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## 13 INSPECTION AND TESTING OF HARDENED CONCRETE

### 13.1 GENERAL

#### 13.1.1 Scope

- 1 This Part of the specification covers the inspection, sampling and testing of hardened concrete.
- 2 Related Section and Parts are as follows:

This Section

Part 6..... Property Requirements

#### 13.1.2 References

- 1 The following standards are referred to in this part of the specification:
  - ACI 214.4R.....Guide for Obtaining Cores and Interpreting Compressive Strength Results
  - ACI 318 .....Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary
  - ASTM C42.....Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
  - ASTM C823.....Standard Practice for Examination and Sampling of Hardened Concrete in Constructions
  - BS 1881-124 .....Testing concrete. Methods for analysis of hardened concrete
  - BS 1881-204, .....Testing concrete. Recommendations on the use of electromagnetic covermeters
  - EN 12350 .....Testing fresh concrete
  - EN 12504-1 .....Testing concrete in structures cored specimens taking, examining and testing in compression
  - EN 12504-2 .....Non-destructive testing. Determination of rebound number
  - EN 12504-3 .....Testing concrete in structures. Determination of pull-out force
  - EN 12504-4 .....Determination of ultrasonic pulse velocity
  - EN 13791 .....Assessment of in-situ compressive strength in structures and precast concrete components
  - ISO 1920-6..... Testing of concrete – part 6: sampling, preparing and testing of concrete core.

#### 13.1.3 Submittals

- 1 The Contractor shall submit to the Engineer his quality assurance procedures for the particular parts of the testing work that will be carried out.
- 2 The Contractor shall submit for the Engineer's approval the curriculum vitae (CV) of the supervisor proposed for the work.
- 3 The Contractor shall through testing agency prepare a factual report that identifies the test methods used and the test results. The report shall also identify any unusual results or pertinent information relating to the testing. The report shall be presented in hard and electronic copies.
- 4 For each of the test results the Contractor shall identify the precision or repeatability of the particular sampling and testing method. This shall be as given from experience of the particular test by the laboratory or as expected from information in the particular test standard.

- 5 In-place tests will be valid only if the tests have been conducted using properly calibrated equipment in accordance with recognized standard procedures and acceptable correlation between test results and concrete compressive strength has been established and is submitted.
- 6 Non-destructive tests shall not be used as the sole basis for accepting or rejecting concrete, but they may be used to "evaluate" concrete when the standard-cured strengths fail to meet the specified strength criteria

#### **13.1.4 Quality Assurance**

- 1 All field and laboratory testing of concrete shall be carried out by an independent laboratory approved by the Engineer.
- 2 The evaluation of concrete in structure is needed when an existing structure is to be modified or redesigned; to assess structural adequacy when doubt arises about the compressive strength in the structure due to defective workmanship, deterioration of concrete due to fire or other causes; when an assessment of the in-situ concrete strength is needed during construction; to assess structural adequacy in the case of non-conformity of the compressive strength obtained from standard test specimens; assessment of conformity of the in-situ concrete compressive strength when specified in a specification or product standard.

#### **13.1.5 Non-Compliance of Work**

- 1 If the 28 d works test cubes as defined in clause 6.6 of this Section fail to meet the minimum criteria, the Engineer shall direct the Contractor to carry out in-place methods to estimate the concrete strength by non-destructive testing, in-situ drilling of concrete cores or load testing.
- 2 The parts or elements of the structure made from the defective batch or batches of concrete as represented by the works test cubes shall be identified by the Engineer and based on this information the Engineer shall instruct the Contractor on the required number and position of concrete cores.
- 3 The Engineer shall review the concrete core test results in conjunction with EN 13791 or ACI 318 whichever is applicable to the structural design.
- 4 Based on this assessment the Engineer shall decide the acceptability of the concrete in the structural element and may either:
  - (a) accept the concrete
  - (b) instruct that certain remedial works are carried out
  - (c) instruct that the element is replaced.

