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## दृढ़ीकृत कंक्रीट — परीक्षण पद्धतियाँ

भाग 2 बल सामर्थ्य के अतिरिक्त  
दृढ़ीकृत कंक्रीट के अन्य गुण

खण्ड 4 त्वरित कार्बनीकरण पद्धति द्वारा  
कार्बनीकरण प्रतिरोध ज्ञात करना

( पहला पुनरीक्षण )

## Hardened Concrete — Methods of Test

Part 2 Properties of Hardened Concrete  
other than Strength

Section 4 Determination of the  
Carbonation Resistance by Accelerated  
Carbonation Method

( First Revision )

ICS 91.100.30

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## FOREWORD

This Indian Standard (Part 2/Section 4) (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Cement and Concrete Sectional Committee had been approved by the Civil Engineering Division Council.

Testing plays an important role in controlling the quality of cement concrete work. Systematic testing of raw materials, fresh concrete and hardened concrete, is an inseparable part of any quality control programme for concrete. This helps achieve a higher efficiency of the materials used and greater assurance of the performance of the concrete, in regard to workability, strength and durability. The test methods used should be simple, direct and convenient to apply. This standard was formulated with this objective in view.

This standard was first published in 1959. In this revision, it was decided to review and update the various existing test methods of concrete taking into consideration the latest international practices and developments in this field in the country, and also to introduce certain new test methods wherever required. In the process, the various existing test methods covered in IS 516 : 1959 'Methods of tests for strength of concrete' have been revised taking into consideration primarily the corresponding ISO standards while also examining the other best practices world over and in the country. In addition, test methods for determination of additional properties have been included in areas such as permeability, initial surface absorption, corrosion of reinforcement, carbonation of concrete (field test), accelerated carbonation test, and creep of concrete. Also, for better understanding and implementation, some of the other test methods which were spread over in number of other Indian standards have been brought together under the fold of IS 516 as its various parts, such as the splitting tensile strength, ultrasonic pulse velocity test, rebound hammer test, bond in reinforced concrete, and determination of water soluble and acid soluble chlorides. This is with a view to making the standard complete in all respects, and rendering it a comprehensive source of provisions for testing of concrete and reference in other Indian Standards.

In this revision, IS 516 is split into 12 parts. The other parts in the series are:

- Part 1 Determination of strength of hardened concrete
- Part 3 Making, curing and determining compressive strength of accelerated cured concrete test specimens
- Part 4 Sampling, preparing and testing of concrete cores
- Part 5 Non-destructive testing of hardened concrete
- Part 6 Determination of drying shrinkage and moisture movement of concrete samples
- Part 7 Determination of creep of concrete cylinders in compression
- Part 8 Determination of modulus of elasticity
- Part 9 Determination of wear resistance
- Part 10 Determination of bond in reinforced concrete
- Part 11 Determination of Portland cement of hardened hydraulic cement concrete
- Part 12 Determination of water soluble and acid soluble chlorides in hardened mortar and concrete

This standard (Part 2/Section 4) covers the procedure for measurement of carbonation depth by accelerated carbonation test. This is a new test method included in the IS 516 series.

After a period of preconditioning, this test is carried out under controlled exposure conditions using an increased level of carbon dioxide to which the vertical sides of the specimen are exposed. The test results are designed to compare the carbonation resistance of similar concretes, which may be used in the same environmental conditions.

*(Continued to third cover)*

*Indian Standard***HARDENED CONCRETE — METHODS OF TEST****PART 2 PROPERTIES OF HARDENED CONCRETE OTHER THAN STRENGTH****Section 4 Determination of the Carbonation Resistance  
by Accelerated Carbonation Method***( First Revision )***1 SCOPE**

This standard (Part 2/Sec 4) lays down a procedure for evaluating the carbonation resistance of concrete using an accelerated carbonation test. After a period of preconditioning, the test is carried out under controlled exposure conditions using an increased level of carbon dioxide to which, the vertical sides of the specimen are exposed.

