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Finite Element Analysis of Composite Deck Slab Using Perfobond Rib as Shear Connection System under Vertical Loading

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ABSTRACT
Nowadays, the composite decks are very common to use in composite or steel construction. In this case of study the composite slabs have been investigated numerically by Finite Element Method (FEM). Five composite slabs were analyzed using finite element software LUSAS. The deflection of each model were obtained and compared with experimental test. Results showed a good agreement with the experimental data and indicate that the perfobond rib is appropriate shear connector for the bridges decks.
***Keywords* -** Composite Slab Deck, Deflection, Finite Element (FE) Analysis, Interface, LUSAS

I. INTRODUCTION

In civil engineering, composite structures exists when two materials are bound strongly that act as a single unit from a structural point of view. This is called composite action. One example is the steel beams supporting concrete floor slabs. If the beam and slab are not connected strongly together, then the slab contributes nothing to the load carrying capability of the beam [1].

One common application of composite structures is the design of steel box beam whereby concrete is placed on steel sheeting which carries the construction loads and act compositely with concrete slabs upon hardening of concrete. Profiled sheeting acts as the tensile reinforcement; which could be removed and light mesh reinforcement is generally placed in the concrete for temperature, shrinkage, cracks and fire [2]. The steel sheeting acts also as a permanent formwork and when placed in a cellular configuration, has an additional advantages to allow the passage of electrical and communication services. The commonly used of this method is in the building industry [1, 2].

There are many experimental studies of perfobond ribs in composite construction which some of them study the behaviour of perfobond shear connectors using push-out test. In recent years also there are some studies focused on the analysis of perfobond shear connection between steel and lightweight concrete. This study by using finite element software and utilizing the sample model of Kim et al (2006), tried to estimate the deflection of composite slab deck under vertical loading with different thicknesses. Additionally, discussed the interaction behaviour between steel sheeting and concrete using the interface element in FE software.

II. COMPOSITE SLAB

Generally, composite slabs failure under the bending is divided in three major modes. Mode 1 is flexure failure which is generally happened in a long and thin slab. Mode 2 is the vertical shear failure which is close to support due to high concentrated load where the slab must be very short and thick. Mode 3 is the horizontal shear failure which is more common to happen for majority of composite slab systems under the vertical loads (Porter and Ekberg 1978). The behavior of composite action between concrete and steel in the slabs are depended to some factors which are shear connectors, steel thickness, condition of supports and slab thickness. The shear connectors are generally combined to steel sheeting shape, indentation or embossments on steel profile [4].

III. FINITE ELEMENT MODEL

According to the experimental study and push-out test, the influence of the holes is negligible on the ultimate shear capacity and end-slip and the maximum difference was less than 7% (Kim et al 2006). For this reason, in the numerical study the holes were not modeled and it is assumed the maximum composite action between concrete and steel sheeting. The FE model is showed in Fig. 1. The steel sheeting and concrete were modeled in software using 3D solid continuum element. For the constitutive model, the concrete model 64 was employed for the concrete in compression and tension, and a Von Mises model was used for the steel sheeting and perfobond.

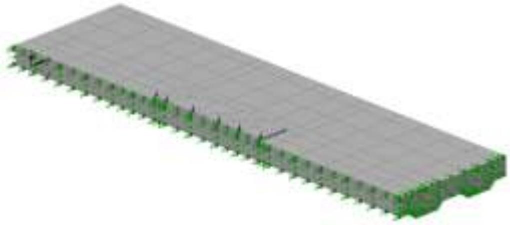

Fig 1. Finite Element Model

In order to simulate the interaction between steel profiled and concrete and due to crack propagation, the three dimensional interface element is selected for the numerical study. This element is adequate for modelling bonded joints or contacts where delamination and crack propagation is likely to occur. The material specification which was used for interface element is indicated in Table 1.

Table 1. Material Specification of Interface Element

Description	Value
Fracture Energy	4,000 N/m
Initiation Stress	2,500 N/m2
Relative Displacement	0.75x10-8

For loading condition according to the experimental study, two global distributed loads are applied on the top of FE model surface through a 20mm thickness timber plate with dimension of 250 mm × 500 mm. Load increment procedure is set in software to simulate the real loading condition and to reduce the elapsed time of the analysis. The unit load was applied in the vertical direction near to shear span (Ls= L/4) which is around 875 mm from support. The starting load factor set as 1N and slab was loaded up to the maximum load factor or until the maximum number of increments achieved.

