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Determination of the modulus of elasticity of concrete in the construction process of prestressed bridge structures

Doctoral dissertation in the discipline of Civil Engineering, Geodesy and Transport

Summary

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Summary

The subject of the dissertation is the analyses leading to the explanation of discrepancies revealed at construction sites between the results of numerical calculations and deflections of the actual structure of prestressed concrete bridge structures. These problems do not effectively predict the final geometry of concrete structures or assess their stiffness, which is most often due to uncertainties in determining the modulus of elasticity of concrete. The thesis includes an extensive literature review of the material and technological factors that affect the deformability of concrete, which is so important for prestressed bridge structures. Methods proposed by standards and academic papers for estimating the value of the modulus of elasticity have been reviewed in the context of changes resulting from the use of increasingly diverse aggregates and changes in the cement industry enforced by the need to reduce CO_2 emissions. The experience of contractors related to excessive displacements of spans during construction stages is presented, which indicate uncertainties in the estimation of the modulus of elasticity of concrete sometimes causing inconvenient complications at the construction site. The results of test loads on a large number of bridges performed over the years by the Site Survey Team of the Silesian University of Technology were also analysed. Based on these analyses and acquired knowledge, it was concluded that the only way to have a reliable value of the modulus of elasticity of concrete is through laboratory tests that take into account the actual concrete curing conditions in the superstructure.

The research described in the thesis was carried out both in the laboratory and at the construction site of prestressed bridge structures. The structures are described in detail, including the concrete mix recipes and the construction methods used. The laboratory testing methodology is presented, together with an implemented system of structure conditions of concrete curing. The results of laboratory tests on almost 400 cylindrical specimens made in 16 batches from 5 different concrete mix recipes are presented. Half of them were cured under standard conditions, while the rest were cured under conditions close to those in the superstructure at the construction site. The site investigations mainly consisted of tests of the structures under static load and the geodetic surveys of the structures during the construction process, especially during prestressing. The results of the laboratory tests were verified by comparing them with the results of deflection measurements of the superstructure. The conclusions from the discussion of the research were used to propose a procedure for determining the deformability of concrete and to use the results in the design and construction process of prestressed bridge structures. This procedure can become a supplement to existing standards by providing the opportunity to more reliable determination of the modulus of elasticity of concrete in situations where such a need is crucial to the construction process, i.e., in the construction of prestressed concrete bridges, where different aggregates and new types of cements may be used. An analysis of the influence of the elastic modulus on the results of the design process of these structures was also carried out. Two sources of concrete properties were used for this. On the one hand, these were the standard values commonly used by designers and, on the other hand, the results of own laboratory tests on concretes with different types of aggregate. The results showed some slight influence of the modulus of elasticity on the ultimate limit states, but in the case of structural deformations (and especially span displacements), the deformability of the concrete proved to be crucial.

The dissertation also proposes a direct method for testing the elastic modulus of concrete, which is presented in the form of a precise and concise procedure.

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