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Modeling of steel and concrete strains between primary cracks for the prediction of cover-controlled cracking in RC-beams

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ABSTRACT

After cracking, the intact concrete between two consecutive primary cracks remains elastic and the maximum concrete stress is less than the tensile strength of concrete. However, under increasing loading, cover-controlled cracks occur at the steel–concrete interface causing a loss of bond and hence a loss of tension stiffness. The cover-controlled cracks are internal concrete cracks that initiate at steel rib location and are contained within the concrete cover. In this paper, steel and concrete strain distribution between two consecutive primary cracks are modeled based on a linear assumed distribution of the bond stress at the steel–concrete interface. The accurate calculation of the tensile concrete strain allows introducing new criteria for cover-control cracking initiation based on a peak value of steel stress calculated at crack location.

1. Introduction

Under normal conditions, reinforced concrete beams are always cracked because of the low tensile strength of concrete. The overall stiffness reduction of the beam with increasing load is attributed to the formation of new bending cracks labeled primary cracks [1]. The crack stabilization phase is reached after all primary cracks have developed. At this stage, the tensile concrete located between two consecutive primary cracks helps to enhance the flexural stiffness of beams because the bond between the steel bars and the concrete is always active. This is called the "tension stiffening" phenomenon, well known to civil engineers as it influences significantly the deflection of structural members under service loading.

When the loading level does not exceed the one leading to the crack stabilization, the intact concrete between two consecutive primary cracks remains elastic and the maximum concrete stress is less than the tensile strength of concrete [1,2]. However, under increasing loading, cover-controlled cracks occur at the steel–concrete interface causing a loss of bond and hence a loss of tension stiffness. The cover-controlled cracks are internal concrete cracks that initiate at steel rib location and are contained within the concrete cover [1,3].

Wu and Gilbert [1] developed a continuum-based finite element model by taking into account the reduction in tension stiffening due to cover-control cracking. In the model, the cover-controlled cracking formation in the concrete located between the primary cracks versus loading is triggered when the steel stress calculated at crack location reaches a specific value. It was convenient to consider the steel stress at crack location as it is proportional to the loading applied and can be calculated accurately. The steel stress at crack location leading to cover-control cracking was arbitrary fixed to a constant value equal to 250 MPa.

In this paper, steel and concrete strain distribution between two consecutive primary cracks are modeled based on a linear assumed distribution of the bond stress at the steel–concrete interface. The accurate calculation of the tensile concrete strain allows introducing new criteria for cover-control cracking initiation based on a peak value of steel stress calculated at crack location.

2. Steel and concrete strain and bond stress distributions along the transfer length

After cracking, the tensile force is transferred from the steel bar to the concrete by the bond. The transfer length L_t is defined as the embedment length from the crack to the first point at which the strains of the reinforcing bar and concrete are equal to each other. The distribution of bond stress is non-uniform along the transfer length. Bond stress is zero at the cracked section because

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