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Design aspects of the safe structuring of reinforcement in reinforced concrete bending beams

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Abstract

In the paper problems with safe and optimal design of reinforcement in reinforced concrete elements were presented. There were two methods considered: analytical, based on tensile forces envelope with the influence of bending moment and shear force as well as a simplified method based on bending moments envelope. In order to compare both methods a numerical analysis was carried out. Load bearing capacity in critical sections and the amount the reinforcing steel were taken as comparative parameters.

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Keywords: Reliability of RC structures, design of reinforcement, material envelope, load bearing capacity factor.

1. Introduction

The broadly defined analysis of reliability of structures finds wider and wider use in the analysis of engineering structures [1,2,3]. The reliable design becomes an important part of modern engineering software. It permits to design structures as safely as possible and simultaneously is optimal from the viewpoint of the structure costs [4, 5]. One of the basic parts of safe design of reinforced concrete structures is an appropriate choice of reinforcement in a structure.

The longitudinal reinforcement in reinforced concrete elements should be adopted in the way to safely resist tensile forces caused by bending moments and resultant shear forces in all sections. To that end each reinforcing bar

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should be appropriately anchored beyond the section, where it is computationally required due to load bearing conditions of the section. Furthermore, the extension of reinforcing bars beyond the computational section should be designed without creating weak points in the structure. The correct layout of longitudinal reinforcement should not generate considerable additional costs. From the viewpoint of the structure safety the correct layout of reinforcement, additionally, should cater for the appropriate reserve of the load bearing capacity resulting from the reinforcement introduced in representative sections.

Nomenclature

F_{td}	the acting tensile force
F_{Rd}	the resisting tensile force
M_{Ed}	the acting bending moment
M_{Rd}	the resisting bending moment
V_{Ed}	the acting shear force
a_l	radius of
f_{yd}	the design yield strength of reinforcement
g	the value of permanent action
l_{bd}	the design anchorage length
q	the value of variable action
s	the contribution of variable action
z	the inner lever arm
α	the angle between shear reinforcement and the main tension chord
θ	the angle between concrete compression struts and the main tension chord
σ_s	the stress in reinforcing steel

2. The design of longitudinal reinforcement

The arrangement and anchorage of longitudinal reinforcement based on tensile forces envelope according to conditions contained in recommendations of EC2 [6] arise from provided computational truss model of support zone. During calculations of design value of tensile force F_{td} in reinforcing bars there is necessary taking into account the influence of shear force [7], which cause increase of tensile force in bars in value ΔF_{td} (1).

$$F_{td} = \frac{M_{Ed}}{z} + \Delta F_{td} = \frac{M_{Ed}}{z} + 0.5V_{Ed}(\cot\theta - \cot\alpha) \tag{1}$$

The consideration of the influence of additional force ΔF_{td} in tensile reinforcement could be replaced by drawing back of tensile forces envelope chart in value a_l (2)

$$a_l = 0.5z(\cot\theta - \cot\alpha) \tag{2}$$

The correct arrangement of bars required the appropriate anchorage in distance l_{bd} beside the section, where they are computational required (fig. 1).

The layout of the material envelope based on tensile forces envelope (fig. 1) is awkward issue to calculate and require appropriate software. The alternative method, hereafter the engineering method, of safe longitudinal reinforcement structuring is the classic method based on bending moments envelope. There is the assumption that the influence of shear force is not considered in the engineering method, therefore for saving the appropriate safety level during using of this method, the assumption that reinforcing bar does not work on the anchorage length was introduced (fig. 2).