all respects comply with the requirements of 9.2.

10.3 Apparatus — The apparatus shall consist of the following.

10.3.1 A variable frequency oscillator with a working range up to 10 000 cycles per second, reading to an accuracy of ± 0.5 percent. A means of varying the output power shall be incorporated, and the output power shall be not less than 2 watts.

10.3.2 An electro-magnetic exciter unit of the moving-coil or variable air-gap type. If the moving-coil type is used, the former and coil should have as low an inertia as possible, the mass being not more than 0.2 percent of the mass of the specimen (the former should be of light card or paper). A suitable type of instrument is shown in Fig. 4. If a variable air-gap exciter unit is used, this shall be of a similar type to the pick-up unit.

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*The adhesive or other method of attachment should preferably allow paper cylinder to be detached after test for further use.

FIG. 4 ARRANGEMENT OF SPECIMEN FOR THE DETERMINATION OF MODULUS OF ELASTICITY BY ELECTRODYNAMIC METHOD

10.3.3 An electro-magnetic pick-up unit of the ordinary telephone type. Alternatively, a piezo-electric gauge may be used, provided that its mass is not more than 0.2 percent of the mass of the specimen.

10.3.4 An audio-frequency amplifier.

10.3.5 An amplitude indicator consisting of a voltmeter, milliammeter or cathode-ray oscilloscope.

10.3.6 A fixed clamp or support with a maximum width of $\frac{1}{10}$ th of the length of the specimen. If a variable air-gap exciter unit is used in conjunction with a variable air-gap pick-up, the support shall be metallic and earthed.

10.4 Procedure — Immediately on removal from water, except when the specimen is less than 24 hours old, and while still in a wet condition, the specimen shall be clamped or balanced at its centre on the fixed support. Where a moving-coil type of exciter unit is used, the moving-coil portion shall be fixed to the middle of one end face of the specimen as indicated in Fig. 4. It may be fixed to the specimen by means of resin or other suitable adhesive. The resin can conveniently be applied with an electric soldering iron. A disk of tinfoil, of 5 cm diameter, shall be lightly greased to ensure adhesion and placed on the centre of the other end of the specimen, and the pick-up unit shall be placed with the diaphragm as close as possible to the foil but the pick-up unit shall not be allowed to touch the tinfoil or the specimen. If a variable air-gap exciter is used, this shall be mounted in a similar manner to the pick-up, using a disk of tinfoil. The exciter unit shall be driven by the variable frequency oscillator, and the oscillations received by the pick-up unit shall be amplified by the audio-frequency amplifier and applied to the indicator in such a manner as to show the amplitude of the oscillations received. The frequency of excitation shall be varied until resonance is obtained in the fundamental mode of longitudinal vibration. The frequency shall be recorded as the natural frequency of the fundamental mode of longitudinal vibration.

NOTE — Resonance is indicated by a maximum deflection of the indicator, but several maxima may be obtained, and experience is necessary to know which is the maximum required. Frequencies within ± 10 percent of the expected value, which may be calculated from the formula given in 10.6 should be investigated. Values of the modulus of elasticity range from 1.4×10^6 kg/sq cm for low-quality concretes at early ages to 5×10^6 kg/sq cm for high-quality concretes at greater ages. This represents a frequency range of 125 000/l cycles per second to 225 000/l cycles per second where l is the length of the specimen in cm. It is usually possible to obtain resonance also at the frequency of the first harmonic which is twice the fundamental frequency and these two conditions are normally the most well defined.

10.5 Measurements — The following measurements shall be made on the specimen:

- a) **Weight** — The wet specimen shall be weighed to an accuracy of 0.25 percent.

- b) *Length* — The length of the specimen shall be determined to an accuracy of ± 1 mm, the average being taken of at least four symmetrically placed measurements.
- c) *Depth and Breadth* — The average depth and breadth of the specimen shall be determined to an accuracy of ± 0.2 mm, the average being taken in each case of at least six measurements spaced equally along the length of the specimen.

10.6 Calculation — The density of the wet concrete shall be calculated from the formula:

$$w = \frac{10^6 \times W}{l \times b \times d}$$

10.6.1 The dynamic modulus of elasticity shall then be calculated to the nearest 1 000 kg/sq cm from the formula:

$$E = 4.083 \times 10^{-5} n^2 w$$

where

- E = dynamic modulus of elasticity in kg per sq cm,
 n = natural frequency of the fundamental mode of longitudinal vibration of the specimen, in cycles per second,
 w = density in kg per cu m,
 W = weight in kg of the specimen,
 l = length in cm of the specimen,
 b = breadth in cm of the specimen, and
 d = depth in cm of the specimen.

10.7 Number of Specimens — At least three specimens shall be tested for each age of test.

10.8 Report — The following information shall be included in the report on each specimen:

- identification mark,
- date of test,
- age of specimen,
- curing conditions,
- average dimensions of specimen,
- weight of wet specimen,
- natural frequency of the fundamental mode of longitudinal vibration of specimen, and
- dynamic modulus of elasticity.