Estimation of compressive strength for structural assessment of an existing structure

1. Introduction

There are times when it is considered necessary to assess the *in situ* characteristic compressive strength ($f_{ck,is}$) for structural assessment of an existing structure. This guide covers the most practical procedure set out in BS EN 13791 Clause 8, *Estimation of compressive strength for structural assessment of an existing structure*. This determination of the characteristic *in situ* compressive strength for application with EN 1992-1-1.

NOTE 1 BS EN 13791 Clause 9 covers *Assessment of compressive strength class of concrete in case of doubt*. Clause 9 procedures is based on the approach that where concrete is supplied with product conformity certification then the criteria are set at a level where concrete supplied at the required strength class is not rejected. For clause 8 it is assumed there is little or no prior information on the concrete and that the value generated is an estimate of the *in situ* characteristic strength. These different approaches may lead to significantly different outcomes, so it is important not to confuse the two issues. BRMCA Guidance on Clause 9 procedures are in other documents.

In order to ensure a valid assessment, the first task should be to review all the available data and complete a visual survey prior to drawing up a programme of testing. Drawings should be available on which to plot results as this will help identify any patterns that could help minimise additional testing. It is preferable to start with indirect testing as this is both less expensive and destructive than core testing. It is important to try an establish if the structure may be considered a single strength class or if the structure should be considered as regions of different strength classes.

For an assessment of an existing structure, there is no limit on the volume of concrete under consideration, and a minimum of eight ≥ 75 mm diameter cores with length : diameter ratios of either 2:1 or 1:1 are required. It is strongly recommended to obtain at least 10 cores due to the possibility that one or two core results may be rejected e.g. due to excess voidage or reinforcement inclusions.

NOTE 2. BS EN 13791 includes procedures for the use of indirect testing specifically calibrated against core test data taken from the structure under consideration. The standard also covers procedures and requirements for the use of 50 mm diameter cores. Due to the extra consideration required it is these procedures or outside the scope of a concise guide such as this.

2. Testing

Indirect testing where use is either by rebound number in accordance with BS EN 12504-2 or ultrasonic pulse vibration (UPV) in accordance with BS EN 12504-4. Core testing should be carried out in accordance with EN 12504-1 where specimens are stored in sealed containers, apart from when they are either trimmed to length or the ends are capped ready for testing. The density of each core should be determined in accordance with EN 12390-7 and recorded as it is useful when interpreting core results.

Cores with a trimmed length : diameter ratio of 2:1 or 1:1 and a diameter ≥ 75 mm should be used. The permitted range of 2:1 cores is 0,90:1 to 1,10:1 and the permitted range of 1:1 cores 0,90:1 to 1,10:1. Where 1:1 cores are used the core test result is converted to the equivalent value of a 2:1 core using the core length factor (CLF). For normal-weight and heavyweight concrete the CLF for converting a 1:1 core to a 2:1 core is 0,82 unless a different value is justified by testing.

Cores should be free from reinforcement. Where a core contains reinforcement that is arranged perpendicular to the direction of loading, this shall be recorded and evaluated separately. Any core that contains reinforcement in the direction of coring or close to the direction of coring shall be rejected immediately and a further core taken from around same test location.

3. Characteristic *in situ* compressive strength for test regions and small test regions

3.1 Test region

The test regions should be defined, where it may comprise a series of similar elements, one large element or a defined volume associated with a source or time period where this is known. Different concretes should have separate test regions. Where there is little or no information about the concrete strengths in a structure then engineering judgement shall be applied to group elements into test regions, e.g. concrete columns may be a different strength class to concrete in floors. Test results should be checked to see whether they comprise more than one concrete.

A location is where at least one ≥ 75 mm diameter core is taken, at least one UPV measurement or a minimum of nine rebound number tests.

The *in situ* compressive strength values ($f_{c,is}$) are checked to ensure that all values are valid. All valid test results are used to estimate the mean *in situ* compressive strength ($f_{c,m(n)is}$) and the sample standard deviation *s* of the test region in the structure under investigation. To guard against an unrealistically low value of *s* the minimum value should not be less than that equivalent to a coefficient of variation of 8% e.g. *s* shall not be less than 2 MPa for a concrete where the mean *in situ* strength is 25 MPa.

The estimation of the characteristic *in situ* strength is based upon a minimum of eight valid test results of *in situ* compressive strength based on ≥ 75 mm diameter cores of length : diameter either 2:1 or 1:1.

NOTE No method for converting core results other than those for 2:1 and 1:1 cores into an *in situ* compressive strength ($f_{c,is}$) is covered by BS EN 13791.

The characteristic *in situ* strength ($f_{ck,is}$) is the lower of both:

$$f_{ck,is} = f_{c,m(n)is} - k_n s$$

$$f_{ck,is} = f_{c,is,lowest} + M$$

Where:

$f_{c,m,\ (n)\ is}$	Mean value of eight or more valid test results
k_n	Coefficient whose value depend on the number valid results, n, see Table 1.
s	Sample standard deviation of the test result for the region, but not less than that equivalent to a coefficient of variation of 8%.
$f_{c,is.lowest}$	Lowest value of the eight or more test results
M	4 for mean strength ≥20 MPa 3 for mean strength ≥16 <20 MPa 2 for mean strength ≥12 <16 MPa 1 for mean strength <10 MPa

Table 1– k_n values

n	8	10	12	16	20	30	∞
k_n	2.00	1.92	1.87	1.81	1.76	1.73	1.64

3.2 Small test region, 10 m^3

A small test region may be considered one to three elements and a total volume not exceeding approximately 10 m^3. a volume of concrete up to 10 m^3. At least three cores ≥ 75 mm diameter are taken including at least one core from every element in the test region and the *in situ* compressive strengths ($f_{c,is}$) are calculated. Where the core locations represent concrete that will remain in the structure, and where the spread of test results is not more than 15 % of the mean value, the lowest value of three or more cores may be considered *in situ* compressive strength ($f_{ck,is}$) for structural assessment purposes. If the spread of results is more than 15 % of the mean, this is an indication that more information about the test region should be sought.

3.3 Small test region, 30 m^3

Where there are no issues over the compressive strength of the supplied concrete and where indirect testing is used for an initial survey the small test region may be considered as up to approximately 30 m^3 of concrete. The variability and locations of lower compressive strength should be identified with the initial survey. From the locations or location with the lowest indirect test result at least three ≥ 75 mm diameter cores are taken and the *in situ* compressive strength ($f_{c,is}$) calculated. If the core locations represent concrete that will remain in the structure, and provided the spread of test results is not more than 15 % of the mean value, the mean value of three or more cores may be assumed to be the characteristic *in situ* compressive strength ($f_{ck,is}$) for structural assessment purposes.

Where the spread of the test results is higher than 15 % of the mean value, and if an investigation provides a justified reason for rejecting one of the core test results, the *in situ* compressive strength ($f_{ck,is}$) may be taken as being the mean of the remaining valid values.

STANDARDS

BS EN 1992-1-1	Eurocode 2: Design of concrete structures — Part 1-1: General rules and rules for buildings
BS EN 12390-7	Testing hardened concrete — Part 7: Density of hardened concrete
BS EN 12504-1	Testing concrete in structures — Part 1: Cored specimens – Taking, examining and testing in compression
BS EN 12504-2	Testing concrete in structures — Part 2: Non-destructive testing – Determination of rebound number
BS EN 12504-4	Testing concrete in structures — Part 4: Determination of ultrasonic pulse velocity
BS EN 13791	Assessment of in-situ compressive strength in structures and precast concrete components

Enquiries: Chris A Clear, chris.clear@mineralproducts.org