IV. ANALYSIS AND DISCUSSION

As indicated in Fig 2. in FE model the ultimate load of proposed composite slab is about 1199 KN which is compatible with the experimental result 1211 KN. The vertical displacement at mid- span of proposed slab in experimental observation at ultimate load is 27.3 mm while the numerical model displacement is around 28.6 mm at mid-span. The results are summarized in Table 2.

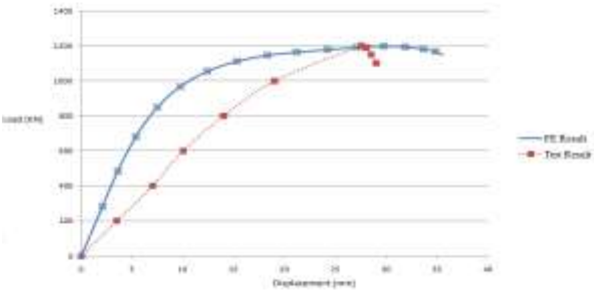

Fig 2. Comparison of FE model and Experimental Test Result

Table 2. FE results and Experimental results for Composite Slab

Description	FE Result	Experimental Result
Ultimate Load (KN)	1198	1211
Displacement at mid span(mm)	28.6	27.3

Five composite slabs with various thicknesses of concrete and the same material properties of sample have been modeled to investigate the effect of concrete thickness on displacement at mid-span of deck. The thicknesses of the slabs were analysed is 165 mm, 180 mm, 200 mm, 250 mm and 270 mm. According to the analysis, the five composite slabs with various thicknesses of concrete were failed under the vertical loading which was caused increasing of the cracks at the interface between steel sheeting and concrete. Results showed that, the thickness of concrete is significant factor on the vertical displacement at mid span. In additional the horizontal shear resistance of the composite slab is changed directly by changing the thickness of the of the composite steel-concrete deck slab.

The horizontal shear resistance of composite decks can be estimated by using a semi-empirical method, so-called the m-k method [5, 6]. For this case of study, the width of composite slab is 1000 mm as b and the Ls is equal to 875 mm (L/4), also dp which is the depth form top of the deck to centroid of the steel sheeting, k and m factor are obtained from the test data as 0.1936 and 0.0008, respectively. According to the equation, the value for the this composite slab is around 0.83 N/mm2 which is approximately 1.9 times greater than the required horizontal shear strength of 0.44 N/mm2 .

V. DEFLECTION OF COMPOSITE SLAB

The maximum deflection is occurred in the middle of composite slab deck. The deflection of composite slabs with the thickness of 165 mm and 200 mm, which have been obtained from the FE models, were indicated in the Fig 3 and 4.

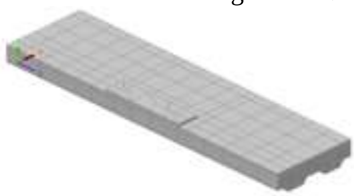

Fig 4. Deflection of Composite Slab with 165mm Thickness

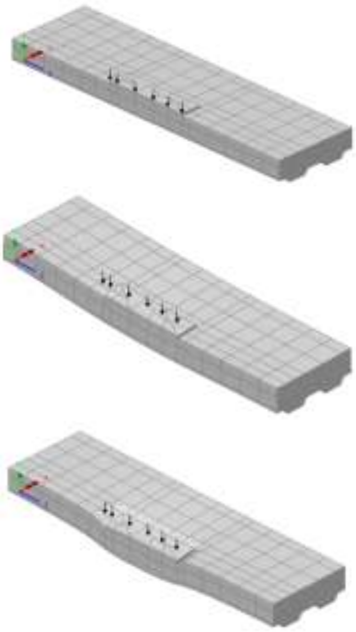

Fig 5. Deflection of Composite Slab with 200mm Thickness

VI. CONCLUSION

- In this study, the deflection of slab with perfobond rib as a shear connection system under vertical loading has been studied. The results show that the thickness of concrete has significant effect on the deflection at mid-span. When the thickness of concrete in slab increased the deflection at mid-span decreased accordingly.
- The horizontal shear resistance in the slabs with different thicknesses is more than the required shear resistance based on Euro code Part 4 [7] and all of them are in the safe range.
- The interface element properties are depending on the geometry of the composite slab. In this case of study, an appropriate interface element in numerical modelling by LUSAS software has been proposed to model the shear bond between the concrete and steel sheeting for the composite slab system.

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