#### **13.1.6 General Fieldwork Requirements**

- 1 The Contractor shall make all arrangements to provide safe stable access to testing locations.
- 2 When gaining access to testing locations and whilst testing the Contractor shall take care not to damage the structure or leave it in an untidy or unclean state.
- 3 The Contractor shall take precautions to ensure that cooling water from concrete coring/other operations is discharged such as not to cause a mess or damage the interior or exterior parts of the structure.
- 4 The Contractor shall be responsible for arranging the water supply required for testing.
- 5 The Contractor shall arrange for a suitable power supplies. Where testing is being carried out on an occupied structure a power supply from the building services may not available and the Contractor shall make arrangements for power supply and extension leads of adequate length.

- 6      The Contractor shall appoint a qualified field supervisor to co-ordinate and manage the field work. The supervisor shall have not less than five years experience of such work.
- 7      Before starting the work, the Engineer with the Contractor's supervisor will mark the positions where field testing is to be carried out. A unique referencing system to identify each sample or testing location will be adopted, and this will either be referenced on sketch plans or drawings or by a detailed description used throughout the report to identify test locations.
- 8      If testing is being carried out on an occupied structure the Contractor shall co-ordinate with the owner or operator of the structure to arrange the detailed programme for the works and gain access to the various parts of the structure.
- 9      As soon as laboratory test results are available these shall be submitted by hand or faxed to the Engineer in draft form. The testing laboratory, or technical bureau assigned by the testing agency, assigned by the contractor shall provide a technical report providing visual information and analysing the tests conducted.
- 10     All core holes, dust sample holes and exploratory investigation areas shall be reinstated with a proprietary non shrink cementitious repair mortar. The preparation of the hole or area before reinstatement shall be carried out as per the recommendation of the repair mortar supplier.
- 11     Before filling any core holes, dust sample holes or exploratory investigation areas, the Contractor shall allow the Engineer time to inspect these areas and obtain written confirmation from the Engineer before filling.

## 13.2 CONCRETE CORES

### 13.2.1 General

- 1      The drilling and testing of cores shall be carried out in accordance with EN 13791 & EN 12504-1, or ISO 1920-6 or ASTM C42 and ACI 214.4 whichever is applicable to the structural design.
- 2      All of the supplementary information listed by the relevant standards shall be included in the test report with photographs of the cores.
- 3      An assessment of in-situ compressive strength for a particular test region shall be based on at least 3 cores. Consideration shall be given to any structural implications resulting from taking cores. The diameter of concrete core shall be at least 100 mm for strength evaluation unless clear spacing of reinforcement is less than 100 mm and approved by Engineer.
- 4      The preferred minimum core diameter is three times the nominal maximum size of the coarse aggregate, but it shall be at least two times the nominal maximum size of the coarse aggregate
- 5      The Engineer will advise the required number and locations of cores. If the results of the initial coring are inconclusive, the Engineer may instruct that further cores be taken at certain locations.
- 6      Unless otherwise directed by the Engineer, the Contractor shall ensure that coring does not cut through any reinforcing steel. The required diameter and depth of concrete cores shall be as stated in table 13.1

Table 13.1

Minimum Depth of Sampling of Concrete for Testing Purposes<sup>1</sup> (ASTM C823)

Types of Construction	Thickness of Section, m	Minimum Depth to Be Sampled, m
Slabs, pavements, walls, linings, foundations, structural elements accessible from one side only	0.3 or less	entire depth
	0.3 or greater	0.3
Suspended slabs <sup>2</sup> , walls, conduits, foundations, structural elements exposed to the atmosphere at two or more sides; concrete products	0.15 or less	entire depth
	0.15 – 0.6	one half the thickness or 0.15 whichever is greater
Massive sections	0.6 or greater	0.6

1 The requirements of table 13.2.1 may not provide the quantities or dimensions of samples that are required for all tests, in that case, the necessary additional quantity of concrete in pieces of appropriate minimum size should be taken at each sampling location.

