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Mechanical behavior of composite joints for connecting existing concrete bridges and steel–concrete composite beams

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ABSTRACT

In a technique of widening existing concrete bridges with steel–concrete composite beams, the old existing concrete bridge and new composite beam was connected by a composite cross beam with a composite joint. Since there have been no experimental studies on the mechanical behavior of composite joints, six specimens were tested. Based on the existing methods, the shear strength of the interface of the old and new concrete was calculated. The results showed that the shear failure of the interface between the old and new concrete is the failure mode of the composite joint and the interface between the steel plate and new concrete is always in good condition. There was nearly no slip between the old and new concrete before the bonding failure of the interface. The interface between the old and new concrete has good ductility and high strength. Based on the constitutive law of the materials, the simplified three stage mechanical model was proposed and the load–slip relationship was also predicted. Comparison between theoretical and test results has showed that the theoretical method has good accuracy. The ultimate shear strength of the interface was determined by the strength of the concrete, roughness degree and friction coefficient of the interface, and the normal stress could increase the ultimate shear strength. The residual shear strength of the interface was determined by the embedded bars, and the ratio and yield strength of the embedded bars were the main influence factors. At last the practical design method was proposed.

1. Introduction

With the rapid growth of traffic volumes in China today, the traffic capacity of many expressways has already reached the design limit, therefore, it is urgently necessary for most highway bridges to be widened. In the traditional widening methods, the pre-cast or cast-in-place concrete beams are used for the existing concrete bridges. However, there are still some problems such as requirement for high capacity of hoisting cranes for the pre-cast concrete beams, and the massive wet work of the cast-in-place concrete beams that have great effect on the traffic of the existing bridges, which results in great time and financial costs.

In order to solve these problems of the traditional widening methods, the technique for widening the existing concrete bridges with steel concrete composite beam (SCCW technique for short) has been proposed. Compared with the traditional methods for widening existing bridges, the SCCW technique has many advantages, such as low height and light weight of the new composite beam, and lower cost of the foundation for the new composite beam. Furthermore, the SCCW technique has a few major advantages: (1) fully utilization of the material strength of both steel and concrete, (2) high bearing capacity and rigidity, (3) low construction cost, (4) little effect on the traffic of the existing bridges, and (5) rapid construction. As a result, there are already some practical applications of the SCCW technique for widening existing concrete bridges in China [1].

The SCCW technique for widening existing concrete bridges is a new technique, and the composite joints are used for the transverse connection of the new steel concrete composite beam and the existing concrete beam, so the mechanical behavior and design methods of the composite joints need to be studied.

The construction details of the composite joints and the SCCW technique are illustrated in Fig. 1: the I-shape steel cross beam is used to connect the existing concrete beam and the new steel concrete composite beam. The one end of the cross beam is welded to the web of the composite beam and could be prefabricated in the factory, and a vertical steel plate with shear connectors is welded to the other end of the cross beam. The steel bars are embedded in the web of the existing concrete bridge and welded to the vertical steel plate with shear connectors. A steel rebar mesh is placed and the concrete is filled into the inter-space between the web of the existing concrete bridge and the vertical steel plate at the end of the steel cross beam. In this way the composite action between the concrete and steel could be formed in the composite joints.

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