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Influence of concrete strength probability distribution on safety margin of concrete cross-section subjected to shear

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Abstract

The subject of the work was the assessment of the safety margin of concrete cross-section subjected to shear. The assessment was performed with use of the assumptions and models taken from the two Polish standards: formerly valid PN-84/B-03264 and currently valid PN-EN-1992-1-1:2008. The goal of the performed analysis was the assessment of the influence of the probability distribution type of the concrete strength on the level of the safety margin. Two types of concrete distribution was used: normal and lognormal. On the basis of the results it was stated that values of partial security exponent Δ_R show clear differences in the level of safety margin due to the distribution of strength of concrete only for models of shear resistance due to the concrete tension and that the distribution type of concrete strength affects the skewness of the shear resistance distribution in most cases.

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Keywords:

1. Introduction

Probabilistic analysis of structures has not only its history but also future. It is wider and wider used not only in order to assess the safety margin of existing structures but also to design the structures with the assumed, certain level of reliability [1,2]. If the safety level of concrete cross-sections subjected to shear is concerned there are not many examples of such analyzes. Some attempts to analyze probabilistic shear capacity were undertaken in [3]. This

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work is intended to fill some of the white spots in probabilistic analyzes of concrete cross-sections subjected to shear.

There are many models of the shear resistance in the literature. Some of them are described in [4,5]. It was impossible to analyse all or even the most of them in this work so it was decided that only models from two Polish standards, as the practically used ones, will be the subject of the performed analyzes. The selected models and the assumption were taken from the formerly valid standard PN-84/B-03264 and currently valid PN-EN-1992-1-1:2008. These two standard were chosen because of the fundamental differences between the models included. The models in both standard were based on different assumptions. Models from PN-84/B-03264 is based on the research of Borishanskii [6]. He has proposed the model of destruction of the concrete element subjected to shear which assumed rotation of two parts of the element split by a diagonal crack around the end point of the crack. The detailed description of the model can be found in [4,5,7]. In contrast, the models included in PN-EN-1992-1-1:2008 were based on the modified Kupfer [8] truss analogy which was originally developed by Mörsch [9].

For the purpose of the work an original computer programme was developed to perform Monte Carlo simulations calculations of the shear resistance. Results of simulations were statistically analysed to investigate the influence of the type of distribution of concrete strength on the level of safety margin and on the form of the resulting shear resistance distribution. Due to the complexity of the issues related to shear models, this study is limited to consideration of shear resistance of rectangular cross-section due to the compressive and tensile strength of concrete without taking into account the participation of the reinforcement in the form of stirrups.

2. Analyzed models of shear resistance

2.1. General description and assumptions

Since in the considered models the same parameters are marked with different symbols the formulas describing models of PN-84/B-03264 were transformed by replacing the original symbols with corresponding markings from the PN-EN-1992-1-1:2008. In the formulas of shear resistance models some assumptions were also included to limiting the scope of the analysis and the number of possible variants of the models. It was assumed that calculated analyzed cross-section of a beam is rectangular and the element is loaded and supported directly with no normal forces occurring. The beam is made of concrete which characteristic compressive strength f_{ck} is less than 60 MPa and at least 50% of the tensile reinforcement required at mid-span continue past the near face of the support. The following models have been formulated in the form which takes into account the above assumptions.

2.2. Models in PN-84/B-03264

Models of the shear resistance contained in PN-84/B-03264 are described in [7,10]. The Q_{max} force, which is the ultimate shear force due to the compression of concrete, can be calculated using formula (1):

$$Q_{max} = 0.25 \cdot f_c \cdot b \cdot d \tag{1}$$

where f_c is the compression strength of concrete, b is the width of the cross-section and d is its effective depth.
The Q_{min} force, which is the ultimate shear force due to the concrete tension, can be calculated using formula (2):

$$Q_{min} = 0.75 \cdot f_{ct} \cdot b \cdot d \tag{2}$$

where f_{ct} is the concrete tensile strength and the other symbols as in formula (1).

2.3. Models in PN-EN-1992-1-1:2008

Models of the shear resistance included in PN-EN-1992-1-1:2008 are described in [11]. After taking into account the assumptions the ultimate shear force which can bear a non-reinforced concrete element due to the ultimate