Guidance on the assessment of strength in structures

Workshop 4 March 2010

Hong Kong

Three standards

- BS EN 13791: Assessment of strength in structures and precast concrete components
- BS EN 12504-1: 2010: Testing concrete in structures- Part 1: Cored specimens – Taking, examining and testing in compression
- BS 6089: 2010: Assessment of in-situ compressive strength in structures and precast concrete components – Complementary guidance to that given in BS EN 13791

Starting point

- BS 6089 as this gives guidance on planning an investigation
- However in cases of dispute over concrete quality, start with CIRIA C519: *Action in the case of nonconformity of concrete structures*
- This may lead to an assessment of in-situ strength, in which case follow BS 6089

Identify purpose of investigation

- See flowcharts in BS 6089:2010, 5.1
- Pre-planned conformity of in-situ strength
- Assessment of old structures
- Disputes over the quality of the supplied concrete or workmanship on site
- Concrete has been declared as nonconforming by the producer

Steps in the process

- For each of these four purposes, BS 6089, 5.1 provides a flowchart that:
  - Gives the steps in the process;
  - Identifies options;
  - Identifies where relevant information is given.

Decide method of structural assessment

- Core testing only
- Indirect methods, e.g. Rebound hammer, UPV, calibrated against core data (minimum 9 pairs)
- Indirect methods with at least 4 cores that are used to:
  - Determine the average strength of a lot, or
  - Determine the lowest strength of a lot
- Relative testing using indirect methods

Decide method of structural assessment

- Based on equivalent cubes?
- If so, specify any cores as having a length to diameter ratio of 1:1
- Based on equivalent cylinders?
- If so, specify any cores as having a length to diameter ratio of 2:1

Acceptance of test data

- See BS 6089: 2010, 5.3
- Agree validity of the testing procedure
- Testing to be undertaken by an accredited laboratory?
- Agree procedure for interpreting the data
- Agree treatment of more than one core at each test location
- Agree criteria for acceptance, if appropriate

Criteria for acceptance

- Two equally valid principles:
- Does the concrete conform to its specification?
- In this case, the criteria are:

$f_{m(n),\,is} \geq 0.85(f_{ck} + 1.48\sigma)$

and

$f_{is,\,lowest} \geq 0.85(f_{ck} - 4)$

Criteria for acceptance

- Other equally valid principle
- Is the structure strong enough?
- In this case, structural codes will be applied, e.g. BS EN 1992-1-1:2004, Annex A
- Such methods make allowance for test data from the structure, but use 'f_{ck}' and not (f_{ck} -4)
- Usually, but not always, the two principles give the same result

Select test regions and test locations

- Test regions have to be identified when:
  - Testing old structures
  - Relative testing
- Old structures have to be assessed on a case-by-case basis
- Try to avoid mixing concretes of different strengths into the same region
- Assess indirect test data before finalising core locations

Test locations

- See BS 6089: 2010, 5.5
- When coring avoid highly stressed areas, rebar and prestressing steel
- Covermeter check prior to coring is strongly recommended
- Test locations will depend upon the purpose of the investigation

Test locations

- Core after cutting to length should not contain:
  - Concrete within 50mm of any surface
  - Concrete within 50mm or 20% of the top of lift where section height $\leq$ 1.5m
  - Concrete within 300mm of the top of a lift for depths of lift >1.5m

Number of test locations

- BS 6089: 2010, 5.6
- BS EN 13791 recommends minimum numbers of test locations for various procedures
- BS 6089 does the same for procedures not covered by BS EN 13791
- BS 6089 recommends a minimum of 4 cores, but with some procedures, BS EN 13791 recommends only two test locations

Solutions to this issue

- Take two cores at two test locations. Test for outliers then combine the pairs of cores into a two results
- Take a single core at four test locations
- Four cores are essential if a determination of potential strength is to be undertaken

Test locations for relative testing

- Use equivalent locations in the elements that are acceptable and those under investigation
- Select 20 pairs of test locations
- See BS 6089:2010, 6.4 for analysis
- Use established statistical principles if more than 20 pairs of test locations are selected

Core strengths

- Prior to coring, agree the target length to diameter ratio, either 1:1 or 2:1
- Take, prepare and test the core in accordance with BS EN 12504-1
- Note that BS EN 13791,7.1 requires cores to be laboratory air-cured for at three days prior to testing
- Such curing will enhance the core strength

Core strengths

- Consequently, BS 6089, 5.4 permits the strength of cores that have been tested immediately after water curing to be enhanced by 10% to 12% (10% is recommended)
- Strongly recommended that the BS EN 13791 procedure is followed

Core strengths

- The measured core strength is given the notation f_{is}
- The UK NA to BS EN 12504-1 gives corrections for the length: diameter ratio and transverse reinforcement (from CSTR11)
- When applied the result is $f_{is,\ corrected,\ cube\ or\ cyl}$
- Note: No correction for the direction of drilling
- Core report should include f_{is}, $f_{is,\ corrected,\ cube\ or\ cyl}$ and the estimated voidage for each core

Core strengths

- The set of core data should be assessed for statistical outliers using the procedure given in BS 6089:2010, 6.1
- The procedure can be applied more than once
- If the outlier is not a valid result, e.g. it was cracked, the outlier is not included in any further analysis
- Aim is to identify parts of the structure that need special consideration and to establish the reason for the outlier

Core strengths

- BS 6089:2010, 6.1 provides guidance on including or rejecting an outlier from the data analysis
- Outliers are not included in any assessment of potential strength
- Valid data are then used in the analysis

Disputes over concrete quality

- Procedures and rules given in BS EN 13791, clause 9 with complementary guidance in BS6089, clause 7
- Engineer interested in two questions:
  - Did the concrete conform to its specification?
  - Is the structure strong enough?
- As the structure is being tested, its strength depends upon both the quality of the supplied concrete and the workmanship on site

Disputes over concrete quality

- A clear answer to the second question is relatively easy
- Showing conformity to the concrete specification is also relatively easy (but note that the null hypothesis is that the concrete conformed)
- When the concrete in the structure is shown not to conform, the commercial question of who pays has to be resolved

Disputes over concrete quality

- Engineer is advised not to get drawn into this issue
- This is where the voidage measurements on the cores is useful. These data can be used to establish how well the concrete was compacted
- The effects on strength of poor compaction are given in BS6089, A.3

Disputes over concrete quality

- If the effects of voidage are insufficient to establish responsibility for low in-situ strength, the potential strength may be determined (see BS 6089, Annex A)
- 'Very difficult' to quantify the different factors that have to be taken into account when determining the potential strength
- Best avoided