Influence of concrete strength fractile estimation on the safety level of existing structures assessed using the Adjusted Partial Factor Method

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Summary

In case of existing concrete structures, the estimation of the characteristic strength values from limited data is a difficult, but important task. There are currently different assessment methods available, among which the classical coverage method, a Bayesian procedure with vague prior distributions (as mentioned in EN 1990) and the method described in EN 13791. With respect to the assessment of existing structures, the authors have developed and investigated an Adjusted Partial Factor Method, which is compatible with current Eurocodes, but additionally enables to incorporate alternative target reliability levels and reference periods and also additional information based on e.g. on-site inspection data and data from testing. In this contribution the influence of the different fractile estimation methods on the safety level of concrete structures is investigated, considering the Adjusted Partial Factor Method. The performance of the different estimation methods are evaluated and compared using Monte Carlo simulations and FORM analyses.

Keywords: existing structures, concrete, assessment, partial factors, safety level

1. Fractile estimation methods

In case of concrete structures, the estimation of the characteristic strength values from limited data is a difficult, but important task when assessing the performance of existing structures. There are currently different assessment methods available in literature, namely the classical coverage method, a 'Bayesian procedure with vague prior distributions' which is also incorporated in the European Standard EN 1990 and the European standard EN 13791.

These estimation methods inherently result in an additional uncertainty with respect to the parameters of probabilistic models used in risk analyses and as such these phenomena are important to consider when comparing the risk-based performance of partial factor methods for existing structures. Although specifically applied to concrete strength, this contribution provides an original framework for combining the performance of estimation methods and structural risk analyses, which can also be used for other structural parameters which have to be assessed when dealing with existing structures.

2. The Adjusted Partial Factor Method

The basic philosophy of the Adjusted Partial Factor Method consists of calculating an adjusted partial factor $\gamma_{X,exist}$ for existing structures, considering alternative values for the reference period t_{ref}, the target reliability index β and the coefficient of variation δ_X of the variable under consideration. For a given variable X this partial factor is established by simply multiplying the partial factor γ_X as provided in the Eurocodes for new structures by an adjustment factor ω_γ, i.e.:

$$\gamma_{X,exist} = \omega_\gamma\left(t_{ref},\beta,\delta_X\right)\cdot\gamma_X \tag{1}$$

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Considering the Simplified Level II method, equations can be suggested for the adjustment factor ω_γ. Consequently a set of easy-to-use graphs can be generated, which is an importance advantage for the practical applicability of the proposed design format by practitioners.

3. Influence of fractile estimation on the safety level of existing structures

A thorough investigation of the numerical performance of the different estimation methods was previously performed by the authors. In the current contribution the influence of the fractile estimation of concrete strength on the structural reliability of concrete columns is assessed using FORM analyses.

In order to establish a probabilistic model for the estimation error in case of the different estimation methods (in order to include this additional uncertainty in the reliability analysis), Monte Carlo simulations are executed. The classical coverage method and the estimation method according to EN 1990 result in a safe estimation of the characteristic strength, which however is becoming rather conservative in case only a few samples are used for the estimation. On the other hand, the method according to EN 13791 yields an overestimation of the characteristic concrete strength. In case of the latter method, however, the variability of the estimation error is smaller (due to the independence from the sample standard deviation in case less than 15 test results are used).

Further, also the adjustment factor for concrete strength is dependent on the estimated coefficient of variation. Similar Monte Carlo simulations are executed in order to establish a probabilistic model and consequently, the mean and standard deviation of the adjusted partial factor for concrete strength is approximated.

Considering lognormal distributions for ζ and $\gamma_{c,exist}$ (with derived characteristics as previously described), a FORM analysis is performed in order to investigate the influence due to the concrete strength estimation from test samples on the structural safety. The results are visualized in Fig. 1 in case of a target reliability index for existing structures of 3.1.

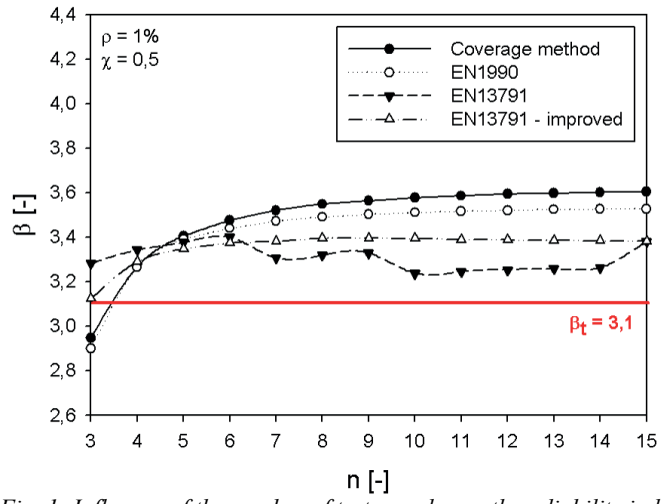

Fig. 1: Influence of the number of test samples on the reliability index of a short concrete column subjected to compression (in case $\delta_c''/\delta_c' = 1$, $\rho = 1\%$, $\chi = 0{,}5$)

The performance of the classical coverage method and the EN 1990 method are comparable and yield a higher safety level when more than 5 test samples are considered. However, in case only very few concrete samples are used for the assessment (i.e. less than 5), the EN 13791 yields a higher safety level, mainly due to the reduced variability with respect to the estimation error. Further, the analysis also showed that for the investigated situation, taking more than 8 test samples into account does not lead to an increase in safety level.