Assessment of in-situ compressive strength class using a minimum number of cores

Chris A Clear *of the* ***British Ready-Mixed Concrete Association*** *– and secretary to the European Technical Standards Task Group (TC 104/SC 1/TG 10) responsible for the revision of EN 13791 – discusses the new Standard and the use of indirect testing in conjunction with selected core test data, and the criteria to confirm that the concrete has conformed to the specified strength class for the test region under investigation.*

BS EN 13791:2019[1] was published under the authority of the BSI Standards Policy and Strategy Committee on 31 January 2020, rapidly following the publication of the associated cored specimen Standard, BS EN 12504-1[2] published on 31 December 2019. As stated in the national foreword to BS EN 13791, all the relevant content of BS 6089:2010 is covered by:
BS EN 13791 and its national annex;
BS EN 12504-1 and its national annex; and
PD CEN/TR 17086[3], which also includes further guidance and additional background.

These revised Standards are useful, as there are times when it is considered necessary to assess the compressive strength class of concrete in case of doubt. BS EN 13791 also covers the estimation of compressive strength for structural assessment of an existing structure, but this is beyond the scope of this article. The standard recommendations should not be used where the supplier has a low level of quality assurance or no documented procedures. Ideally, the supplier should be certified to supply concrete to BS EN 206[4] and BS 8500-2[5] to either the Quality Scheme for Ready-Mixed Concrete or BSI Kitemark Scheme for Ready-Mixed Concrete.

In practical terms, there are three ways to do this in accordance with the main requirements set out in BS EN 13791 Clause 9:

- comparative testing
- using in-situ indirect testing plus selected core test data
- using in-situ core testing.

Using comparative testing is essentially comparing the indirect test results of an accepted concrete element with the results from an element where there may be doubt. This can be very cost effective, as the set up and personnel costs of rebound hammer testing to BS EN 12504-2[6] and ultrasonic pulse velocity testing to BS EN 12504-4[7] are considerably less than core testing. Traditionally, core testing used on its own has been considered the most authoritative method of assessing in-situ compressive strength. But according to the revised Standard to assess volumes of concrete up to 30m^3 it will take at least three core results and then two more core results for each additional 30m^3, such that a volume up to 180m^3 requires 12 core results. This may be considered too onerous for many situations. Where it is feasible to carry out indirect testing before coring, then the number of cores can be minimised to two for up to 30m^3 of concrete and three for up to 180m^3. This is the option considered in greater detail.

Preliminaries

The first stage should be to try and establish from the site and delivery documentation the areas where the concrete supplies of concern were delivered and placed. The next stage is to divide the total area for investigation into regions and volumes, as trying to assess too large an area without sufficient tests will result in an invalid assessment. It will also be useful to complete a visual survey with all parties involved, to ensure that any proposed testing locations are both representative and accessible.

Regions and volumes

In accordance with BS EN 13791, the concrete under investigation shall be divided into regions where each region is no more than 180m^3 of concrete.

Each region shall be further divided into one to six volumes, where each volume is no more than approximately 30m^3 of concrete.

The separation of a region into volumes may be done by simple division into equal volumes. It may be that after consideration of the delivery documentation and site records, including the review of site cube results, it is possible to identify areas of concrete within the region of particular concern where it would be sensible to ensure these are treated as discrete volumes. Where approximately 30m^3 of concrete or less is under consideration, then the region is a single volume, but where around 30m^3 of concrete or less is placed approximately over more than one day, then each day's concrete is a separate volume.

Testing

In accordance with BS EN 13791, indirect testing of site concrete may be either by rebound hammer[4] or UPV[5] in accordance with their respective Standards. Coring is in accordance with BS EN 12504-1 and the additional requirements set out in BS EN 13791, ie, cores shall be ≥75mm diameter and coring shall not be undertaken at a maturity less than 28 days at 20°C. Unless specified otherwise, cores should be kept in a sealed container until strength testing, apart from when they are trimmed to length or the ends capped. As the core results are used to assess concrete normally specified by cube strength, then it is preferable to take cores with a length:diameter ratio of 1. It is worth noting that the permitted range of length:diameter ratio is from 0.90:1 to 1.10, to 1 for 1:1 cores, as no adjustment factors are permitted for cores outside the permitted range.