2 When suspended slabs are cored, it is desirable to leave the lower 25 mm uncored, so as not to lose the core by its falling from the barrel and to make it easier to patch the core hole.

### 13.2.2 Drilling Cores

- 1 Before beginning coring operations the Contractor shall use a proprietary cover meter to identify the position of steel reinforcing bars at the testing location.
- 2 The Engineer may instruct that the core is taken through the concrete without hitting any reinforcement or the Engineer may instruct that the core is taken in a position where it is expected reinforcement will be cut in order to provide a sample of the reinforcement to check its condition. The locations of all drilling points shall be chosen so that the core contains no steel parallel to its length.
- 3 Before capping, the core shall have a length of at least 95 % of its diameter. Once prepared for test the core shall have a length at least equal to the diameter and not more than 1.2 times its diameter.
- 4 Cores of both 100 mm and 150 mm nominal diameters may be tested provided that the aggregate size does not exceed 20 mm and 40 mm respectively. Where possible 150 mm cores should be taken to reduce the variability due to drilling and increase the reliability of the testing, unless reinforcement is congested and the use of 100 mm cores will reduce the possibility that the core will contain steel or it is necessary to restrict the sampling to a length of less than 150 mm.
- 5 Where the size of the section precludes the use of 100 mm or 150 mm cores, smaller cores may be used with the permission of the Engineer.
- 6 During drilling operations, a log of observations that may affect the interpretation of core samples shall be prepared.

- 7 If instructed by the Engineer, immediately after the core has been cut and removed and the structure a carbonation test will be carried out by using a 1 or 2 % solution of phenolphthalein poured over the cut surface. A photograph shall be taken of the cut core with the phenolphthalein solution applied to provide a record of the test.
- 8 If during the drilling of the core, the core collapses due to weak honeycombed or defective concrete, the Contractor shall stop the drilling operation and carry out testing at an adjacent location as advised by the Engineer. If when testing at the second location, the core again breaks due to honeycombed or defective concrete the freshly cut core shall be retained for reference and a note made of the condition.

#### **13.2.3 Testing for Strength**

- 1 The compressive strength of field concrete cores shall be assessed in accordance with EN 13791.
- 2 The details of the concrete core in accordance with EN 13791 shall be recorded and two photographs on either side of the core taken.
- 3 Where there is reinforcement in the core, the size and the type of bar shall be noted along with its cover to the concrete surface, the condition of reinforcing bars shall be noted with a detailed description of any corrosion of the reinforcement.
- 4 Before carrying out the compressive strength testing of the cores, the Contractor shall inform the Engineer to allow him to witness the testing if required.
- 5 Crushed core samples shall be retained by the laboratory and only disposed of after written approval by the Engineer.

#### **13.2.4 Assessment of Strength**

- 1 The estimated in-situ strength of the concrete shall be calculated from the core result using EN 13791, ACI 214.4 or ACI 318 whichever is applicable by the structural design.

### **13.3 REINFORCEMENT COVER MEASUREMENTS**

- 1 The measurement of cover to reinforcing steel and other metallic items in concrete shall be carried out in accordance with BS 1881 Part 204 using an electromagnetic device that estimates the position depth and size of the reinforcement.
- 2 The locations for checking cover and the spacing between measurements shall be advised by the Engineer based on the objective of the investigation. The Contractor shall carry out calibrations of the electric magnetic device for a particular bar size to allow the bar diameter to be measured.
- 3 While testing, the orientation of steel bars shall be checked.
- 4 The electromagnetic device shall incorporate scale or digital display range and shall be calibrated in accordance with BS 1881 Part 204. When calibrated in this manner the indicated cover to steel reinforcement shall be accurate to within  $\pm 5\%$  or  $\pm 2$  mm which ever is the greater over the working range given by the manufacturer.
- 5 The cover meter shall be used in accordance with the manufacturers instructions and checks on the zero carried out as specified.
- 6 The search head shall be traversed systematically across the concrete, and, where reinforcement is located, rotated until the maximum disturbance with electromagnetic field is indicated by the meter.

