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The effects of axial tension on the sagging-moment regions of composite beams

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A B S T R A C T

This paper studies the effects of axial tension on the sagging moment regions of steel–concrete composite beams. The study comprised an extensive experimental programme and nonlinear finite element analyses. Six composite beams were designed and tested under the combined effects of axial tension and positive bending moment. The beams were loaded to their ultimate capacity and the experimental moment-axial tension interaction diagram was constructed. Following the tests, a finite element model was used to simulate the nonlinear response of the composite beams. The validity of the model was thoroughly assessed against the available experimental data and a parametric study was conducted to study different beam sizes and the effect of partial shear connection on the interaction diagram. It was found that the moment capacity of a composite beam is reduced under the presence of an axial tensile force acting in the steel beam section. In addition, the use of partial shear connection does not affect significantly the shape of the interaction diagram. The tensile capacity of the composite section, however, is limited by the axial capacity of the steel beam alone. Based on the experimental results and the finite element analyses, a simplified equation is proposed for the design of composite beams subjected to positive bending and axial tension.

1. Introduction

Steel-concrete composite systems have seen widespread use in recent decades because of their advantages against conventional construction. The optimal use of the two materials together with their individual properties, e.g. steel strength and ductility in tension and concrete robustness and high stiffness in compression, results in a very efficient and economical structural solution. Furthermore, reinforced concrete is inexpensive and provides good fire resistance, while steel members are lightweight and easy to assemble. The effective collaboration between a concrete slab and a steel beam which is achieved through the shear connection system significantly increases the rigidity and the ultimate moment capacity of a composite beam compared with the properties of a bare-steel or reinforced concrete beam. In this way much larger beam spans can be obtained.

There are situations where a composite beam is subjected to axial loads and bending moments [1]. Some characteristic examples include:

- Beams located at the leeward side of high-rise buildings. In these buildings the wind suction can assume large values, depending on the height of the building, and imposes axial loads to the steel beams of the structural frame.
- The effect of shrinkage in the concrete slab indirectly imposes an axial tensile load to the steel beam.
- Inclined car park ramps and grandstands in stadia are usually constructed with a large inclination angle, and thus the beam is subjected to combined bending and axial forces.
- Cable stayed bridges, where the cables can introduce tensile forces in the concrete deck.

The effects that the simultaneous action of axial load and bending moment produce in the ultimate capacity of a composite beam are not yet covered in a comprehensive way by the current code of practice. In fact, modern steel and composite construction codes, including Eurocode 4 [2], Australian code AS2327 [3] and American AISC [4], give detailed guidance on the design of composite columns under bending and axial loads, but they do not address the effects of combined loading in composite beams, which are asymmetric in nature.

There exists a considerable amount of research on the flexural behaviour of composite beams [5–7], although the behaviour under combined actions is not yet thoroughly investigated. Limited research results exist on the behaviour of composite beams under generalised loading conditions. The effect of pre-stressing on composite beams under positive bending was studied by Uy and Bradford [8] and Uy [9]. The performance of composite beams under combined bending and torsion was reported by Nie et al. [10] by studying experimentally and theoretically eleven steel-concrete composite beams. The effects of torsion on straight and curved beams were also studied by Tan and Uy [11,12]. Their research provided experimental data for the

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