The test results are designed to compare the carbonation resistance of similar concretes, which may be used in the same environmental conditions.

**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 edition of the standards indicated below:

<i>IS No.</i>	<i>Title</i>
516	Hardened concrete — Methods of test
(Part 1/Sec 1) : 2020	Testing of strength of hardened concrete, Section 1 Compressive, flexural and split tensile strength ( <i>first revision</i> )
(Part 5/Sec 3) : 2019	Non-destructive testing of hardened concrete, Section 3 Carbonation depth measurement ( <i>first revision</i> )
1199	Fresh concrete — Methods of sampling, testing and analysis:
(Part 2) : 2018	Determination of consistency of fresh concrete ( <i>first revision</i> )
(Part 5) : 2018	Making and curing of test specimens ( <i>first revision</i> )

**3 TERMINOLOGY**

For the purpose of this standard, the following terms and definitions apply.

**3.1 Depth of Carbonation** — Depth as measured using a phenolphthalein solution sprayed on a freshly-split concrete surface.

**3.2 Single Point Carbonation Depth** — Depth of carbonation measured at a single point on a specimen,  $d_{k, \text{point}}$ .

**3.3 Specimen Face Carbonation Depth** — Mean depth of carbonation of a single exposed face of a single specimen,  $d_{k, \text{face}}$ .

**3.4 Specimen Carbonation Depth** — Mean depth of carbonation of a single specimen,  $d_{k, \text{spec}}$ .

**3.5 Mean Carbonation Depth** — Mean depth of carbonation of two specimens,  $d_k$ .

**4 PRINCIPLE**

Two concrete cubes are cast and cured for 28 days in accordance with IS 1199 (Part 5). The two concrete cubes are then conditioned in a laboratory air environment for 14 days prior to sealing the top, bottom, and two opposite side faces. After sealing of all but two faces, the cubes are placed in a storage chamber meeting the conditions specified in 5.4 and having a carbon dioxide level of  $3.0 \pm 0.5$  percent for a period of 70 days. After 70 days of exposure, the cubes shall be split in half, perpendicular to the exposed faces, and the depth of carbonation measured in accordance with the procedure given in 7.

The test under reference conditions takes therefore a minimum of 112 days period that comprises a minimum age of the specimen of 28 days prior to conditioning, a minimum conditioning period of 14 days, and a minimum exposure to increased carbon dioxide levels of 70 days. In case of concretes made with blended cements or having mineral admixtures, extended curing and drying times are allowed and the same should be reported.

If required, additional cube specimens may be cast and used for measurement of the depth of carbonation at exposure periods other than 70 days. Each cube specimen shall be used for testing at one period of exposure only.

When the purpose of the test is to measure the depth of carbonation on the same specimen at more than one exposure period, concrete prisms shall be used.

In this case, two prisms are cast and cured for 28 days in accordance with IS 1199 (Part 5). The prisms are conditioned in a laboratory air environment for 14 days prior to sealing the top, bottom, and two end faces. After sealing all but two longitudinal faces, the prisms are placed in a storage chamber, meeting the conditions specified in 5.4 and having a carbon dioxide level of  $3.0 \pm 0.5$  percent for the overall test period which should be 70 days. After each exposure period, a 50 mm slice is broken from each prism and tested for carbonation depth. After splitting off a slice, the split end faces of the prisms are sealed and the remainder of the prisms returned to the storage chamber.

The specimens, cubes, or prisms shall be positioned with their exposed faces in the vertical position.

## 5 REAGENTS AND APPARATUS

**5.1 Paraffin Wax or Equivalent**, for sealing the non-exposed faces of test specimens.

**5.2** A solution made of 1 g of phenolphthalein powder dissolved in 100 ml solution composed of 70 ml ethanol and 30 ml of de-ionised water.

**5.3 Magnifier and a Gauge**, to measure the depth of carbonation perpendicular to the exposed concrete surface with a precision of 0.5 mm.

