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DEPENDENCY OF ELASTIC MODULUS AND STRESS REDISTRIBUTION COEFFICIENTS ON A LAYOUT OF STEEL REINFORCEMENT IN STEEL-CONCRETE CROSS SECTION

ZÁVISLOST MODULU PRUŽNOSTI A PŘEROZDĚLOVACÍCH NAPĚŤOVÝCH KOEFICIENTŮ OCELOBETONOVÉHO PRŮŘEZU NA ROZLOŽENÍ OCELOVÝCH PRVKŮ V PRŮŘEZU

Abstract

The paper presents the outputs of a computational parametric study investigating the influence of both reinforcement ratio and scheme of a cross-section reinforcement on a design value of the elastic module for the homogenized cross-section and the values of the stress redistribution coefficients. The design value of the elastic module represents the steel-concrete cross section in the calculations. The stress redistribution coefficients converts the state stress in the homogenized cross-section for the state stress in steel and concrete individually. The design value of the homogenized cross-section elastic module and the stress redistribution coefficients are determined from the theory of the cooperating rings and computed by program HOMO. The result of a study is a set of the stress redistribution coefficients and a dependency of stress redistribution coefficients on the reinforcement ratio of a steel-concrete section.

Keywords

Module of elasticity, steel-concrete cross section, reinforcement ratio, stress redistribution coefficient.

Abstrakt

Článek uvádí výsledky výpočtové parametrické studie, zkoumající vliv stupně a způsobu vyztužení ocelobetonového průřezu na výpočtovou hodnotu modulu pružnosti homogenizovaného průřezu a na hodnoty přerozdělovacích napěťových koeficientů. Homogenizovaným průřezem je ocelobetonová výztuž reprezentována ve výpočtech. Napěťové přerozdělovací koeficienty slouží k přepočtu stavu napětí v homogenizovaném průřezu na stav napětí v ocelových prvcích a ve stříkaném betonu. Výpočty modulu pružnosti homogenizovaného průřezu a hodnoty přerozdělovacích napěťových koeficientů jsou provedeny metodou, která je založena na teorii spolupracujících prstenců

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výpočetním programem HOMO. Výsledkem parametrických výpočtů je závislost hodnot přerozdělovacích napěťových koeficientů na stupni vyztužení ocelobetonového průřezu.

Klíčová slova

Modul pružnosti, ocelobetonový průřez, stupeň vyztužení, přerozdělovací napěťový koeficient.

1 INTRODUCTION

A steel-concrete cross section is the most frequent form used for the primary lining of underground constructions realized by sequential methods and it is the essential part of the New Austrian tunnelling method. The steel-concrete cross section is formed by one or several layers of sprayed concrete, applied gradually with some intervals, steel components – different types of bars (rolled, welded) and an expanded metal.

The steel-concrete linings of the underground works, contrary to the reinforced concrete constructions, are structures theirs cross-section, strength and strain parameters are changing during a construction phase and short time after due to the hardening of a sprayed concrete. Another significant feature is a variability of the geometric shape: total thickness of steel-concrete cross section; thickness of partial construction layers of sprayed concrete; placement of steel props in the cross-section. The geometric variability of the steel-concrete cross section is a consequence of some objective reasons as over break or subjective reasons as accuracy of the construction thickness both total and particular of the sprayed concrete layers. The placement accuracy of steel props can vary in the cross-section profile as well.

This article is related to surveying the influence of steel props placement in the cross-section profile of the steel-concrete lining on the E-modulus value of homogenized cross-section and on the stress redistribution coefficient values a_1 at inner ring radius and a_2 at outer ring radius. A method of cooperating rings was used for the analysis (Aldorf, 2009; Vojtasík, 2010) – the computer program HOMO. This method is based on an analytic model for the calculation of the stress-strain state in a multiple-layer circular ring (Bulytchev, 1982). Setting the stress in the steel-concrete cross section is effectuated according the scheme at display on the figure 1.

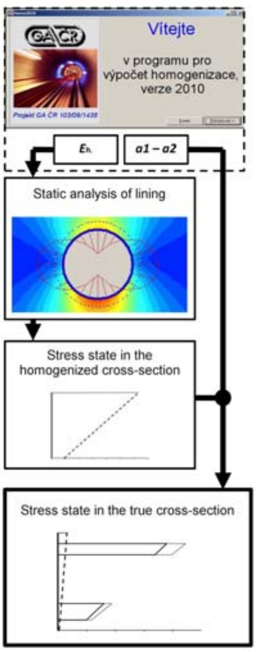

Fig. 1: The scheme of the setting the stress state in the steel-concrete cross section

2 SOLUTION METHOD

The steel prop placement mode in the cross-section profile can vary in many options. The two most frequent situations of steel prop layout in the steel-concrete cross section were surveyed in this parametric study.

