(Photo: Socotec.)

Assessment of in-situ concrete strength – revised BS EN 13791 and BS EN 12504-1

On 14 January 2020, BSI published a revised BS EN 13791[1] Assessment of compressive strength in structures and precast concrete component *(effective from February 2020). This uses the revised BS EN 12504-1[2]* Testing concrete in structures. Part 1 – Cored specimens – taking, examining and testing in compression *published on 9 December 2019.* ***Neil Crook*** *of* ***The Concrete Society*** *looks at the changes.*

Both these Standards have been subject to in-depth review. The revisions are significant and will require changes to the taking and testing of cores and the method by which the data is used to: a) estimate the characteristic in-situ compressive strength of the concrete for existing (unknown/old) structures; and b) assess the compressive strength class where there is doubt over the strength of recently supplied concrete.

The revised BS EN 13791, which supersedes the withdrawn 2007 version, includes a national foreword and annex that covers all the relevant content of BS 6089:2010[3], which is also withdrawn. A new publication PD CEN/TR 17086[4] is anticipated later in 2020 and will include further guidance and worked examples based on BS EN 13791 using in-situ strengths from direct and indirect test methods.

It should be realised that the characteristic in-situ compressive strength $f_{ck,is}$ is not a direct substitute for the characteristic strength f_{ck} for specifying the strength. When using an estimated characteristic in-situ strength for design, a lower partial factor for concrete can be used (minimum 1.3), see BS 1992-1-1:2004 Clause A.2.3[5].

Testing

The main changes to the taking and testing of core samples given in BS EN 12504-1, with its national annex, relate to the procedure for extracting the sample, its storage, preparation and any adjustment to the core strength $f_{c,core}$.

Samples should ideally be at least 75mm diameter but smaller cores are permitted (not less than 50mm) if this is not possible. The number of cores required is increased for small diameters. The diameter of the core should also be at least three times the upper aggregate size used in the concrete.

The assessment of in-situ strength is based on the concrete as it exists in the structure without change to its moisture condition. After extraction, the sample is to be retained in a sealed container until prepared for testing. The water used in the extraction of the core, density measurement and end preparation is not considered to impart

a material change in the overall moisture condition of the specimen.

The samples are prepared by grinding (recommended) or capping to produce a core with a length:diameter ratio of 1:1 or 2:1. Generally, but not exclusively, 1:1 cores of 100mm diameter should be used in cases of doubt (as these reflect the aspect ratio of production and identity test cubes). Estimation of characteristic in-situ strength is based on a 2:1 core, as cylinder strength is used in structural design. A 1:1 core can be converted to an equivalent 2:1 core using the core length factor (CLF) of 0.82 (0.91 in the case of lightweight concrete).

There are permitted limits on the length:diameter ratio:

- for a 1:1 specimen the length to diameter ratio is to be within 0.90:1 and 1.10:1
- for a 2:1 specimen the length to diameter ratio is to be within 1.95:1 and 2.05:1.

Undersized specimens should be rejected; oversized cores trimmed to meet the limits.

Reinforcement reduces the strength of the core and its presence should be avoided if possible. If reinforcement is present, it should be predominantly horizontal to the direction of testing and not more than 2% of the volume of the specimen. In addition, with 2:1 specimens the reinforcement should be contained within 30mm of each end.


(Photo: RSK.)


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Provided that the requirements for moisture containment, length:diameter ratio limits and limits on the presence of reinforcement are met, there is no adjustment to the core strength. If any of these requirements are not met, the values obtained are considered unrepresentative of the true strength of the concrete and should be excluded from the assessment.

Density and excess voidage may be recorded. While there is an accepted relationship between excess voidage and strength, it is not used to adjust the recorded core strength in the assessment. However, high voidage and/or low density values may indicate problems during the execution of the works that have adversely affected the strength obtained.

Assessment of in-situ strength

The structure of BS EN 13791 remains substantially the same as the previous version, with the primary focus to estimate the characteristic in-situ strength for structural design with BS EN 1990[6] and BS EN 1992-1-1[5].

However, substantial changes in the methodology have been made to the procedures to estimate characteristic in-situ strength of an existing structure (Clause 8) based on a 2:1 core strength and for those cases where there is doubt over the compressive strength class of recently supplied concrete (Clause 9). Both applications have a number of common steps but the assessment methods differ and may lead to significantly different outcomes.

Before embarking on a course of in-situ strength determination, the test region, number of test locations, testing procedures and how the results are to be analysed needs to be set out and agreed. The number of valid test results should be sufficient to ensure there is confidence in the strengths obtained and they are representative of the


(Photo: RSK)

region tested. This is particularly important where there is doubt over the strength of recently supplied concrete (Clause 9), as there are many interested parties involved in the production, placement and design of the concrete and structure.