Assessment of up to 30m^3

Where up to 30m^3 is supplied in one day and needs to be assessed, then an indirect

Table 1 – Summary of indirect testing locations, cores and assessment criteria for a region of concrete[a] up to 180m³

Number of volumes in test region, all <30m³	Minimum total number indirect-test locations for region	Minimum number of 1:1 core results and locations for coring[b]	Assessment criteria[c] Note: Both criteria need to be satisfied for the acceptance of conformity of compressive strength.	
			Mean of core test results at the locations closest to the median rebound number or the mean UPV for the test region.	Lowest core result[d]
1[e]	9	2 cores: One core at each of the two lowest indirect test values for the test region	—	≥ 0.85($f_{ck,spec,cube}$ – M)
2	12	3 cores: One core at the lowest indirect test value for the test region and one core at each of the test locations closest to the median rebound number or the mean UPV for the test region.	≥ 0.85($f_{ck,spec,cube}$ + 1)	
3				
4				
5	20		≥ 0.85($f_{ck,spec,cube}$ + 2)	
6				

a) Requirements where the concrete producer has product conformity certification.
b) Where the core diameter is ≥75mm and the length:diameter ratio from 0.90 to 1.10.
c) $f_{ck,spec,cube}$ = specified characteristic strength in terms of cube strength. '0.85' = EN 1992-1-1[8] factor that accounts for the difference between the design strength obtained by testing specimens taken from a finished structure or element and the value based on standard test specimens.
d) Where M – 4MPa for strength class C20/25 or higher. For C16/20, C12/15 and C8/10 M is reduced to 3, 2, and 1 respectively.
e) Only where the 30m³ is supplied in one day. Where the concrete is supplied over two or more days then each day's volume shall be considered a different volume.

test survey is carried out using a minimum of nine test locations. At each of the two lowest indirect test values, at least one 1:1 core shall be taken and tested in accordance with BS EN 12504-1. The concrete is assessed as conforming if the lowest core result expressed as MPa is:

$$\geq 0.85(f_{ck,spec,cube} - M).$$

M = 4MPa for compressive strength class C20/25 or higher. For C16/20, C12/15 and C8/10, the value for M is 3, 2 or 1 respectively.

Assessment of 30–120m³

Where between 30 and 120m³ of concrete requires an assessment, then an indirect test survey is carried out, where each test location should represent each truck delivery of ready-mixed concrete, but with a minimum of 12 test locations. At least three 1:1 cores are then taken, where one core is at the location of the lowest indirect test value for the test region and one core at each of the test locations closest to the median rebound number or the mean UPV for the test region. The concrete is assessed as conforming if the lowest core result is:

$$\geq 0.85(f_{ck,spec,cube} - M)$$

and the mean of the two or more results from the mean or median locations is:

$$\geq 0.85(f_{ck,spec,cube} + 1).$$

Assessment of 120–180m³

Where between 120 and 180m³ of concrete requires an assessment, then an indirect test survey is carried out where each test location should represent each truck delivery of ready-mixed concrete, but with a minimum of 20 test locations. At least three 1:1 cores are taken, one at the location of the lowest indirect test value and a further two at locations closest to the to the median rebound number or the mean UPV for the test region. The concrete is assessed as conforming if the lowest core result is:

$$\geq 0.85(f_{ck,spec,cube} - M)$$

and the mean of the two or more results from the mean or median locations is:

$$\geq 0.85(f_{ck,spec,cube} + 2).$$

Assessment of more than 180m³

Where more than 180m³ requires assessment, then the separate assessment should be made on each region where the total is divided into regions of 180m³ or less.

A summary of the indirect testing locations, cores and assessment criteria for a region of concrete up to 180m³ is shown in Table 1. ■

References:

1. BRITISH STANDARDS INSTITUTION, BS EN 13791. *Assessment of in-situ compressive strength in structures and precast concrete components*. BSI, London, January 2020.
2. BRITISH STANDARDS INSTITUTION, BS EN 12504. *Testing concrete in structures. Part 1 – Cored specimens. Taking, examining and testing in compression*. BSI, London, December 2019.
3. BRITISH STANDARDS INSTITUTION, PD CEN/TR 17086. *Further guidance on the application of EN 13791:2019 and background to the provisions*. BSI, London, (publication anticipated in 2020).
4. BRITISH STANDARDS INSTITUTION, BS EN 206. *Concrete. Specification, performance, production and conformity*. BSI, London, 2013+A1:2016.
5. BRITISH STANDARDS INSTITUTION, BS 8500. *Concrete. Complementary British Standard to BS EN 206. Part 2 – Specification for constituent materials and concrete*. BSI, London, 2015+A2:2019.
6. BRITISH STANDARDS INSTITUTION, BS EN 12504. *Testing concrete. Part 2 – Non-destructive testing – Determination of rebound number*. BSI, London, January 2013.
7. BRITISH STANDARDS INSTITUTION, BS EN 12504. *Testing concrete. Part 4 – Determination of ultrasonic pulse velocity*. BSI, London, October 2004.
8. BRITISH STANDARDS INSTITUTION, BS EN 1992-1-1. *Eurocode 2: Design of concrete structures. General rules and rules for buildings*. BSI, London, 2004+A1:2014.

Further information:

Further guidance is available from the BRMCA website *www.brmca.org.uk*. Go to the downloads page for a range of extra information.