21st International Conference **ENGINEERING MECHANICS 2015**
Svratka, Czech Republic, May 11 –14, 2015
Paper **#072, pp. 34–35**

Assessment of Cast-Iron Structures

Ivan Brych[a]*, Miroslav Sýkora[b]

CTU in Prague, Klokner Institute, Šolínova 7, Prague 6, 166 08, Czech Republic

[a] ivan.brych@klok.cvut.cz, [b] miroslav.sykora@klok.cvut.cz,

Keywords: cast-iron columns, material characteristics, cross-section characteristics, imperfections, ultimate strength, slenderness, brittleness in tension, model uncertainty

Abstract: The paper focuses on the assessment of cast-iron columns in industrial heritage structures. For cast-iron structures it is difficult to verify metallurgical composition and processing technology, which directly affect the geometry of cross-sections. The crucial issue of reliability of cast-iron structures is their brittle fracture in tension at higher slenderness ratios. The load carrying capacity of columns is determined by their stability and cast-iron strengths in compression and tension. Outcomes of several computational methods, including the procedure recommended in ČSN ISO 13822, are compared with extensive experimental data and model uncertainty is identified. Unknown input parameters for the model proposed by Rondal and Rassmussen [1] that fits best to the data are then validated. The validated model is in a good agreement with experimental data and provides conservative estimates of load carrying capacity. The study provides suggestions to complete the calculation of buckling coefficient contained in ČSN ISO 13822.

Introduction

The study is focused on reliability assessment of cast-iron columns that were in the 19th and 20th century used in industrial structures including textile factories, railway stations, shelters of platforms and bridges. Eurocodes provide no methodology that would reflect specific characteristics of cast iron - a non-linear stress-strain diagram without obvious yield stress and significant differences between compressive and tensile strengths. Behaviour of cast iron is close to aluminium or stainless steel. A simplified procedure indicated in ČSN 73 0038:2014 (Czech national annexes to ISO 13822:2010 for assessment of existing structures) and analytical models proposed in [1,2] for the assessment of cast-iron columns are compared.

Considered models

Assessment of existing structures should be based on real geometrical properties of structural members. For cast-iron structures it is difficult to identify metallurgical composition and technological process that directly affect the geometry of structural members. The primary issue in determining the resistance of cast-iron structures in compression is their brittle fracture without plastic deformation for higher slenderness ratios. Stability affected by geometrical imperfections and compressive and tensile strengths determines the load-bearing capacity of cast-iron columns. The imperfections result from a commonly unknown process of casting such as hand casting or forging. That is why cross-sections often have inner eccentricities and different wall thicknesses due to casting in a horizontal position. Moreover, axis of cast-iron columns is typically deviated.
The study critically compares the following models for estimating load-bearing capacity of cast-iron columns centrically loaded in compression:

- *Approach 1* [1] determines the ultimate strength σ_{ult} for a column susceptible to buckling as a minimum value of ultimate compressive strength $\sigma_{\mathrm{ult,c}}$ and ultimate tensile strength $\sigma_{\mathrm{ult,t}}$ (tension strength playing a role for slender columns); $\sigma_{\mathrm{ult}} = \min(\sigma_{\mathrm{ult,c}}; \sigma_{\mathrm{ult,t}})$.
- *Approach 2* [2] is similar to the design method for columns exposed to buckling according to EN 1993-1-1:2006. The ultimate compressive strength $\sigma_{\mathrm{ult,c}}$ takes into account buckling by a coefficient χ_c dependent on slenderness ratio and specified buckling curves, and eccentricities of cross-sections; $\sigma_{\mathrm{ult}} = \sigma_{\mathrm{ult,c}}$.

- *Approach 3* is based on the recommendations of ČSN 73 0038. The ultimate strength σ_{ult} is obtained considering a modified buckling coefficient χ_{c} covering effects of slenderness ratio and recommended strength of cast iron σ_{u}, and the procedure indicated in EN 1993-1-1 for steel structures; $\sigma_{\mathrm{ult}} = \chi_{\mathrm{c}} \times \sigma_{\mathrm{u}}$.

Model uncertainty

The considered models are compared using model uncertainly θ. Its individual values are obtained as the ratio of test and model values, $\theta_i = \sigma_{\mathrm{ult,\ test,}\ i} / \sigma_{\mathrm{ult,\ model,}\ i}$. Basic information on the available database of tests and model uncertainty characteristics for *approach 1* is provided in Tab. 1 [1].

Tab. 1: Test database [1] and model uncertainty characteristics for *approach 1*

Cross-section	Sample size	Slenderness ratio	Column strength [MPa]	Model uncertainty - mean	Coefficient of variation
Solid cylindrical	50	26 – 242	14.8-537	1.09 - 1.2	0.05 - 0.14
Hollow cylindrical	18	50.8 - 242	31.9-186	1.12	0.11
Square	4	153.8 - 204	24.2-43.6	1.43	0.08

Model outcome based on *approach 2* is compared with an individual test result - hollow cylindrical column with complete cross-section characteristics and effective length of 3050 mm; model uncertainty is $\theta_i \approx 1.18$. *Approach 3* is compared against a test result of a column shown in Fig. 1. The column consists of four parts with different cross-sections; the effective length is 6650 mm. For the middle part of the column (hollow cylindrical cross-sections) the model uncertainty is $\theta_i \approx 0.648$; for the upper part (square cross-sections) a conservative estimate is obtained, $\theta_i \approx 1.47$.

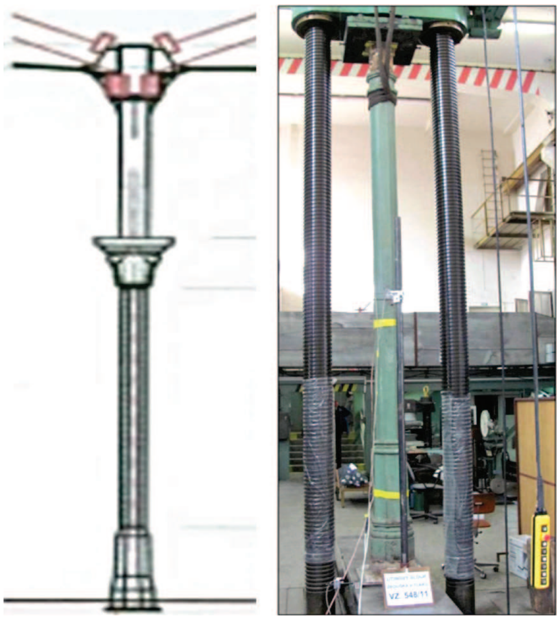

Fig. 1: Example of cast-iron column - scheme and test assembly

Conclusions

The ultimate strength σ_{ult} of cast-iron columns is significantly affected by the slenderness ratio. Critical comparison of the selected models reveals that the *approach 1* is in a good agreement with the experimental data. *Approach 2* also provides a good estimate, however comparison with more test results is needed. *Approach 3* is overly conservative due to overestimation of buckling effects. The study will be extended to provide background information for improving the technique recommended in ČSN 73 0038.

Acknowledgement: The study is a part of the research project NAKI DF12P01OVV040 supported by the Ministry of Culture of the Czech Republic.

References

[1] J. Rondal, K.J.R. Rasmussen, On the Strength of Cast Iron Columns. Journal of Constructional Steel Research 60 (2004) 1257–1270.

[2] S. Heyde, J. Lindner, Investigations on Historic Grey Cast-Iron Columns. Technical University Berlin, Department for Steel Structures, Berlin, Germany (2008).