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Strength of composite slabs with end anchorages. Part II: Parametric studies

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ABSTRACT

Results of parametric studies on steel-deck-reinforced composite slabs with end anchorages provided by welded shear stud connectors are presented. The studies are based on the analytical model described in the companion paper. Effects of the number of studs, longitudinal shear strength, deck height, steel thickness, deck yield strength, concrete cover depth, concrete compressive strength, and deck span conditions on strength of the composite slabs and the stud strength mobilization were investigated. Simplified formulas for the determination of the minimum number of welded shear studs required to achieve the full moment of the section were developed. The formulas account for deck height, slab depth, concrete cover depth, steel thickness, steel yield strength, longitudinal shear strength, and slab span length, and predict the required number of studs with reasonable accuracy.

1. Introduction

End anchorages in the forms of welded shear stud connectors, mechanically attached connectors, or deformations of deck ribs are often provided at the ends of steel-deck-reinforced composite slabs [1]. They improve the composite action between the deck and concrete and contribute to strength and ductility of the slabs. Even though effects of various design parameters on strength of composite slabs with end anchorages have been studied experimentally [2–9] and analytically using a finite element model [7,8], the published data on this subject is limited. Previous research had shown that strength of the end anchorages is of importance [8], but it may not be fully mobilized because of the presence of deck embossments [6,8,9].

This paper contributes to the knowledge in the area of the composite slabs with end anchorages by presenting results of parametric studies conducted using the analytical model described in the companion paper [10]. Two parametric studies have been conducted on the composite slabs with welded shear stud connectors, which are the most common type of the end anchorages. One parametric study was concerned with an investigation of the influence of the number of studs, longitudinal shear strength, deck height, steel thickness, deck yield strength, concrete cover depth, concrete compressive strength, and deck span conditions on strength of the composite slabs and the stud strength mobilization. A total of 456 composite slabs were analyzed. Values of the studied parameters covered those used in construction practice.

Another parametric study dealt with the determination of the minimum number of welded shear studs required to achieve the full moment of the composite section. SDI Composite Deck Design Handbook [11] gives a formula for the required number of studs. However, the formula was developed based on a limited number of tests performed on the slabs over embossed deck profiles [3–5]. As was shown in the companion paper [10], the SDI Handbook method may result in an overestimated strength of the slabs over non-embossed profiles. A total of 324 composite slabs were analyzed in this part of the study. Simplified formulas for the minimum number of welded shear studs required to achieve the full moment of the section were developed. The formulas account for deck height, slab depth, concrete cover depth, steel thickness, steel yield strength, longitudinal shear strength, and slab span length, and predict the required number of studs reasonably well.

2. Studied composite slabs

The composite slabs analyzed in the study were assumed to be made from normal weight concrete with unit weight of 2323 kg/m^3. Shear stud connectors with a diameter of 19 mm were assumed to be welded through deck bottom flanges to steel beams supporting the deck. Span lengths were selected in such a way that no shoring was required in the construction stage. A uniform superimposed load was applied to the slabs.

Strength of the composite slabs with welded shear studs was analyzed using the following two terms: (1) degree of composite action, k_c, defined as a ratio of the calculated maximum superimposed load for a composite slab to the calculated maximum superimposed load for a similar composite slab with the full composite action and (2) coefficient

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of the slab strength increase due to the end anchorage, k_s, defined as a ratio of the calculated maximum superimposed load for a composite slab with end anchorages to the calculated maximum superimposed load for an identical composite slab without end anchorages. The stud strength mobilization was analyzed in terms of the end anchorage strength mobilization coefficient, k_m, defined as a ratio of the end anchorage force when the ultimate superimposed load is applied to the slab to the end anchorage strength.

The degree of composite action, k_c, is determined based on the following definition of full and partial composite actions. The composite action between the deck and concrete is full when an increase in the longitudinal shear strength or in the end anchorage strength would not increase the maximum superimposed load that can be supported by the slab. Otherwise, the composite action is partial.

The influence of eight parameters on k_c, k_s, and k_m was investigated. The parameters and their values were as follows:

- Number of studs, N_s: 0, 1.6, 3.3, and 6.6 studs per 1 m of slab width (which correspond to 0, 0.5, 1, and 2 studs per 1 ft of slab width, respectively);
- Longitudinal shear strength, τ_u: 0 N/mm^2, 0.14 N/mm^2, and 0.28 N/mm^2;
- Deck height, h_d: 38 mm and 76 mm;
- Steel thickness, t: 0.91 mm, 1.20 mm, and 1.52 mm;
- Concrete cover over deck, h_c: 51 mm, 89 mm, and 127 mm;
- Steel yield strength/tensile strength, f_y/f_u: 228/310 N/mm^2, 276/379 N/mm^2, 345/448 N/mm^2;
- Concrete strength, f'_c: 21 N/mm^2, 28 N/mm^2, and 34 N/mm^2;
- Span condition: single span and end span of a three-span continuous deck.

The values of the parameters used in the study are typical for construction practice. The longitudinal shear strength values of 0 N/mm^2, 0.14 N/mm^2, and 0.28 N/mm^2, represent composite slabs with no bond, with mediocre bond, and with strong bond between the deck and concrete, respectively. The friction strength at the support was calculated using a friction coefficient of 0.6 as recommended in [12,13].

