Reliability assessment of Slender Concrete Columns at the stability failure

Alfred Strauss[1] Vladimír Benko[2] Benjamin Täubling[3] and Adrián Valašík[4] *

[1] *Department of Civil Engineering and Natural Hazards, Universität für Bodenkultur*
Peter-Jordan-Straße 82, 1190 Wien, Österreich
e-mail: alfred.strauss@boku.ac.at

[2] *Faculty of Civil Engineering, Slovak University of Technology in Bratislava,*
Radlinského 11, 810 05 Bratislava, Slovakia
e-mail: vladimir.benko@stuba.sk

[3] *Department of Civil Engineering and Natural Hazards, Universität für Bodenkultur*
Peter-Jordan-Straße 82, 1190 Wien, Österreich
e-mail: benjamin.taeubling@students.boku.ac.at

[4] *Faculty of Civil Engineering, Slovak University of Technology in Bratislava,*
Radlinského 11, 810 05 Bratislava, Slovakia
e-mail: adrian.valasik@stuba.sk

Abstract

The European Standard for designing concrete columns within the use of non-linear methods shows deficiencies in terms of global reliability, when the concrete columns fail by the loss of stability. The buckling failure is a brittle failure which occurs without warning and the probability of its formation depends on the columns slenderness. Experiments with slender concrete columns were carried out in cooperation with STRABAG Bratislava LTD in Central Laboratory of Faculty of Civil Engineering SUT in Bratislava. The following article aims to compare the global reliability of slender concrete columns with slenderness of 90 and higher. The columns were designed according to methods offered by EN 1992-1-1: which are: a general non-linear method and methods based on nominal stiffness and nominal curvature. The mentioned experiments were used as basis for deterministic nonlinear modelling of the columns and subsequent the probabilistic evaluation of structural response variability. Final results may be utilized as thresholds for loading of produced structural elements and they aim to present probabilistic design as less conservative compared to classic partial safety factor based design and alternative ECOV method.

Keywords: Probabilistic assessment, Nonlinear modelling, Slender concrete columns, Stability failure, Reliability analysis

1. Introduction

The European Standard for designing of concrete columns offers three methods for taking second order effects into account: a method based on nominal curvature, method based on nominal stiffness and general nonlinear method. Stability failure of slender concrete columns can occur before reaching the design resistance in the critical cross-sections. In such cases, it would be appropriate to define the partial reliability factor for stability failure of compression member because partial coefficients of materials could not yet be applied and contribute to ensuring the overall reliability of the design. In the European standardized regulations the recommended partial safety factor for stability failure can be found only in the Austrian National Annex [1].

2. Experimental program

The experimentally verified concrete slender columns were designed in such a way that the columns collapse due to stability loss inside the interaction diagram, i.e. before achieving the design resistance in critical cross-section with approximate compressive strain in concrete εc1 = 1,5 ‰ (Benko et al., 2016). Cross-section is rectangle with dimensions 240 x 150 mm, while overall length of specimens is 3840 mm. The shape and reinforcement of columns is depicted on Figure 1.

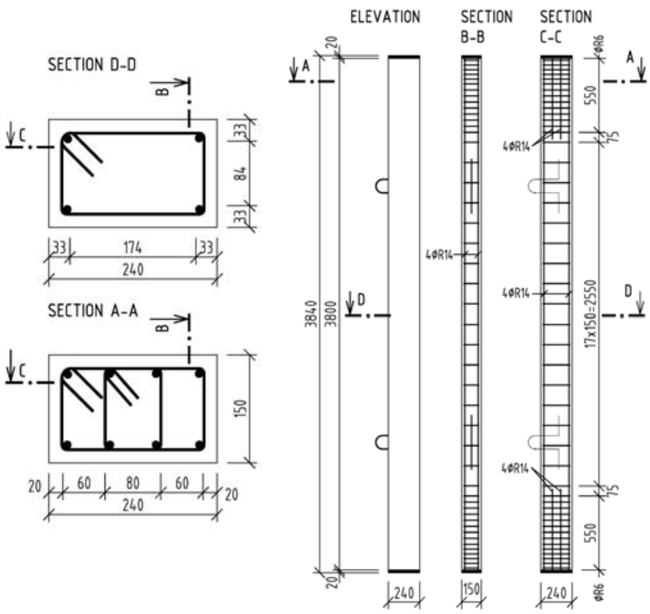

Figure 1: Dimensions and scheme of reinforcement of specimens [2], [4]

Test samples were tested in Central Laboratory of Faculty of Civil Engineering STU in Bratislava.

