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FULL LENGTH ARTICLE

Interfacial shear behavior of composite flanged concrete beams

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Abstract Composite concrete decks are commonly used in the construction of highway bridges due to their rapid constructability. The interfacial shear transfer between the top slab and the supporting beams is of great significance to the overall deck load carrying capacity and performance. Interfacial shear capacity is directly influenced by the distribution and the percentage of shear connectors. Research and design guidelines suggest the use of two different approaches to quantify the required interfacial shear strength, namely based on the maximum compressive forces in the flange at mid span or the maximum shear flow at the supports. This paper investigates the performance of flanged reinforced concrete composite beams with different shear connector's distribution and reinforcing ratios. The study incorporated both experimental and analytical programs for beams. Key experimental findings suggest that concentrating the connectors at the vicinity of the supports enhances the ductility of the beam. The paper proposes a simple and straight forward approach to estimate the interfacial shear capacity that was proven to give good correlation with the experimental results and selected code provisions. The paper presents a method to predict the horizontal shear force between precast beams and cast in-situ slabs.

Introduction

Composite concrete decks are commonly used in the construction of highway bridges, as one of the rapid forms of construction. The system consists of precast beams (web elements) supporting a cast-in-situ reinforced concrete slab (flange). Under service dead and vehicular live loads, considerable interfacial shear stresses develop which impose a significant demand on interfacial shear transfer elements, namely shear

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connectors. The behavior of the interface between the precast web and the cast-in-situ flange as well as the load carrying capacity of the composite girder is greatly influenced by the distribution and the percentage of shear connectors. In the absence of interfacial shear resistance, the composite action of the girder will not develop and the deck will respond as two separate elements. On the other hand, well distributed shear connectors with significant shear transfer capacity will clamp the components together and the behavior of the composite girder will approach that of the monolithically cast deck as shown in Fig. 1a–d.

Research and design guidelines, AASHTO, ACI and CSA codes [1–3] suggest the use of two different approaches to quantify the interfacial shear, namely based on the maximum compressive forces in the flange at mid-span or the maximum shear forces at the supports. Several proposals were suggested to calculate the interfacial shear capacity as follows:

1. In 1958 Mast [4] introduced a linear shear-friction equation, and was later revised in 1960 by Anderson [5]. The equation is as follows:

$$v_n = \rho_v f_y \mu \tag{1}$$

where μ is the coefficient of friction at the interface, $\rho_v f_y$ refers to the clamping stress and v_n refers to the horizontal shear strength.

2. In 1978 Shaikh [6] proposed an equation for interfacial shear capacity that was used by PCI [7] as the basis for the design equations. The equation is as follows:

$$v_n = \phi \rho_v f_y \mu_e \tag{2}$$

$$\mu_e = \frac{6.9\lambda^2}{v_n}(\text{MPa}) \tag{3}$$

where $\phi = 0.85$ for shear, $\lambda = 1.0$ for normal weight concrete, 0.85 for sand lightweight concrete, and 0.75 for all lightweight concrete and $v_n = \lambda\sqrt{6.9\phi\rho_v f_y} \leqslant 0.25 f'_c \lambda^2$ and $6.9\lambda^2(\text{MPa})$

3. In 1994 Loov et al. [8] introduced an equation applicable for both high and low clamping stresses.

$$v_n = k\lambda\sqrt{(0.1 + \rho_v f_y) f'_c} \leqslant 0.25 f'_c(\text{Mpa}) \tag{4}$$

where $k = 0.6$ for concrete placed monolithically, and 0.5 for concrete placed against hardened concrete with rough surface.

4. In 2001 Patnaik [9] proposed a linear variation on his previous horizontal shear equations. Patnaik states that it is possible to obtain some nominal shear strength from a smooth interface with no reinforcing, but for design this is not recommended.

$$v_n = 87 + \rho_v f_y \leqslant 0.2 f'_c \text{ and } 800(psi) \tag{5}$$

$$v_n = 0 \text{ for } \rho_v f_y \leqslant 50 psi \tag{6}$$

This paper presents an experimental/analytical investigation in the performance of composite flanged concrete decks. In this respect, six composite flanged concrete beams with precast webs supporting reinforced concrete slab connected with shear connectors with different spacing, distribution and ratios were statically tested under monotonic loading up to the appearance of the first crack at the interface while control beam was tested up to failure.

Experimental program

The experimental program consisted of testing seven reinforced concrete flanged beams, each beam has a thickness of 240-mm web, 150-mm web width, 60-mm flange thickness, 450 mm flange width and 2350-mm span. The beams are simply supported with a clear span of 2100-mm. The main reinforcement of all beams is 5Φ16-mm while the top reinforcement is 2Φ12-mm in the web, 5Φ10-mm/m for transverse steel (stirrups), passing through both the web and the flange in control beam (B01), and through the web only in the other six beams. The flanges are reinforced with 4Φ10-mm and transverse steel of 5Φ6/m. The beams were tested as will be described later up to the appearance of the first crack at the interface between the web and flange except for the control beam which was tested up to failure. This is mainly to allow for strengthening the beams subjected to excessive horizontal shear forces and evaluate the strengthening scheme. The test results of strengthened beams are given in a different research study (Awry et al.) [10]. The beams had various shear connector configurations; namely in terms of the provided shear connector's reinforcement area and the scheme of connector's distribution. Table 1 and Fig. 2 summarize the details of the tested beams. The beams were cast and tested at the concrete laboratory of the HBRC (Housing and Building National Research Center).

Beams B02 and B03 have the same area of equally spaced shear connectors using different diameters and spaces. Beams B06 and B07 have the same area of shear connectors varying

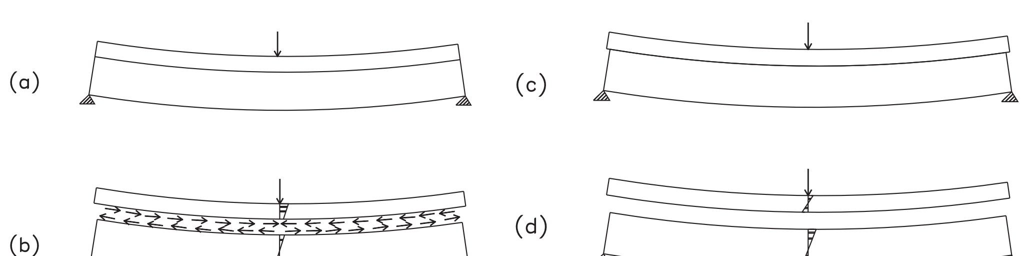

Fig. 1 (a) Fully composite section, (b) interfacial shear transfer in composite section, (c) horizontal slip, (d) non-composite section.