The first one places the steel props on single line. There are three assumed variants for this situation. Each differs in the placement of steel props in the cross-section profile (figure 2, A, B, C variants). In the A variant, the steel props are placed in the cross-section middle. In the B and C variants the steel props are placed close to the cross-section boundary. In the B variant the steel props are near upon to the cross-section boundary with the ground rock, in the variant C the steel props are on the opposite cross-section flank close to the inner lining boundary.

The second most frequent prop placement mode is if the steel props are double lined in parallel way with the cross-section boundaries. (figure 2, variant D)

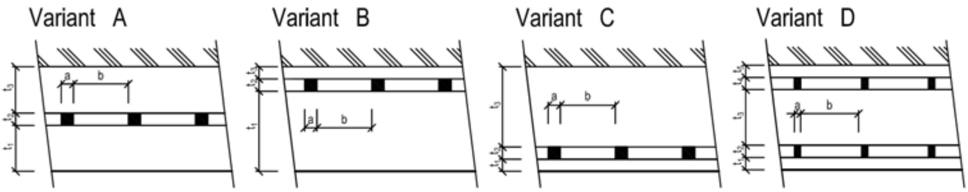

Fig. 2: The modes of steel prop layout in the cross-section

Another variable parameter is the reinforcement ratio of a steel-concrete cross section. It means a rate of total sum of section area of all steel props to the area of the concrete section part. The values of the reinforcement ratio for the sectional dimension of 1,0 m width and 0,17 m thickness are 0,03; 0,015; 0,005; 0,002 a 0,001. All the solutions keep the steel props thickness constant and it counts 0,01 m. A change in the reinforcement ratio is achieved by a change of optional steel props width (a) and props span in between (b).

The analysis examines as well the dependency, when there is the same reinforcement ratio that is achieved by different layout schemes of steel props with regard to the steel prop number and layout geometry parameters of the prop width (a) and the props span (b).

The last variable parameter on a focus is the modulus of elasticity of concrete that is dependent on time.

3 SOLUTION RESULTS

Solution results are processed, summarized and realized by graphic charts in the following pictures. The graphs on figure 3 show a dependencies between the modulus of elasticity of homogenized cross-section and the reinforcement ratio of the cross-section for the time periods in variant A.

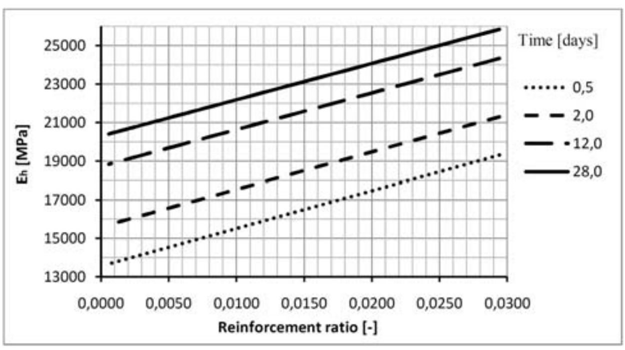

Fig: 3

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The graphs on figure 4 show the stress redistribution coefficients values a_1 and a_2 for the steel prop in dependency on the reinforcement ratio for the time periods in variant A.

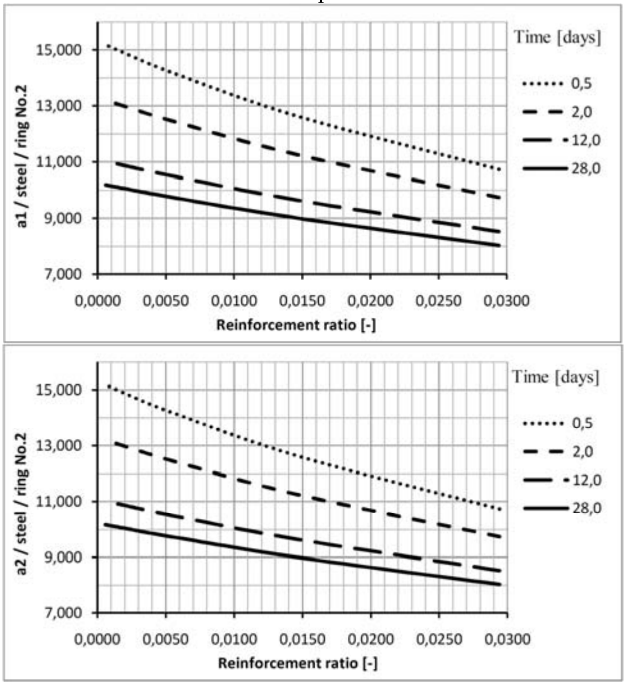

Fig: 4

The graphs on figure 5 show the values of stress redistribution coefficients a_1 and a_2 for the concrete layer in between the steel props in dependency on the reinforcement ratio for the time periods in variant A.

