A Novel Approach to Residual Stiffness Analysis of Flexural Concrete Elements with Composite Reinforcement

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Abstract

This study introduces a simplified tension-stiffening approach for the flexural stiffness analysis. It employs a new testing layout designed with the purpose to form multiple cracks in a small laboratory specimen. The proposed analytical model is based on the following assumptions: smeared crack approach; linear strain distribution within the section depth; elastic behaviour of reinforcement and compressive concrete; a rectangular distribution of stresses in the tensile concrete. The latter assumption enables obtaining a closed-form solution of the tension-stiffening problem. The achieved solution requires neither iterative calculations nor description of the loading history. The proposed methodology is acceptable for estimating residual stiffness of elements with various combinations of reinforcement. The application of the proposed technique is illustrated experimentally. Several composite reinforcement schemes are considered. The specimens are subjected to monotonic and cyclic loading patterns.

Keywords: composites; reinforced concrete; flexural tests; tension-stiffening; constitutive models.

1. Introduction

Residual stiffness of reinforced concrete elements is closely related with structural integrity of cracked sections. Tension-stiffening models could represent the stiffness in an averaged manner. Numerous studies investigated the tension-stiffening issue. However, only several works addressed the flexural effects. Fundamental studies by *Kaklauskas & Ghaboussi* [1] and *Torres et al.* [2] could be mentioned in this context. Elaborate numerical procedures are intrinsic attribute of the "exact" approaches [3]. Iterative nature of the analysis procedures often complicates applicability of the exact procedures: the calculation errors are accumulated following the load history [3]. Development of more reliable algorithms employed the reinforcement-related tension-stiffening concept was a consequence of the further improvements [4-6]. Such models, however, are not useful for the analysis of the elements reinforced with a combination of different types of internal bars, near surface mounted strips, and/or external sheets. This study introduces a new simplified tension-stiffening approach for the flexural stiffness analysis.

The proposed methodology is acceptable for estimating tension-stiffening of elements with different combinations of reinforcement.

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