Strength characteristics for the structural assessment of existing concrete structures

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Summary

For the assessment of the in situ compressive strength when there is doubt about the strength in existing structures EN 13791 is applied. For assessing the structural safety of existing structures, however, the method given in EN 13791 seems not to be applicable and may lead to an unsafe approach for determining $f_{ck,cube}$.

In this paper a method is presented for determining the characteristic concrete strength obtained from in situ cored cylinders for the assessment of the structural safety of existing structures. The method is based on EN 1990 (Eurocode *Basis of Design*) and has been validated by experimental results of almost 200 existing concrete structures in the high way road network in The Netherlands. From the results of these tests it is confirmed that the method given in EN 13791 overestimates $f_{ck,cube}$. Nevertheless a substantially higher strength may be expected for existing concrete structures compared to the design strength.

Next, the results of the material tests on cored cylinders have been adopted for estimating a reliable strength value for comparable structures for which no core drilling test results are available. Taking into account uncertainties, this results in lower estimates for $f_{ck,cube}$ for such structures. Nevertheless, it is found that the strength for assessing the structural safety is still higher than adopter in the original design.

Keywords: concrete bridges, compressive strength, in situ, cores, experiments, probabilistic analyses, reliability

1. Introduction

For determining the in situ compressive strength of existing structures when doubting the actual compressive strength EN 13791 applies. For assessing the structural safety of existing structures, $f_{ck,cube}$ can be determined according to clause 5.2. of EN 1990 (Eurocode *Basis of Design*).

In the method based on EN 1990, $f_{ck,cube}$ is obtained from the minimum of two values: A) the strength based on the measured test results including the statistical uncertainty and B) the strength based on the mean values of the measured test results and a minimum, constant standard deviation s_{min}. This is a safe approach. Based on a lognormal strength distribution, the characteristic concrete compressive strength is then obtained from the lowest value of:

method A: $$f_{ck,cube} = \exp\left\{f_{cm,cube}(Y)\right\} \cdot \exp\left\{-t_{n-1}(p=0,05)\cdot s(Y)\cdot\sqrt{1+\frac{1}{n}}\right\} \quad (1)$$

and

method B: $$f_{ck,cube} = \exp\left\{f_{cm,cube}(Y)\right\} \cdot \exp\left\{-1,64\cdot\sqrt{\ln\left(1+\left(\frac{s_{min}}{f_{cm,cube}}\right)^2\right)}\cdot\sqrt{1+\frac{1}{n}}\right\} \quad (2)$$

In which $f_{ck,cube}$ is the in situ cube concrete compressive characteristic strength;

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$f_{cm,cube}(Y)$	is the mean of the natural logarithm of the in situ measured strength values;
$f_{cm,cube}$	is the mean of the in situ measured strength values;
n	is the number of tested cores;
$s(Y)$	is the standard deviation of the natural logarithm of the measured values;
s_{min}	is a minimum value for the standard deviation
t_{n-1}	is the value of t_{n-1} according to the *student-t* distribution.

For determining the value of the constant, minimum standard deviation s_{min}, the test results of cores from existing structures have been studied. Similar types of structures or structures that are equally produced may serve as a solid basis for determining s_{min}. From the results, the following values for s_{min} are suggested for the different construction types: s_{min} = 10 N/mm^2 for in situ cast structures; s_{min} = 12 N/mm^2 for in situ prefabricated structural elements and s_{min} = 8 N/mm^2 for structural elements that have been prefabricated in a factory

2. Results

The results are summarized in Fig. 1. In the figure $f_{ck,cube}$ is plotted for each structure. The results are ordered in magnitude and per type of structure that is considered. The dotted horizontal lines ($f_{ck,cube;5\%}$) indicate the strength that is advised as a lower estimate for structures from which no core test results are available.

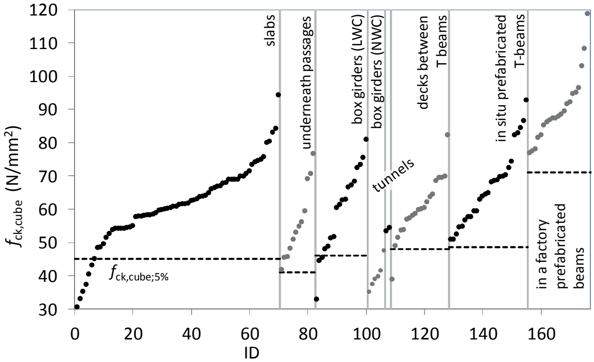

Fig. 1: $f_{ck,cube}$ for all tested structures. The dotted lines indicate the lower estimate for structures from which no cores are drilled and tested

From the results in Fig. 1 it may be concluded that the concrete strength has increased enormously over the years. For the in situ cast elements (slabs, underneath passages, tunnels, box girder bridges, decks between T-beams) the average strength class is minimum C45/55 (except for the light weight box girder bridges) . For the in situ prefabricated T-beams a mean strength class of C55/67 is found, whereas for the beams that are prefabricated in the factory a strength class of average C95/88 is found.

When taking into account uncertainties for structures that have been designed, constructed and maintained by the Dutch Ministry of Infrastructure and the Environment and from which no cores were drilled, a strength class C35/45 is suggested for all structures that are cast in situ. For beams that are prefabricated in factory conditions a strength class of C53/65 is suggested. The suggested lower bounds are indicated by the dotted lines in Fig. 1.

3. Conclusions

In this paper a method is presented for determining the characteristic concrete compressive strength ($f_{ck,cube}$), according to EN 1990. From the results of tests representing almost 200 existing structures in The Netherlands it is confirmed that the method given in EN 13791 overestimates $f_{ck,cube}$. Nevertheless, a substantially higher strength (compared to the design strength) may be expected for existing concrete structures. For structures from which no core drilling results are available a lower bound is suggested, but still a higher value is found compared to the design strength.