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Calculation of Stresses for Composite Structures

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Summary

The calculations of the stresses for the statically indeterminate composite structures as general, are presented. The approximate methods EM and AAEM and exact method are applied. The stresses, for the example of statically indeterminate composite structures due to uniformly distributed load and the shrinkage of concrete are determined. Using the limiting concrete creep functions the upper and lower limits of the stresses are determined.

1. The exact method (TM)

The cross section of the composite structures contain concrete (b), prestressing steel (p), steel member (n) and reinforcing steel (m). Concrete is considered as a linear viscoelastic material. The relaxation of the presstresing steel is taken into account.

$$\sigma_b = E_{bo}\hat{R}'(\varepsilon - \varepsilon_s), \qquad \sigma_p = E_p\hat{R}_p\varepsilon \tag{1.1}$$

Other kinds of steel: steel member (n) and reinforcing steel(m) obey Hook's law :

$$\sigma_k = E_k\varepsilon \qquad \text{k=n,m}. \tag{1.2}$$

The exact method, established by Lazic , using linear integral operators, is applied. Starting from the integral stress-strain relationship the expressions for stress and strain, in the exact method, are derived without mathematical negligence. Calculation of statically indeterminate composite structures is same as calculation of the corresponding structures whose material is homogeneous and elastic except that in composite structures we solve integral equations.

2. The approximate methods (AAEM, EM)

The algebraic stress-strain relationship for concrete contain two independent parameters: the reduced creep coefficient φ(t,to) and the aging coefficient χ=χ(t,to) (AAEM). When χ=1 the same equations represent the EM method.

$$\sigma_b = E_{bo}\zeta_b(\varepsilon - \varepsilon_s) - \rho_b\sigma_b \ , \qquad \sigma_b = \sigma_b(t_o,t_o) \ ,$$

$$\zeta_b = \frac{1}{1+\chi\varphi_r} \ , \ \rho_b = (1-\chi)\varphi_r \ . \tag{2.1}$$

When the relaxation of prestressing steel is introduced, the algebraic stress-strain relationship for the prestressing steel may be written as:

$$\sigma_p = E_p \zeta_p \varepsilon \tag{2.2}$$

Calculation of statically indeterminate composite structures is same as calculation of the corresponding structures whose material is homogeneous and elastic.

The redistribution of stresses for the example of composite structures due to uniformly distributed load and the shrinkage of concrete is calculated. Values of stresses are shown on the graphs 1,2 as follows.

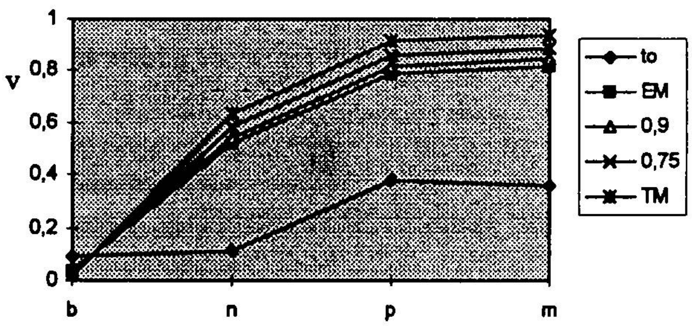
Data: Concrete (b) $E_b = 30GPa$, $\varphi_r = 3{,}5$, $\varepsilon_s = -30 \cdot 10^{-5}$

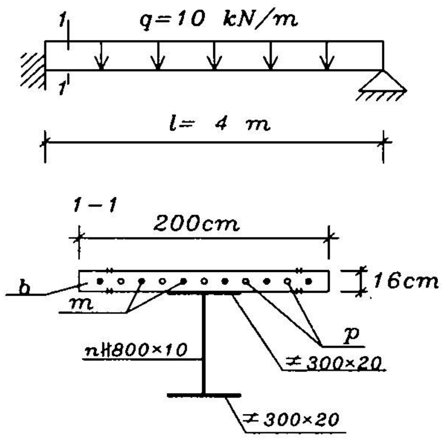
Prestressing steel (p): $E_p = 210GPa$, $F_p = 100cm^2$, $\varsigma_p = 8\%$

Steel member (n): $E_n = 200GPa = E_u$

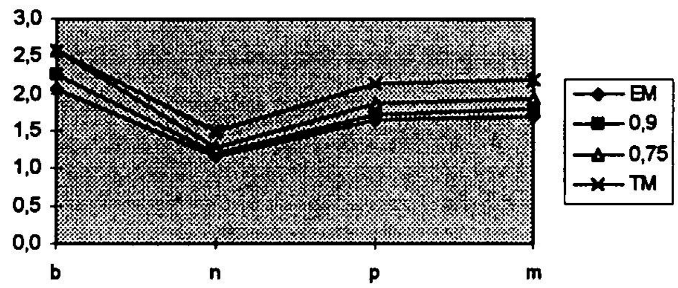
Reinforced steel (m) : $E_m = 200GPa$, $F_m = 80cm^2$

stresses due to distributed load q





stresses due to shrinkage s



3. Conclusion

The redistribution of stresses for the composite section during in time, occurs due to viscoelastic properties of concrete and relaxation of prestressing steel. Stresses of concrete are reduced and stresses of steel parts are increased. Using the concrete creep function of the aging theory in the exact method and the hereditary function in the EM method the upper and the lower limits of the stresses are determined. We choose the aging coefficient χ in the AAEM method to lie within these limits. As we can see in graphs this conditions for the values of coefficient χ from 0,75 to 0,9 are fulfilled.