- 7 The cover to the reinforcement shall be noted along with the axis of the reinforcement. The cover shall also be recorded on the concrete surface with chalk or a suitable non-permanent marking pen.
- 8 Care should be taken to avoid interference from other metallic sources or magnetic material.
- 9 The cover meter checks shall be carried out by an operator with five years experience.
- 10 The test report on cover shall include the following information:
  - (a) date
  - (b) time and place of test
  - (c) description of the structure or component under investigation
  - (d) location of test areas
  - (e) make and type of cover meter used
  - (f) date of last laboratory calibration of cover meter
  - (g) details of site calibration of cover meter, indicated values of cover
  - (h) estimated accuracy of quantitative measurements
  - (i) configuration of steel reinforcement

## **13.4 ULTRASONIC PULSE MEASUREMENTS**

### **13.4.1 General**

- 1 The ultrasonic velocity test equipment shall be capable of measuring the transit time of a pulse vibration through concrete. The length of the pulse part between the transducer equipment shall be measured, and the pulse velocity calculated.
- 2 Ultrasonic pulse velocity testing shall be carried out in accordance with the provisions of EN 12504-4.
- 3 Velocities shall be measured at a number of locations around a structure and a velocity contour of the structure established. A minimum of 40 velocities shall be measured for each structural element.

### **13.4.2 Selection of Test Locations**

- 1 Wherever possible direct transmission arrangements shall be used. The transducers shall be mounted on a specially formed moulded surface.
- 2 The minimum path length shall be 100 mm for concrete in which the nominal maximum size of aggregate is 20 mm or less and 150 mm for concrete in which the nominal maximum size of aggregate is between 20 mm and 40 mm. but the path length shall not be longer than required to detect small regions of bad concrete.
- 3 Where concrete contains steel the pulse velocity shall be adjusted in accordance with the requirement of EN 12504-4.
- 4 Locations that contain reinforcement directly along or close to the pulse paths shall be avoided.
- 5 Where repositioning is not possible the semi-direct transmission measurement, where transducers are placed on adjacent faces of the concrete, may be used.

### **13.4.3 Execution of Tests**

- 1 Positions chosen for the test locations shall be clearly and accurately marked on the surface of the concrete.

- 2 The surface of the concrete shall be cleaned and free from grit and dust. Path lengths shall be determined to an accuracy of  $\pm 1\%$  and a suitable couplant (such as grease) applied to each of the test points.
- 3 Pulse transit times shall be measured by a skilled operator, with a minimum of five years experience in the use of the equipment.
- 4 Pulse velocity measurement equipment shall be in accordance with the requirements of EN 12504-4.
- 5 Test results shall be examined and any unusual readings repeated carefully for verification or amendment.

#### **13.4.4 Estimated In-Situ Cube Strength**

- 1 A correlation shall be established between the cube crushing strength of the particular mix used in the structure and the pulse velocity.
- 2 Where it is not possible to obtain cubes with the same mix design as the original structure a combination of coring and ultrasonic pulse velocity testing may be carried out at the direction of the Engineer, where the cores are used to provide the correlation information required for the interpretation of the ultrasonic pulse velocity tests.

### **13.5 RADIOGRAPHY OF CONCRETE**

- 1 Gamma rays and high energy X-rays, which illustrate by radiographs the concrete defects: The testing shall be carried out in accordance with the requirements of BS 1881-205 or equivalent.

