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Load Carrying Capacity of Steel Arch Reinforcement Taking into Account the Geometrical and Physical Nonlinearity

Petr Janas[a], Lenka Koubová[b], Martin Krejsa[c,*]

VSB–Technical University of Ostrava, Faculty of Civil Engineering, Department of Structural Mechanics, Ludvika Podeste 1875/17, 708 33 Ostrava–Poruba, Czech Republic

[a]petr.janas@vsb.cz, [b]lenka.koubova@vsb.cz, [c]martin.krejsa@vsb.cz

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Abstract: The paper deals with the calculation of the load carrying capacity of the steel arch reinforcements of underground and mine workings respect for the resulting large displacement and physical nonlinearities. Solution is based on the application of the so-called effective bending stiffness, which is defined as a function of the normal forces and bending moment. The results of the numerical analysis are compared with the values of the load carrying capacity, which have been experimentally obtained using strain-stress test of mining reinforcement. The computational procedure was also applied to software that allows you to very effectively calculate the load carrying capacity of steel arch reinforcements.

Introduction

Steel arch reinforcements are mounted usually from special rolled profiles. They are designed to have a sufficient plastic reserve and withstand large displacements. These profiles are significantly more complex from a geometric point of view than the profiles applied in steel constructions of buildings and civil engineering structures. This fact does not count in the EC3 [4] - profiles of steel arch reinforcements cannot be correctly classified in the relevant cross-section class according to this standard.

Therefore, attention was also the inclusion of the TH-29 profile to the corresponding cross-section class during the development of steel H500M in the framework of the project TA CR TA01010838 for the arch reinforcement specified particularly for the mining and underground construction [3]. The basis for this classification were mathematical modelling and bending tests.

Modelling of bending tests of this profile as well as whole sets of steel arch reinforcement is based on the knowledge of effective bending stiffness of this profile. The effective bending stiffness is a function of the bending moment and normal force. For clarity of its expression it should be expressed as a function of the relative rotation dφ considering the variable value of axial forces [1]. The effective bending stiffness was derived from the results of the modelling using the finite element method.

The rotating capacity of cross-section is evaluated for its classification. This rotating capacity shall be determined according to the relation:

$$R = (\varphi - \varphi_{pl})/\varphi_{pl} \, . \tag{1}$$

The angle φ_{pl} is the rotation of the pin supported beam under three-point bending test on the increasing part of the function $\varphi = F(M)$ for the value of the bending moment $M = M_{pl}$. The rotation φ for the same value of the bending moment is the value on the decreasing part of the chart (refer with: Fig. 1).

The value of rotating capacity R for the cross-section classification in class 1 is not fixed in EC 3 [4]. The comment to the American AISC LRFD [5] gives the value $R = 3$ for cross-section class 1, while Japanese AIJ LSD [6] gives $R = 4$.

The values of R for the TH-29 profile of the steel H500M were intended for modelling of bending tests and experimentally as well. Rotating capacity of the profile according analysis is sufficient for inclusion in cross-section class 1 and is substantially greater in the load profile at its root - profile is more stable. This fact is reflected in the curves of the effective bending stiffness. Their validity was confirmed by the good agreement between results of mathematical modelling of the mining reinforcements under the load [2] and the experimental load tests.

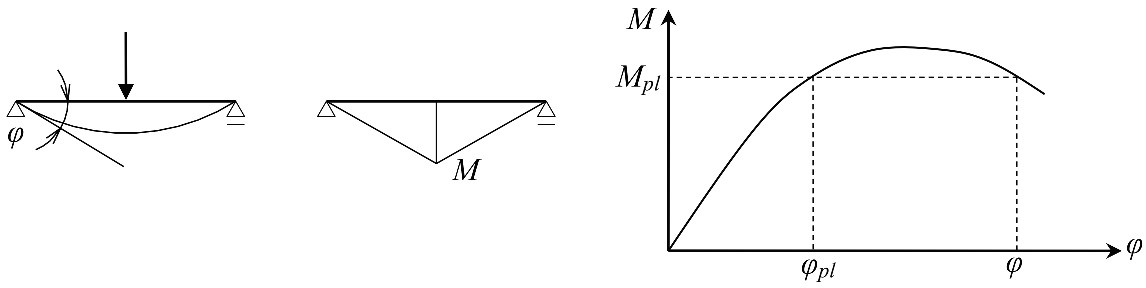

Fig. 1: Scheme of bending tests and the curve of bending moment and rotation

The software titled *Calculation of Load Carrying Capacity of Steel Arch Reinforcements of Corridors from the TH-29 Profile and TH-34 Profile of Steel H500M (31Mn4) – VÚOOVCH TH29/H500M and TH34 TH29/H500M* was developed as utility for the operative calculations of yielding and unyielding steel arch reinforcement with the focus to the resulting load carrying capacity in accordance with EC3 [4]. Alternatively it can be determined also for the higher value of limit bending moment when the load is applied on the root of the profile (for details see [8]).

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