**5.4 Storage Chamber with Carbon Dioxide Concentration at  $3.0 \pm 0.5$  Percent by Volume, Temperature at  $27 \pm 2$  °C, and Relative Humidity at  $65 \pm 5$  percent.** Usually, if saturated surface-dry specimens are placed in the storage chamber shortly after removal from water curing, the relative humidity could exceed the permitted value. Also, in storage chambers without active control of carbon dioxide, the levels could drop below the permitted tolerance as the carbonation process continues. It is recommended that the storage chamber shall have active control on carbon dioxide, relative humidity, and temperature (*see Annex A for details of suitable chamber*).

Other levels of carbon dioxide concentration, humidity, and temperature may be used. However, this shall be recorded and reported.

NOTE — Relative humidity levels may be maintained using any method as per the discretion of the laboratory, for example, active humidification/dehumidification or saturated salt solutions.

**5.5** Apparatus for recording the relative humidity and temperature with a precision of  $\pm 2.0$  percent and  $\pm 0.5$  °C, respectively.

**5.6** Apparatus for recording CO<sub>2</sub> concentration with a precision of  $\pm 0.1$  percent by volume.

It is recommended that recording apparatus be fitted with an audio/visual alarm to alert breaches of CO<sub>2</sub> concentration within the storage chamber due to possible apparatus malfunction.

**5.7 Fans**, to facilitate steady circulation of air within the storage chamber.

## 6 PREPARATION OF SPECIMENS

### 6.1 General

Cubes and/or prisms for the determination of the carbonation resistance shall be made in accordance with IS 1199 (Part 5). If the specimens are to be made by a test laboratory, the test laboratory shall be supplied with a full specification of the concrete mix and the mixing procedure. Where the specimens are prepared by the client or their representative, the test laboratory shall be informed of the day of casting and provided with a confirmation that the specimens were stored as required by this standard.

For the determination of the depth of carbonation at any given exposure period, two cube specimens having a cross-section of 100 mm or 150 mm shall be prepared. For the determination of the depth of carbonation at more than one exposure period on the same test specimen, two prisms, 500 mm long and having a cross-section of 100 × 100 mm, shall be prepared. The use of mould release agents should be avoided or minimized, as they might influence the carbonation depth.

### 6.2 Making, Curing, and Testing of Prisms and Cubes

Cast two prisms/cubes from a single batch of concrete for each mix. Before casting, appropriate workability test shall be carried out as per IS 1199 (Part 2). Cast and cure the prisms/cubes as per IS 1199 (Part 5). The specimens shall be stored in water or in a chamber having a temperature in the range of  $27 \pm 2$  °C and a minimum relative humidity of 95 percent. After finishing the prisms/cubes, cover the exposed surface with polythene or similar impermeable sheeting to prevent drying. After  $22 \pm 2$  h, the moulds shall be stripped and the prisms/cubes transferred without delay into a water-filled bath with temperature control set in the range of  $27 \pm 2$  °C.

It is recommended that at least three compressive strength specimens be made and tested in accordance with IS 516 (Part 1/Sec 1) at 28 days.

After removal from the curing tank, the specimens shall be immediately wrapped and sealed in polythene or similar material that will prevent drying during transportation. Alternatively, they should be transported while remaining fully immersed in water, like in a mobile curing tank. On arrival at the test laboratory, the test specimens shall be unwrapped, checked for damage, and then stored in a water-filled curing tank with temperature in the range of  $27 \pm 2$  °C until they are 28 days old.

At an age of 28 days, the prisms/cubes shall be removed from the water bath and transferred for 14 days to a laboratory air drying environment having a temperature in the range of  $27 \pm 2$  °C and relative humidity in the range of  $65 \pm 5$  percent.

Alternative conditioning environments may be used; however, they shall be recorded and reported.

After 14 days of conditioning, the top and bottom longitudinal faces and the two end faces of prisms (or top, bottom, and two opposing side faces of cubes) shall be sealed using paraffin wax or a similar material that will prevent ingress of carbon dioxide and so as to allow carbonation to occur only on the two cast longitudinal surfaces (see Fig. 1A).