3. Results and analyses

3.1. Effects of welded shear studs quantity and longitudinal shear strength

Effects of the number of shear studs and longitudinal shear strength on k_c, k_s, and k_m were studied on simply supported composite slabs made from concrete with compressive strength of 21 N/mm^2 and steel decks with yield strength of 276 N/mm^2 and tensile strength of 379 N/mm^2. Concrete toppings were 51 mm, 89 mm, and 127 mm. Composite slabs with 1.6, 3.3, and 6.6 studs per 1 m of slab width, as well as the slabs without studs were analyzed. The longitudinal shear strengths between the deck and concrete were 0 N/mm^2, 0.14 N/mm^2, and 0.28 N/mm^2.

Figs. 1 and 2 show the effects of the number of studs on k_c and k_s, where the longitudinal shear strength is referred to as bond. As one could expect, an increase in the number of shear studs, N_s, resulted in

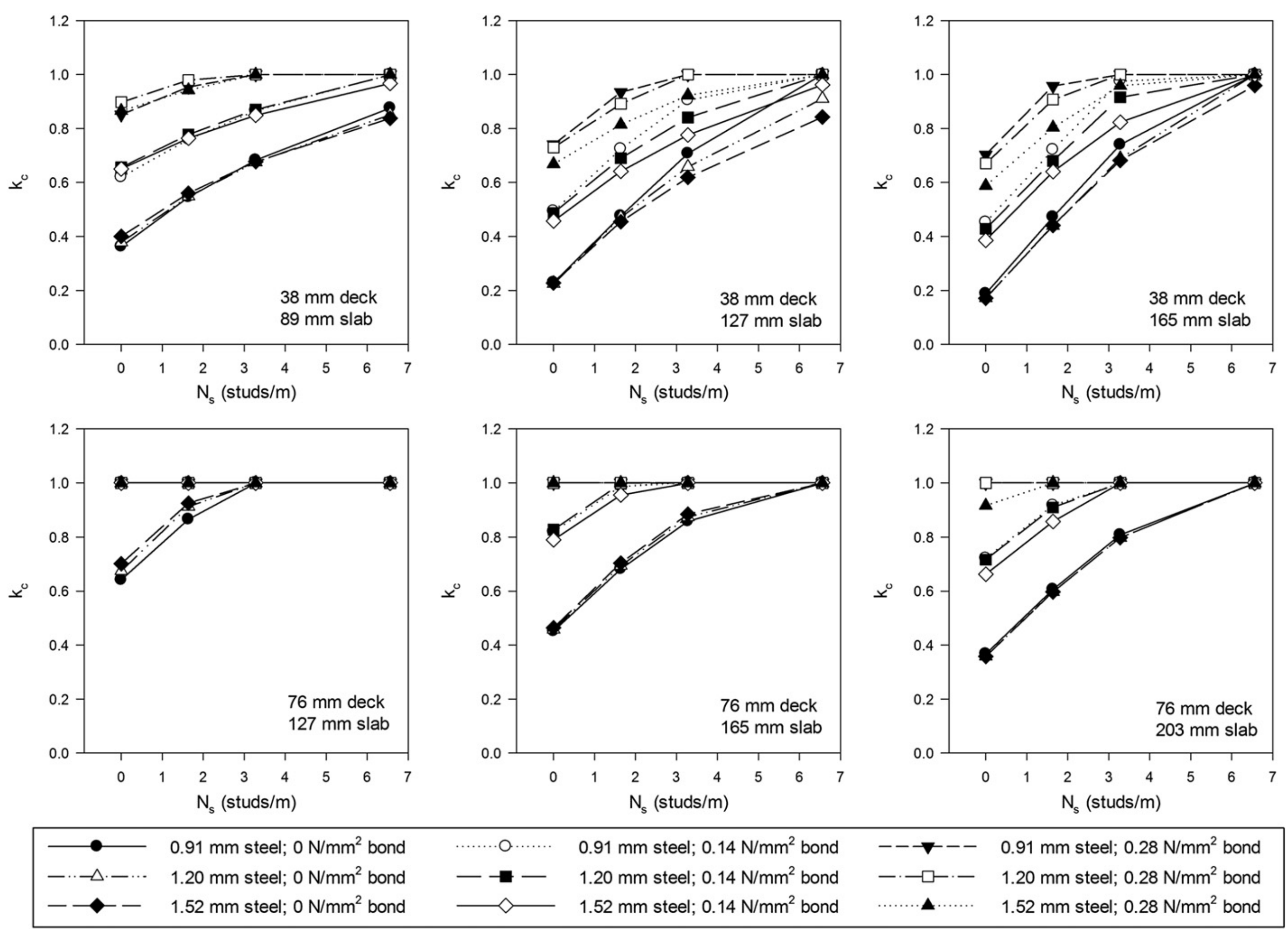

Fig. 1. Effects of number of welded shear stud connectors, longitudinal shear strength (bond), and steel thickness on degree of composite action.