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Closed-Form Formulations in Composite Beams Based on Partially-Composite Behavior

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Abstract

Partially-composite beams are composite beams with a more complex behavior which includes fully-composite to non-composite behaviors. Hence, fully-composite and non-composite behaviors are considered as boundary conditions of partially-composite behavior in this paper. Two new closed-form formulations for slip and flexural rigidity calculation of non-composite and fully-composite beams are obtained respectively, and their results are compared with the conventional methods. Results of the current paper shows that the presented closed-form formulations have the same results with the conventional methods and can be conveniently used in the analysis of composite beams.
Keywords: Stiffness; Flexural rigidity; Slip; Partial; Composite.

1. INTRODUCTION

Composite sections have always been of interest as they combine properties of different materials properly. The first composite sections were constructed without using any shear connector at the interface between materials known as non-Composite beams. In non-composite beams, materials have slip or relative displacement upon each other. Occurrence of considerable values of slip in non-composite beams causes the layers of the beam to act separately and results in a reduction in flexural capacity and stiffness, as well as an increase in deflection of the section. In non-composite beams no shear force is developed at the interface between materials if cohesion is neglected.

Another type of composite sections is known as fully-composite sections in which a specific number of connectors are used uniformly along the length of the beam to connect materials to each other. The number of shear connectors in fully-composite beams is as many as the number that a composite section requires to reach its full plastic capacity. Conventionally, it is assumed that there is no interfacial slip between materials in an ideal fully-composite beam. However, reaching such a state is practically impossible because shear connectors are flexible in practice.

Recently, partially-composite beams have been introduced in which the number of shear connectors are less than that of fully-composite beams and distribution pattern of shear connectors is not necessarily uniform and continuous. Partially-composite beams are a more generalized category of composite beams so that they can also include non-composite and fully-composite behaviors. Number of shear connectors in partially-composite beams (N_{pc}) is between that of fully-composite beams (N_{fc}) and that of non-composite beams ($N_{nc} = 0$) i.e. $N_{nc} < N_{pc} < N_{fc}$. Ratio of N_{pc}/N_{fc} is known as degree of partial interaction or composite ratio which plays a fundamental role in the behavior of composite beams.

Several studies have been conducted to investigate the effect of number of shear connectors on stiffness and flexural capacity of composite beams. In 1971, McGarraugh and Baldwin (1971) used conventional transformed flexural rigidity to calculate deflection in steel-concrete beams by neglecting slip and assuming full-interaction between steel and concrete [1]. Grant et al. (1977) performed tests on large-scale simply supported composite beams under positive moment and changed degree of shear connection in each test [2]. From the test results, the following equation was fit to the data which is currently used in AISC (2016) to approximate elastic moment of inertia.

$$I_{equiv} = I_s + \sqrt{\eta}\,(I_{tr} - I_s) \tag{1}$$