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ASSESSMENT OF MODEL UNCERTAINTIES IN THE ANALYSIS OF REINFORCED CONCRETE STRUCTURES

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Abstract: *Numerical methods of structural analysis enable consideration of material and geometrical non-linearity of reinforced concrete structures. While the effect of variability of materials and geometry can be relatively well described, the model uncertainty is not yet well understood. The present contribution is, therefore, focused on resistance model uncertainties in the analysis of reinforced concrete structures. Simple engineering formulas (beam models, section-oriented approaches) as well as complex numerical solutions are considered. To facilitate practical applications the partial factors for the model uncertainties related to various types of the analysis are derived using the design value method.*

Keywords: ***Model uncertainties, reinforced concrete structures, partial factors.***

1. Introduction

Recent development in structural design of concrete structures reflects advances in the fields of material engineering, reliability theory, structural mechanics and numerical methods of structural analysis. These advances provide exact tools for the reliability assessment of structural resistance in engineering practice. Previous studies indicated that structural resistances could be predicted by appropriate modelling of material properties, geometry variables and uncertainties associated with an applied model. In particular better description of model uncertainties seems to be needed. The submitted study is, therefore, aimed at the model uncertainties with a particular focus on the analysis of reinforced concrete structures. Statistical characteristics of the model uncertainties are summarized from data available in scientific literature considering simple engineering formulas (beam models, section-oriented approaches) as well as complex numerical solutions based on FE methods.

2. Definition of the model uncertainties

According to JCSS (2006) the model uncertainty is generally a random variable accounting for effects neglected in the models and simplifications in the mathematical relations. Commonly the following definition of the model uncertainty θ, considered here as a random variable, is acceptable:

$$R = \theta \, \mathrm{R}_{\mathrm{model}}(\mathbf{X}) \tag{1}$$

where R denotes the response of a structure (actual resistance); $\mathrm{R}_{\mathrm{model}}$ the model resistance; and $\mathbf{X}$ is the vector of basic variables. In deterministic reliability verifications the partial factor γ_{Rd} is applied to describe the model uncertainty.

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Tab. 1: Statistical characteristics of the model uncertainties and model uncertainty factors γ_{Rd}

Failure type	Mean	CoV	γ_{Rd}
Axial compression	1	0.05	1.05
Bending	1.1	0.1	1.05
Shear without stirrups	1	0.2	1.3
Shear with stirrups	1.7	0.35	0.9
FE analyses	1	0.2	1.3

3. Statistical characteristics of the model uncertainties

An extensive review of available literature yields the statistical characteristics of model uncertainties given in Tab. 1 that can be used as a first approximation in the absence of additional data. The uncertainties are related to basic resistance models provided in EN 1992-1-1 (2004) as well as FE analyses. In addition the model uncertainty factors derived using the design value method in accordance with EN 1990 (2004), are provided in Tab. 1.

4. Concluding remarks

Description of the model uncertainties is a crucial problem of the design of reinforced concrete structures. The following concluding remarks can be drawn from the present study:

1. The model uncertainty should always be clearly associated with an assumed resistance model.
2. The model uncertainty should cover the following aspects (if relevant): simplifications of known physical principles, approximations inherent to numerical methods, influence of different interpretations of users of complex software tools and related errors.
3. Relationship between the model uncertainty and resistance obtained by the model can be multiplicative or additive or combination thereof; in common cases the multiplicative form is acceptable.
4. As a first approximation uncertainties related to sectional-oriented models provided in EN 1992-1-1 (2004) as well as to FE calculations can be described by the models given in Tab. 1.
5. However, the present experimental data are insufficient and inconclusive for establishing the model uncertainties for FE calculations.

Further research activities should focus on differentiation of the model uncertainties with respect to the level of the model and complexity of the task. For existing structures uncertainties of degradation models should be specified.

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