Strength results

The strength results, either directly from cores or indirect test methods, need to be visually assessed to determine if there is evidence that the test region contains two or more concretes. The data should also be checked for statistical outliers; more than two outliers could indicate that the test region comprises more than one compressive strength class. The Grubb test is referenced in BS EN 13791 to determine whether a high or low test result is an outlier. The inclusion or exclusion of an outlier is a matter for engineering judgement.

The estimation of characteristic in-situ compressive strength of existing structures (Clause 8) is based on a minimum of eight valid test results expressed as the strength of a 2:1 core (or from 12 test locations if based on single 50mm-diameter cores). To allow for possible outliers, the number of samples taken should be increased by at least two more than the minimum number of valid results required. The standard deviation is calculated and compared against a coefficient of variation with the greater value used. The characteristic in-situ strength of the test region is estimated as the lower value of two formulas, one based on the mean of the valid test results and the other based on the lowest valid test result. A procedure is also given for the estimation of characteristic in-situ strength based on indirect testing, calibrated against core data taken from the structure under consideration.

For the purposes of structural assessments (Clause 8) of the in-situ strength of a small test region comprising one to three elements and not more than $10m^3$, at least three valid test results are required. For a test region not greater than $30m^3$, indirect testing in conjunction with at least three valid core test results can be used.

For the assessment of compressive strength class of concrete in case of doubt (Clause 9), the main source of doubt normally arises from low strength of identity test samples, lack of samples or problems during execution of the works. In the previous Standard, a test region was defined as a region comprising many batches or a small region comprising one or a few batches of concrete. The volume associated with each region was undefined. This had been a matter of controversy and was recognised by the drafting committee. Consequently, in the revised Standard the concrete under investigation is still split into test regions but each test region is limited to a total volume of approximately $180m^3$. It is then broken down into volumes of approximately $30m^3$, which might align with the lots (defined volumes) used for identity testing (BS EN 206 Annex B[7]). If less than $30m^3$, it may be treated as a single volume, provided the concrete was supplied on a single day and there was no information to suggest that one of the loads is different to the others. 'Approximately' is used to allow for a small increase in the volume of a part load.

The minimum number of valid test results for each test location and the criteria to confirm that the concrete has conformed to the compressive strength class based on the specified characteristic strength $f_{ck,spec}$ for the test region under investigation is given in BS EN 13791 Table 8 (see Table


(Photo: Socotec.)

Table 1 – Criteria for assessment based on core test data only

Number of approximate 30m³ volumes in test region	Minimum number of valid test results	Mean of 1:1 core test results for the test region	Lowest 1:1 core test result[a]
1[b]	3	–	≥ 0.85 ($f_{ck,spec,cube}$ – M)
2	4	≥ 0.85 ($f_{ck,spec,cube}$ + 1)	
3	6		
4	8		
5	10	≥ 0.85 ($f_{ck,spec,cube}$ + 2)	
6	12		

[a] where M = 4MPa for compressive strength class C20/25 or higher.
For C16/20, C12/15 and C8/10 the margin M is reduced to 3, 2 and 1 respectively.
[b] provided it is treated as a single volume.

1 above). Logically, to allow for possible outliers, it is recommended that the number of specimens taken is at least one more than the minimum indicated for a single volume of approximately 30m³, increasing to two more than the minimum number for total volumes greater than approximately 30m³.

Where practical, the core should be the same length:diameter ratio as the specimens used for conformity by the producer. In the UK, this would be a 100mm-diameter core having a length to diameter ratio of 1:1 (ie, a length to diameter ratio in the range 0.90:1 to 1.10:1).

If both criteria are satisfied, the concrete can be accepted as having conformed to the specified strength class for the test region under investigation.

Procedures are also given for 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. This procedure will be described in a forthcoming article entitled 'Assessment of in-situ compressive strength class using a minimum of cores' by Chris Clear of MPA–British Ready-mixed Concrete Association (BRMCA).

The UK national annex gives a procedure for comparative testing in the case of doubt, where recently supplied concrete under investigation used in one or more elements is compared against concrete in elements that have been accepted using indirect testing.

If a producer declares a non-conformity in respect to strength, Clause 9.5 lists information the producer must supply to the involved parties, which may necessitate an estimation of characteristic in-situ compressive strength (Clause 8). This can then be used in structural design with an appropriate partial factor for concrete. However, if the purchaser expresses doubt over the strength – and subsequent assessment to Clause 9 shows that conformity with the declared strength class cannot be confirmed – this does not necessarily indicate that the concrete production was non-conforming. The production process may be conforming, albeit to a lower strength class and different design parameters would then be applicable.

Concrete Advice 68[8] goes into greater detail and explanation of the changes to the Standards. It provides examples on the use of core data in the determination of estimated characteristic in-situ strength of an existing structure and the assessment of strength class in the case of doubt of recently supplied concrete. A webinar to watch and guides on the subject, produced by BRMCA, is available at: *www.brmca.org.uk/downloads*. ■

References:

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