Once the prisms/cubes have been sealed, they shall be placed in the storage chamber complying with 5.4. The prisms/cubes shall be positioned in such a way that their exposed faces are vertical and that permits air to circulate freely around the two faces that are to be carbonated (see Annex A).

#### NOTES

1 The purpose of sealing the top, bottom, and end faces is to minimize any corner effect from multi-directional carbonation and also to prevent longitudinal carbonation through the prism/cube.

2 If paraffin wax is used to seal the surfaces, melt it in a temperature controlled crucible and apply to the concrete surface with a paint brush in three equal layers, leaving the wax to set on the concrete between each application.

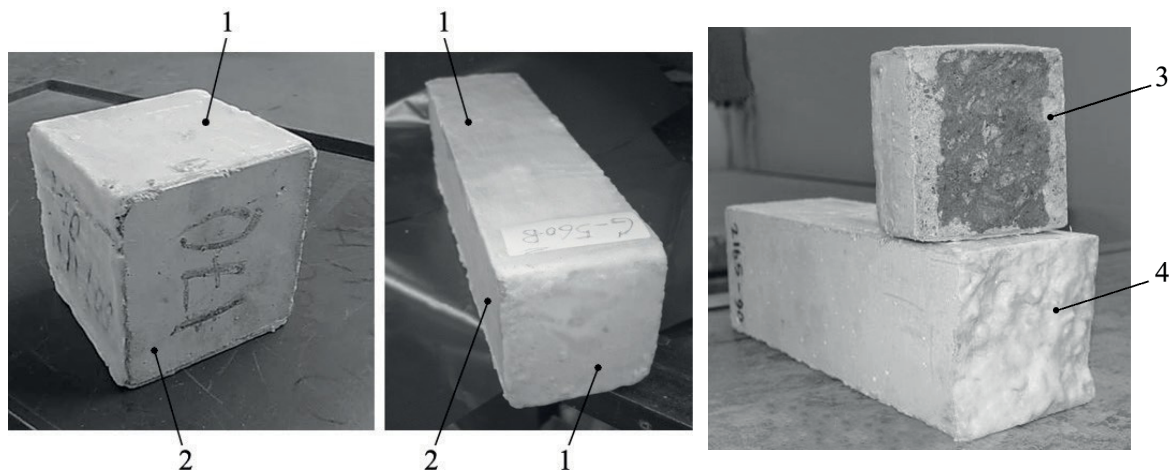
## 7 CARBONATION DEPTH MEASUREMENTS

### 7.1 Exposure Period and Generation of Colour Change

The carbonation depth of prisms shall be measured after the following exposure periods: 56 days, 63 days, and 70 days or as specified after placing in the storage chamber. The carbonation depth of cubes shall be measured at 70 days unless specified otherwise.

Ten single point carbonation depths ( $d_{k, \text{point}}$ ) are measured after each exposure period on each prism or cube and the depth of carbonation  $d_k$  is expressed as the mean of the 20 readings.

A slice approximately 50 mm thick shall be broken off after each exposure period and the split surface on the remaining prism resealed to prevent longitudinal carbonation [see Fig. 1B]. Where a single determination of the carbonation depth is made on a cube after 70 days of storage, the cube shall be split in half. The depths of carbonation on the freshly broken surface of the split slice shall be measured.



1A Sealing Cube and Prism Prior to Placing in Storage Environment for the First Time

1B Sealing of Split End Face of Prism After Removing Slice for Testing Carbonation Depth

#### KEY

- 1 waxed faces
- 2 exposed faces
- 3 concrete slice split and sprayed with phenolphthalein
- 4 prism split and resealed

FIG. 1 SEALING OF PRISM SPECIMEN PRIOR TO AND DURING TESTING



NOTE — The sample shall not be sliced using a saw. A paver cutter or paver slicer may be used.

Clear the broken surface immediately of dust and loose particles after breaking and then spray with a fine mist of indicator solution. Avoid the formation of flow channels on the test surface. If only a weak colouration or none at all appears on the treated surface, spray again after 30 s.

