

## Assessment of compressive strength class of recently supplied concrete using comparative testing

Where a concrete is under investigation, and it is in one or more of a series of elements where there is no doubt about their strength class, then indirect testing may be used as a non-destructive method of assessing comparative strength in accordance with BS EN 13791. Indirect testing may either be by rebound hammer in accordance with BS EN 12504-2 or UPV in accordance with BS EN 12504-4.

For this type of relative testing it is essential to have sufficient data for a valid comparison from both the concrete under investigation and concrete where there is no doubt about its strength class. The concrete where there is no doubt about its strength class is called the reference concrete.

Ideally the reference element should have a similar maturity to the element under investigation or be more mature as the significance effects of maturity reduces significantly after 28 days. It is also preferable that for each region the formwork was removed at about the same age and that subsequent curing was similar. The statistical test is a simple application of Student's t-test, where the  $t_{calc}$  statistic is calculated from the measured results and this value compared with limits for the 95% confidence interval.

For rebound number or UPV results it is reasonable to assume they are distributed normally, and a minimum of 20 results from the reference concrete and a minimum of 20 results from the concrete under investigation is enough. For 20 results from each region the degrees of freedom is 38, and  $t_{.025}$  is 2.024 so the value of  $t_{calc}$  should be in the range from -2.024 to +2.024.

$t_{calc}$  is calculated:

$$t_{calc} = \frac{\bar{x}_r - \bar{x}_s}{\sqrt{\frac{s_r^2 + s_s^2}{n}}} \quad \text{Equation [1]}$$

Where:

- $n$  number of results in each set
- $\bar{x}_r$  is the mean of the  $n$  indirect testing results from the reference concrete
- $\bar{x}_s$  is the mean of the  $n$  indirect testing results from the concrete under investigation
- $s_r$  is the sample standard deviation of the indirect testing results from the reference concrete
- $s_s$  is the sample standard deviation of the indirect testing results from the concrete under investigation

For twenty results from each region where  $t_{calc}$  is within the range -2.024 to +2.024 then there is a 95% probability of no significant difference between the two sets of results, that is the reference concrete and the concrete under investigation are very likely to be of the same strength class. Where  $t_{calc}$  is outside the range -2.024 to +2.024, or where there is no region of concrete that can be used as a reference then it will be necessary to do further testing.

An example of relative testing using rebound hammer is shown in Annex A.

## STANDARDS

- 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

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**Annex A. Example of comparative strength by indirect testing**

A wall was cast on 28 June 2012 and site cubes indicated a strength of only 53.2 MPa, a strength lower than the run of other site cubes for the same concrete on the same project. It was decided to investigate and so the concrete placed on 28 June 2012 was designated region A. A reference region was also agreed for the same type of wall and concrete but cast on 26 June 2012 where the site cubes gave 72.5 MPa, and this designated region B. Tables A.1 and A.2 are the rebound number results for region A and B, respectively. The rebound number was measured at 20 locations on each wall, remembering that a rebound number result is the median value of at least nine readings.

**Table A.1 Rebound hammer results for region A placed on 28 June 2012, site cubes 53.2 MPa**

Test position	Individual rebound readings - R										Median R
1	43	44	47	48	48	46	44	47	48	45	47
2	45	46	45	50	45	45	46	48	48	45	46
3	40	45	44	44	43	42	48	44	45	44	44
4	44	44	42	42	46	44	44	45	42	43	44
5	49	48	48	48	46	47	48	50	52	47	48
6	44	44	43	48	45	44	46	48	48	46	46
7	48	48	47	46	49	44	46	44	45	47	47
8	50	44	46	45	45	44	45	48	44	46	45
9	40	43	42	42	42	42	42	40	42	42	42
10	44	45	50	44	50	53	54	47	52	47	49
11	44	44	42	44	45	46	44	43	42	42	44
12	42	43	43	45	41	41	40	42	44	44	43
13	44	44	44	44	44	44	44	44	43	44	44
14	44	44	45	44	42	44	46	42	46	44	44
15	42	42	42	43	42	44	43	44	44	44	43
16	44	43	44	48	43	46	44	44	42	42	44
17	40	39	38	40	42	43	43	42	39	41	41
18	44	44	42	44	45	50	48	44	44	46	44
19	48	45	44	48	46	44	44	45	44	48	45
20	46	45	46	42	44	46	45	46	41	45	45
Mean											44.58
Sample standard deviation											1.91

**Table A.2 Rebound hammer results for region B cast on 26 June 2012, site cubes  
72.5 MPa**

Test position	Individual rebound readings - R										Median R
1	44	44	46	46	44	44	45	44	46	44	44
2	46	42	42	42	43	47	45	44	46	43	44
3	45	45	46	44	46	44	44	47	43	49	45
4	40	43	44	40	42	45	42	38	38	38	41
5	44	40	45	44	44	43	44	42	42	43	44
6	47	45	46	44	45	45	46	45	44	44	45
7	46	53	45	46	45	46	48	50	47	48	47
8	46	48	45	45	46	45	46	45	46	45	46
9	45	46	54	44	45	48	48	47	47	44	47
10	45	44	45	48	48	44	47	44	45	45	45
11	47	44	44	43	46	46	43	45	47	43	45
12	46	48	48	45	44	46	48	45	47	44	46
13	44	44	44	44	46	44	46	45	47	48	45
14	45	46	44	48	44	44	44	44	48	43	44
15	44	43	44	46	47	44	46	45	44	44	44
16	44	43	44	44	43	44	44	44	44	44	44
17	45	47	48	46	46	42	45	46	44	45	46
18	46	44	44	43	50	48	46	46	44	44	45
19	43	43	46	46	44	45	47	48	51	46	46
20	46	44	44	46	46	47	44	46	44	45	46
Mean											44.73
Standard deviation											1.27

Using the Table A.1 and A.2 values for  $\bar{x}_r$ ,  $\bar{x}_s$ ,  $s_r$  and  $s_s$  in equation [1] then:

$$t_{calc} = \frac{(44.73 - 44.58)}{\sqrt{\frac{1.91^2 + 1.27^2}{20}}}$$

$$t_{calc} = -0.29$$

Where -0.29 is well within the -2.024 to 2.024 range and so there is a 95% probability that there is no significant difference between the strength class of the reference concrete and the concrete under investigation.