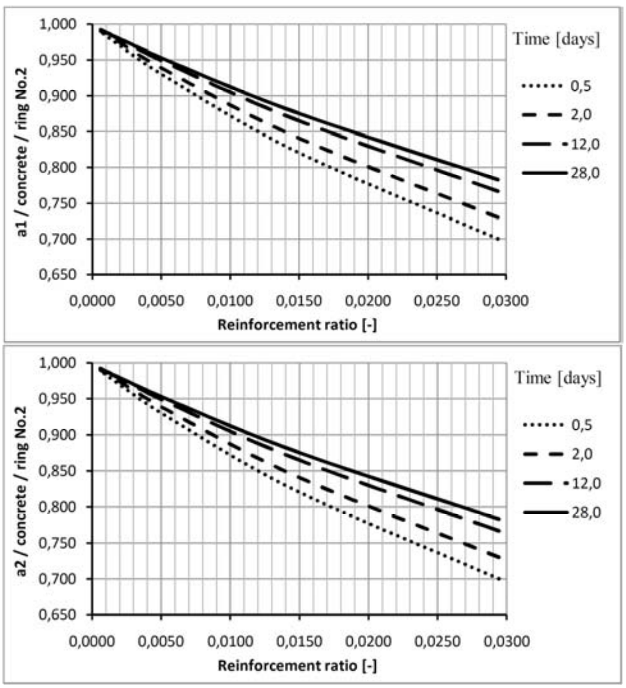

Fig: 5

Analogous outputs and graphs were gained for the other variants that have been surveyed.

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Modules of elasticity of homogenized cross-section and stress redistribution coefficients a_1 and a_2 for both steel and concrete at rings 2 and 5 are on display in table 1.

Table 1

Variant	Time [days]	E_h [MPa]	Ring No.2				Ring No.4			
			concrete		steel		concrete		steel	
			a1	a2	a1	a2	a1	a2	a1	a2
A	0,5	16400	0,823	0,823	12,622	12,620	-	-	-	-
	2,0	18500	0,843	0,843	11,248	11,246	-	-	-	-
	12,0	21500	0,867	0,867	9,644	9,642	-	-	-	-
	28,0	23000	0,877	0,877	9,002	9,000	-	-	-	-
B	0,5	16600	0,817	0,817	12,625	12,620	-	-	-	-
	2,0	18600	0,838	0,838	11,261	11,256	-	-	-	-
	12,0	21600	0,863	0,863	9,664	9,660	-	-	-	-
	28,0	23200	0,873	0,873	9,024	9,020	-	-	-	-
C	0,5	16300	0,829	0,830	12,640	12,642	-	-	-	-
	2,0	18300	0,849	0,850	11,256	11,257	-	-	-	-
	12,0	21400	0,873	0,873	9,642	9,643	-	-	-	-
	28,0	23000	0,882	0,883	8,997	8,998	-	-	-	-
D	0,5	16400	0,823	0,823	12,721	12,715	0,825	0,826	12,551	12,553
	2,0	18500	0,844	0,844	11,336	11,331	0,846	0,846	11,186	11,188
	12,0	21500	0,868	0,868	9,719	9,714	0,870	0,870	9,592	9,593
	28,0	23100	0,878	0,878	9,072	9,067	0,879	0,880	8,954	8,950

3 CONCLUSIONS

The outputs of the parametric study, surveying the impact of steel props in the steel-concrete cross section on the module of elasticity and stress redistribution coefficient to sett the stress in the steel-concrete cross section can be summarized as follows:

- an increase of the reinforcement ratio increases module of elasticity of the steel-concrete cross section
- with an increase of concrete elasticity module in time, there is a decrease of stress redistribution coefficients of steel props and a moderate increase of stress redistribution coefficients of concrete
- the steel prop placement mode in the steel-concrete cross section has no countable impact on the stress redistribution coefficients both in the concrete layers and in the steel props. For the same values of the reinforcement ratio there are only moderate deviations in between the modes with single and double lined layout of the steel props in the steel-concrete cross section. No or moderate differences in the stress redistribution coefficients do not mean that in the concrete layers or in the steel props the stress values for different placement modes will be identical in true steel-concrete cross section. The true stress state in the steel-concrete cross section is conditioned except the stress redistribution coefficients as well with the stress state of the homogenized cross-section that is not constant.

The last finding is very interesting. It implies that it could be possible to set up the stress in the steel-concrete cross section on the basis of the reinforcement ratio. If this finding verifies in some way in the practice than the theory of cooperating rings could underlay a simple approach for design and assessment of the steel-concrete cross section.

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