The measurements shall be conducted immediately after the colour has stabilized.

## 8 DETERMINATION OF THE CARBONATION DEPTH

### 8.1 General

The carbonation depth shall be determined by the colour change in accordance with the method given below.

### 8.2 Measuring the Depth of Carbonation

The carbonation depth shall be measured at five points on each exposed face. To locate these points, the edge length shall be divided into six equal distances. The five central points shall be used. With the help of measuring equipment such as vernier caliper, feeler gauge, ruler sliding gauge and a magnifier, the point carbonation depth ( $d_{k, \text{point}}$ ) shall be determined perpendicular to the exposed surface of the prism with a precision of 0.5 mm per measured point.

The depth of the carbonation shall be measured on the one broken face on both prisms giving (normally) a total of at least 20 measurement points.

The corrections for presence of dense aggregate or air voids on the broken face may be applied as per IS 516 (Part 5/Sec 3).

### 8.3 Expression of the Results

The mean depth of carbonation for each exposed face of a specimen ( $d_{k, \text{face}}$ ) shall be calculated and recorded. The mean depth of carbonation for each specimen ( $d_{k, \text{spec}}$ ) shall be calculated and recorded. The arithmetical mean of the mean carbonation depth of

two specimens ( $d_k$ ) at 70 days shall be reported as the carbonation depth of the concrete mix.

Where testing is undertaken on prisms at alternative exposure periods, these shall be expressed as the arithmetical mean of two specimens ( $d_k$ ) at the reported alternative exposure periods.

## 9 TEST REPORT

The test report shall contain the following:

- a) Details of the concrete mixes/grade of concrete, if known;
- b) Reference of the concrete under test;
- c) Date of casting of the specimens;
- d) Date of the start of test;
- e) All measured minimum and maximum carbonation depths of at least 20 points at the reference exposure period of 70 d or the specified exposure periods;
- f) Mean carbonation depth of specimen faces ( $d_{k, \text{face}}$ ), each specimen ( $d_{k, \text{spec}}$ ), and the overall mean ( $d_k$ );
- g) If any, the number of values of  $\Delta d_k$ , point and their magnitude that were not included in the calculation of the mean value;
- h) Any deliberate deviation from the reference conditions or non-conformity with the test conditions, like, any failure to maintain the required carbon dioxide for an identified short period or changes to the preconditioning environment.
- j) The test report may also contain the following:
  - 1) Details of the concrete mixes;
  - 2) Individual test results and relevant photographic records;
  - 3) Results of additional testing, example compressive strength results at 28 d;
  - 4) Any additional comments or observations; and
  - 5) Any accreditation for undertaking the test procedure.

## ANNEX A

( Clauses 5.4 and 6.2 )

## GUIDANCE ON SUITABLE STORAGE CHAMBERS

The features of a typical storage chamber are given in Fig. 2. For the reference conditions, the carbon dioxide content of the air within the storage chamber is required to be  $3.0 \pm 0.5$  percent by volume. When a large number of specimens are placed in a chamber, the carbon dioxide content might fall rapidly and remain below the required levels. For this reason, it is recommended that the carbon dioxide content be controlled and a suitable method is by means of a carbon dioxide injector connected to the chamber to replace carbon dioxide consumed by the carbonation reaction. A suitable apparatus is shown in Fig. 2, 3 and 4. Monitoring of the readings from the carbon dioxide injection equipment shall be carried out on a daily basis. Any deviations from this level shall be reported.

Prisms should be stored either horizontally or vertically. Where prisms are stored horizontally, they should be positioned in such a way to permit the free flow of air to the exposed, unsealed faces of the prism, that is, using spacers cut from 50 mm diameter plastic piping.

It is recommended that spacers should be placed on the sealed faces of the specimens. Prisms should be placed in the storage chamber in a manner that ensures a gap of at least 50 mm between prisms (*see* Fig. 5). A similar gap should be provided between the prisms and the walls.