### **13.6 SURFACE HARDNESS**

#### **13.6.1 General**

- 1 Testing of concrete surfaces for hardness using rebound hammers shall be carried out in accordance with EN 12504-2.
- 2 The rebound hammer shall only be used for estimation of concrete strength where a specific correlation is carried out of the concrete from the structure being tested; this shall be from works test cubes or cores taken from the structure.
- 3 The correlation between concrete strength and the rebound number shall be carried out in accordance with EN 12504-2. The precision of the correlation curve between the mean rebound number and strength shall be stated and this shall be used when reporting any strength interpretations from surface hardness readings. The use of general manufacturers' correlation or calibration curve for strength shall not be used.
- 4 It should be noted that the rebound hammer number only provides information on a surface layer of approximately 30 mm in depth of the concrete and that this should be quoted in the test report.
- 5 The rebound hammer maybe used to establish the uniformity of the finish products or similar elements in a structure at a constant age, temperature, maturity and moisture condition.

#### **13.6.2 Method of Test**

- 1 A minimum of 12 readings shall be taken to establish a single surface hardness at a particular location.
- 2 The reading shall be on a regular grid between 20 mm to 50 mm spacing over an area not exceeding 300 mm by 300 mm.

- 3 The mean of each set of readings shall be calculated including abnormally high and abnormally low results unless there is good reason to doubt the validity of a particular reading.
- 4 The coefficient of variation and the standard deviation of the readings shall be reported.

#### **13.6.3 Equipment**

- 1 The rebound hammer shall be a proprietary type that has been used successfully and serviced for a minimum of five years.
- 2 The hammer shall comprise of a mass propelled by a spring that strikes a plunger in contact with the surface.
- 3 The manufacturers' literature shall identify the impact energy and contact area of the plunger for the hammer.

#### **13.6.4 Reporting**

- 1 The test report shall affirm that the hardness was determined in accordance with EN 12504-2 and shall provide the following information:
  - (a) date time and place of test
  - (b) description of structure and location of test
  - (c) details of concrete
  - (d) type of cement
  - (e) cement content
  - (f) type of aggregate
  - (g) type of curing
  - (h) age of concrete
  - (i) type of compaction of concrete
  - (j) forming of surface
  - (k) moisture condition of the surface
  - (l) carbonation state of surface
  - (m) any suspected movement of the concrete under test
  - (n) direction of test
  - (o) any other factors that are considered significant in influencing the hardness readings.
- 2 The details of the rebound hammer correlation with strength including the mean, range, standard deviation and coefficient and variation of each reading shall also be included.

### **13.7 CHEMICAL CONTENT**

#### **13.7.1 Sampling**

- 1 The Engineer shall instruct the depth increments over which the dust samples are to be taken, the types of chemical testing to be carried out and the quantity of sample required.
- 2 The depth of sample shall not be less than the concrete cover to the reinforcement and at least 50 mm from the surface of concrete. In presence of reinforcement, the chemical content shall be tested at least at two levels before and after the depth of reinforcement from the surface of concrete.
- 3 To provide uniform samples of cement matrix and aggregate, three separate holes shall be drilled at one location. The diameter of the holes shall be between 12 and 20 mm.

- 4 Care shall be taken to discard the material from any render or finish unless this is specifically required under the investigation.
- 5 Care shall be taken to ensure that dust increments are accurately measured by marking the drill bit.
- 6 The dust samples increments shall be carefully transferred to plastic bags and sealed to avoid contamination. Each sealed bag shall be uniquely identified by the sample identification and depth increment.

#### **13.7.2 Laboratory Testing**

- 1 Residual split samples of dust from the field investigation shall be retained until the Engineer has reviewed the chloride test results. The Engineer may instruct that repeat tests are carried out on certain samples.
- 2 Chloride testing of concrete dust samples shall be by an acid soluble method in accordance with BS 1881 Part 124. The results shall be reported to two decimal places.
- 3 Sulphate testing of concrete dust samples shall be in accordance with BS 1881 Part 124, using an acid soluble method.

END OF PART