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Elastic rigidity of composite beams with full width slab openings

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ABSTRACT

Openings often exist in the concrete slab of composite floors due to the functional requirements of structures. The strength and rigidity of steel-concrete composite beams are reduced by openings. Based on three tests of steel-concrete composite beams with full openings in the concrete flange, the elastic rigidity of composite beams is analyzed. Finite element analysis (FEA) considering the slip effect between the steel and concrete is conducted to simulate the composite beams with full openings in the concrete slab, and the results show that the FEA method is reliable. The analytical calculation method for the deflection of composite beams with full openings in the concrete slab is also proposed, and the results are verified by tests. The predicted deflections using the analytical method and FEA method both agree well with the test results. It is further verified that openings near the supports have insignificant effects on the deflection at the mid-span and this effect can be thus ignored. The simplified method to calculate the rigidity reduction factor is developed by a regression analysis. The analytical method and FEA method can be used for the serviceability limit state design of steel-concrete composite beams with full openings in the concrete flange.

1. Introduction

Steel-concrete composite floors are widely used in buildings [1]. Compared with conventional reinforced concrete floors, steel-concrete composite floors have major advantages in their bending resistance and stiffness by fully utilizing the material strength of both steel and concrete, and taking advantage of light weight and rapid construction features.

Often in order to satisfy functional requirements such as placing heating, ventilating, and water pipes and electric wires, the floors have to be cast with openings. Large openings are also required in industrial buildings. From Fig. 1(a) it can be seen that openings even exist directly over the flanges of steel beams, which are called full openings. When there are openings in the floor, the concrete flange of steel-concrete composite beam is weakened and a stress concentration occurs at the openings, which might significantly affect the flexural strength and rigidity of structures. If the composite effects between the concrete slab and steel beam are not considered in design, i.e., ignoring the composite action, construction cost will be increased due to this conservatism. Therefore, it is necessary to consider the composite action and effects of openings on the rigidity of steel-concrete composite beams.

Refs. [2–4] studied the composite beams with web openings and described the procedures for calculating the shear capacity and deflections of beams. Ref. [5] studied the rigidity and flexural strength of composite beams with opening rate below 50%, as shown in Fig. 1(b). The opening rate was defined as the ratio of the area of the cross section with openings and the section without openings in the concrete flange. Research on the rigidity and flexural strength of steel-concrete composite beams with full openings (a 100% opening rate) in the concrete flange was not reported in the literature.

The concrete slab of composite beams with full openings is divided into several independent parts by the full openings, and the compressive stress flow in the concrete flange is interrupted and not continuous. Therefore, the rigidity and flexural strength of composite beams with full openings in concrete slab are much different from those with opening rates below 50%. Based on experimental observations, in the present study, the FEA method and theoretical method were both developed to calculate the elastic rigidity of composite beams with full openings in the concrete slab. The effects of openings and slip between the concrete slab and steel beam on the elastic rigidity were both considered in the FEA method and theoretical method.

2. Experimental study

2.1. Specimens

Three specimens were tested to study the mechanical behavior of steel-concrete composite beams with full openings in the concrete flange under static load by changing the position of openings. The three test specimens were designed based on ref. [5], and were identified as KCB4-1, KCB4-2 and KCB4-3. The full openings were located

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