Mechanical fans (table fans are suitable) shall be positioned within the storage chamber to ensure air circulation. It is recommended that the turbulence be monitored during commissioning of the chamber by means of a smoke generator test or a similar method. The storage chamber shall be tested with both the minimum and maximum number of prisms to be used to ensure adequate air circulation during use.

Experience has shown that if non-standard saturated surface-dry specimens are placed in the storage chamber, the relative humidity could exceed the permitted level. It is therefore recommended that the storage chamber be provided with active control on relative humidity  $65 \pm 5$  percent and temperature  $27 \pm 2$  °C.

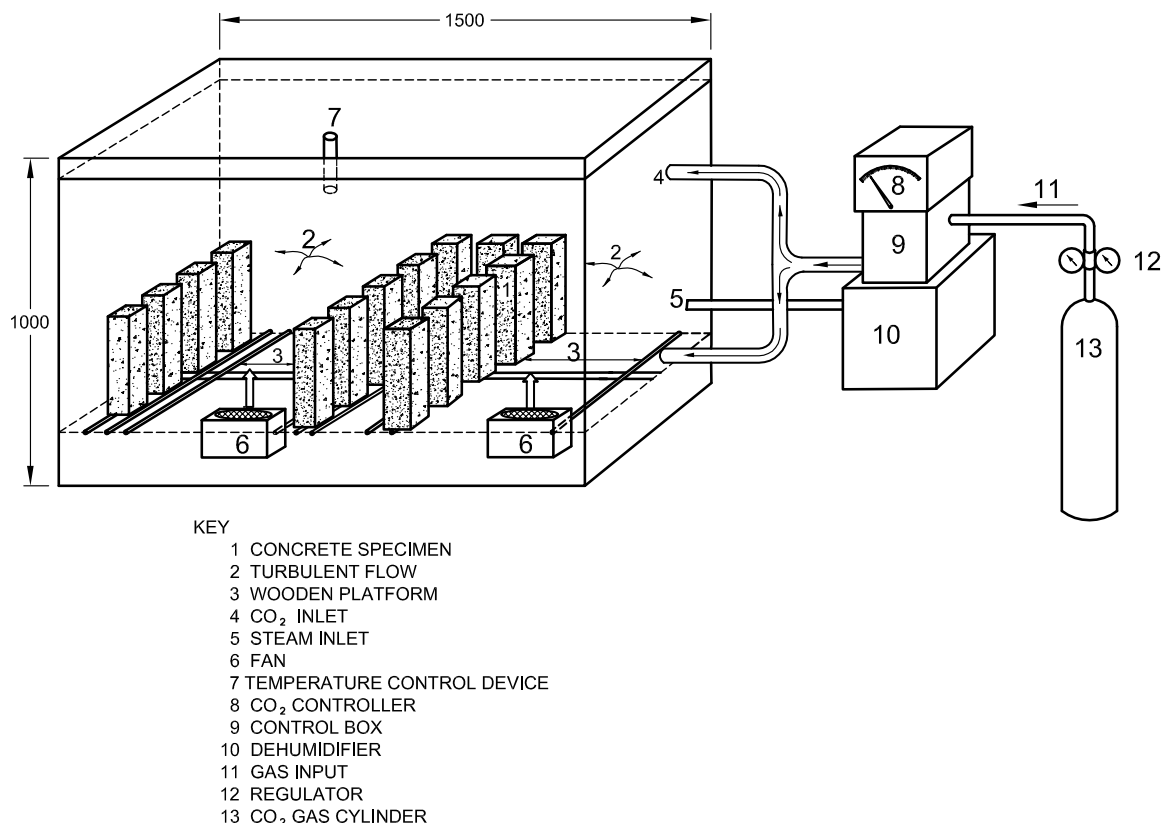
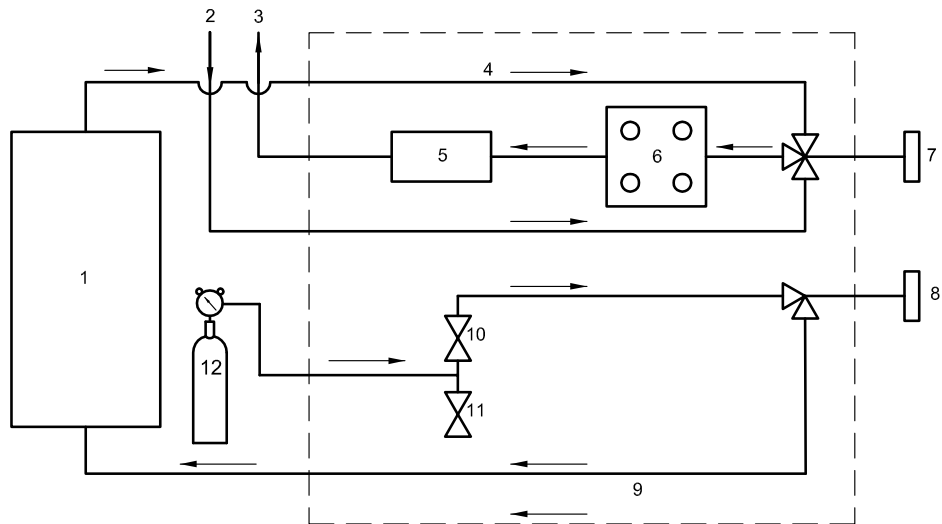