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3. The Reliability of tested columns

Figure 2 represents comparison of results for design methods according EN 1992-1-1. The slenderness of the columns was λ = 89 and initial eccentricity e1 = 40mm. Results obtained through non-linear calculations calibrated to mean values of material characteristics acquired from experiments are marked with a dash-dotted line (Chap. 5.7(4)). Axial force at stability loss has value of 306,5 kN. Using characteristic values of materials properties, it has value of 279,9 kN, while using design values of material characteristics it is 240,0 kN.

Maximal resistance calculated with the method based on nominal stiffness is 208,0 kN. This value represents intersection between stiffness curve and design interaction diagram. Maximal resistance calculated with the method based on nominal curvature is 153,0kN [1].

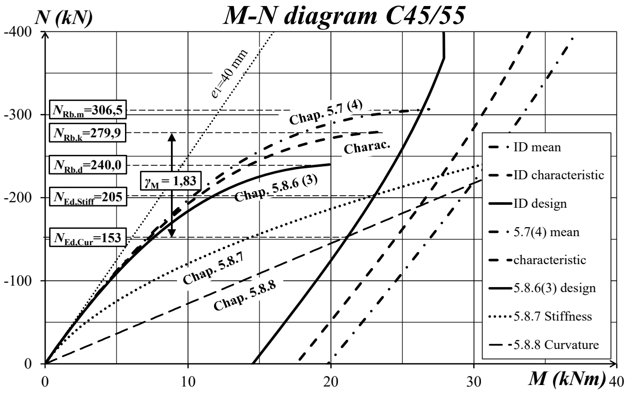

Figure 2: Reliability of the columns by stability loss

Table 1. Comparison of the reliability of columns with slenderness λ=89 and initial eccentricity e_1=40mm.

overall reliability to the characteristic values of material properties			Axial force [kN] design	characteristic	γ_F Load	γ_M material	γ_o overall
-	-	characteristic	279.9	-	1.40	1.00	-
Section	5.8.6(3)	design	240.0	171.4	1.40	1.17	1.63
Section	5.8.7	stiffness	205.0	146.4	1.40	1.37	1.91
Section	5.8.8	curvature	153.0	109.3	1.40	1.83	2.56

Table 1 shows partial factors of reliability for the materials, loads and also overall factor of reliability [1].

4. Probabilistic Analyses

The goal of the probabilistic analysis was to be able to estimate the statistic variability of the Normal-Moment capacity of discussed slender columns and to propose probabilistically based design values or resistances. For the purpose of stochastic analysis the Software environment SARA Science by Cervenka Consulting were used. Stochastic model of concrete was based on data presented in Strauss et al. (2014), Zimmermann et al. (2014) and Routil et al. (2014) obtained by ANN based identification Lehký et al. (2014).

Figure 3 shows the results of one of five calculation series as Normal force – moment diagram (in this case 30 generated samples and mean value sample).

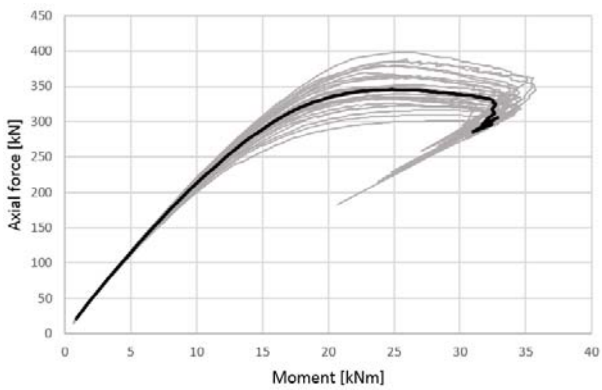

Figure 3: 2D Model (Series 1) - N-M Diagram

Figure 4 compares the results of the fully probabilistic approach, the standard calculation of structural response using partial safety factors and also an estimation of the design values utilizing the ECOV Method (Holický 2006).

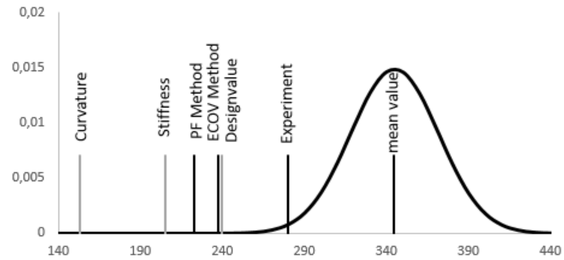

Figure 4: PDF of applied force at ultimate limit state

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