FIG. 2 TYPICAL STORAGE CHAMBER WITH VERTICAL STORAGE



- KEY
- 1 CARBONATION STORAGE CHAMBER
  - 2 ZERO AIR IN
  - 3 SAMPLE OUT
  - 4 SAMPLE IN
  - 5 PUMP
  - 6 THERMAL CONDUCTIVITY DETECTOR
  - 7 SELECTOR VALVE
  - 8 FINE METERING VALVE
  - 9 CO<sub>2</sub> CONTROLLER
  - 10 CO<sub>2</sub> CONTROLLER VALVE HIGH
  - 11 CO<sub>2</sub> CONTROLLER VALVE LOW
  - 12 CO<sub>2</sub> CYLINDER

FIG. 3 SUITABLE SYSTEM FOR CARBONATION DIOXIDE INJECTION AND MONITORING

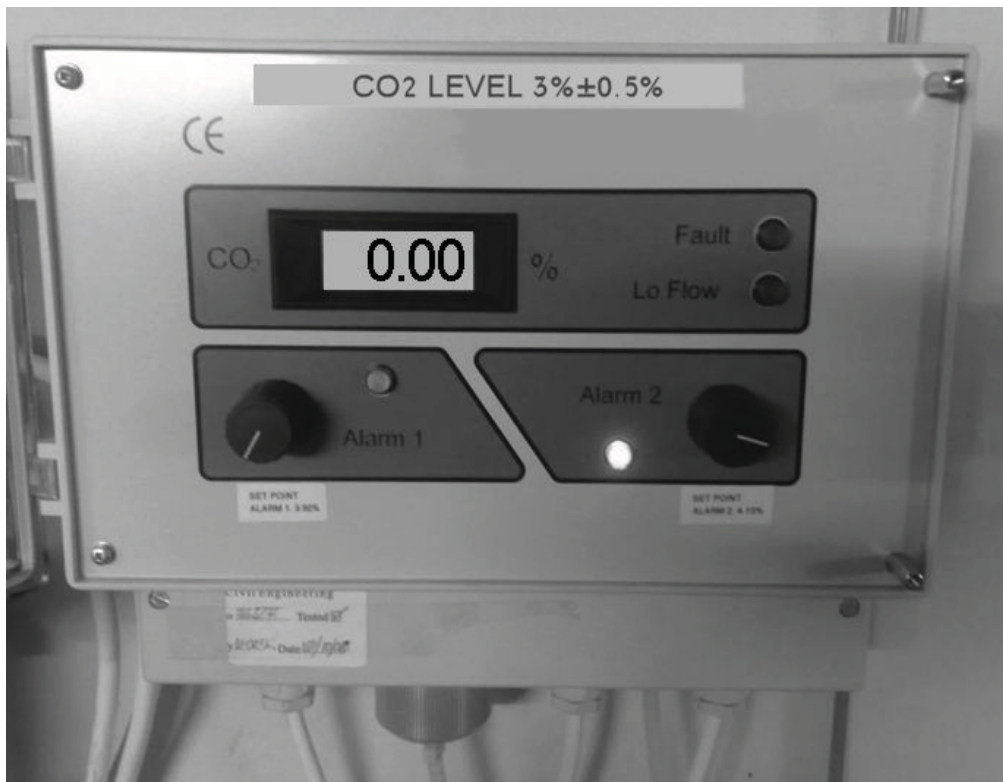
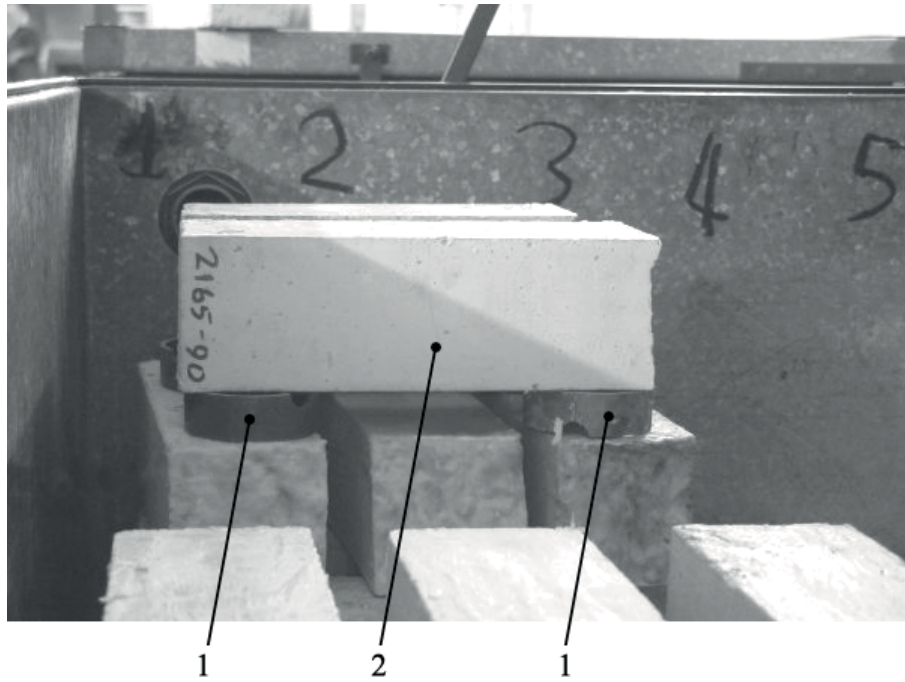


FIG. 4 CARBONDIOXIDE MONITORING/INJECTION APPARATUS





KEY

- 1 50 MM PLASTIC SPACERS
- 2 EXPOSED FACE OF PRISM

FIG. 5 HORIZONTAL STORAGE OF SPECIMENS

## ANNEX B

( Foreword )

### COMMITTEE COMPOSITION

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*(Continued from second cover)*

The test under reference conditions takes therefore a minimum of 112 days period that comprises a minimum age of the specimen of 28 days prior to conditioning, a minimum conditioning period of 14 days, and a minimum exposure to increased carbon dioxide levels of 70 days. In case of concretes made with blended cements or having mineral admixtures, extended curing and drying times are allowed. Details on suitable storage chamber for carrying out this test have also been mentioned.

In the formulation of this standard, assistance was derived from ISO 1920-12 : 2015 Testing of concrete — Part 12 : Determination of the carbonation resistance of concrete — Accelerated carbonation method.

The composition of the Committee responsible for the formulation of this standard is given in Annex B.

In reporting the result of a test or analysis made in accordance with this standard, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values ( *revised* )'. The number of significant places retained in the rounded off value should be the same as that specified value in this standard.

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