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Composite Slab with Profiled Steel Deck

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Abstract

Composite slabs consist of profiled steel deck with reinforced concrete topping. The decking not only acts as a permanent formwork to the concrete, but also provides sufficient shear bond with the concrete and acts compositely. In recent years, the composite slabs are preferred due to light weight, low cost construction and ability to defend the natural disasters. The paper presents the recommendations given by British Standards and Euro codes to use profiled steel deck in composite slab. It also includes the test results of the researchers in composite slab along with shear connectors.

Keywords: Composite Slab, Concrete, Profile Sheet, Shear Connectors

1. Introduction

The use of steel deck as a structural panel element in the construction of composite floors started from 1950's as shown in Fig.01. It consists of a profiled steel deck with a concrete topping and light welded mesh reinforcement. Light welded mesh reinforcement acts as tensile reinforcement, controls cracking, and also resist longitudinal shear. The mechanical interlocking is provided by shear connectors in the deck profile which provides the resistance to vertical separation and horizontal slippage between steel and concrete. The overall weight of the structure is considerably reduced by these composite deck floors. The steel decking has to resist the weight of the concrete, reinforcement and temporary loads during the concreting process. Composite action is obtained by shear bond and mechanical interlock between the concrete and the decking. Following two situations are considered in the design of profiled steel deck,

A) Profiled steel sheets only as shuttering,

B) Composite slab of Profiled steel deck along with concrete

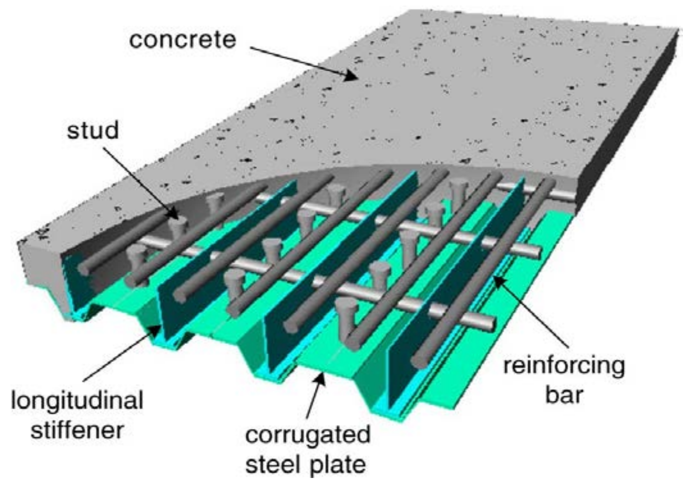

Fig.01 Steel–concrete composite deck

2. Literature review

In the review, research papers of composite slab are referred and studied. Some of the reviews are as follow

Sameh S. Badie; Maher K. Tadros; Hussam F. Kakish; Darin L. Splittgerber; Mantu C. Baishy[5], tested 20 push-off specimens for ultimate strength investigation, 25 push-off specimens for fatigue resistance investigation, and one full-scale beam. The headed steel stud system is the most commonly used shear connector used in structures. Two sizes of studs, 19.1 mm and 22.2 mm diameter are generally used. Here instead of using 19.1 mm and 22.2 mm diameter shear studs researchers have used 38.1 mm diameter shear studs. Study shows the development and application of 31.8 mm studs to steel girder bridges. The use of the 31.8 mm studs will significantly reduces the number of studs needed to achieve full composite action with the concrete deck. This will increase construction speed, ease deck replacement, and reduce the possibility of damaging studs.

W. samuel Easterling and Max L Porter[6] tested 32 composite diaphragms and 112 elemental specimens in two phases of research program. Test results show that the composite diaphragms exhibited brittle inelastic behavior. The diaphragms do not sustained maximum load levels with increasing in-plane displacements. Use of reinforcement or wire mesh or deformed bars improve the ductility of diaphragm which the control the strength by diagonal tension cracking in the concrete.

Hyeong- Yeol Kim, Youn-Ju Jeong [4] tested two full-scale deck slab specimens to evaluate the ultimate strength of the proposed deck system under the action of moments. The initial concrete cracking load and the ultimate load-carrying capacity of the proposed deck system is 230% and 220% greater than the values of an RC deck slab, respectively. Also the proposed deck system weighs about 23% lighter than the RC deck system.

Hyeong - Yeol Kim, Youn Ju Jeong [3] tested eight full-scale deck specimens for horizontal shear capacity of the deck system. The capacity of the shear connectors used in the steel concrete composite members can be identified by the standard push-out test. Study shows that the ultimate strength of the proposed deck system under sagging and hogging bending actions is 20% less than that of a simply supported deck. The profile deck system has initial concrete cracking load and ultimate load-carrying capacity about 7.1 and 2.5 times greater than that of RC deck system. Its weight is also about 25% less than that of RC deck system.

Youn-Ju Jeong, Hyeong-Yeol Kim, Sang-Hyo Kim [7], conducted push- out tests to examine the behavior of steel–concrete interface with the degree of interaction and to consider the effect of the degree of interaction. Three different spaces of stud were selected as 150, 250, and 450 mm. The flexural test consist of deck specimens of 1.0 m width with two different lengths of 2 and 4 m. Tests show that the degree of interaction has significant influence on the ultimate load but the degree of interaction on the relative slip is not influential. Hence as the degree of interaction is higher, the ultimate load and the initial tangential stiffness get inclined to increase.

3. Codal recommendations for composite slab with profiled steel deck.

A) BS 5950 Part -4[1]

In British standard, only M-K method is used for analysis and design. The steel used to make profiled steel sheet should have minimum specific yield strength 220 N/mm^2 and according to BS 1449 Part- 1, or BS 2989.

Slab Thickness and aggregate size

The total Depth of Composite slab D_s should not be less than 90 mm. The thickness of concrete (D_s – D) above the main flat surface of top of the ribs of sheeting should not be less than 50 mm subjected to cover of not less than 25 mm above any shear connection. The nominal size of aggregate H_{agg} is depends on the smallest dimensions in the structural element within which the concrete is poured and should not be greater than the least of 0.4 (Ds – D) or $b_b/3$ or 30 mm

Deflection limit of profiled steel sheet and composite slab

The deflection of the sheeting under its own weight plus the weight of wet concrete but excluding the construction load should not exceed,

(a) The lesser of L/180 or *Ds/10* when the effect of ponding is not taken into account;

(b) L/130 when ponding is taken into account, i.e. the weight of additional concrete is included in the design of the floor and supporting structure;

Where, L is the effective span between supports.

The deflection of the composite slab should not normally exceed the following limits:

(a) 103d or *L/350* or 20 rnrn, whichever is the lesser;

(b) *L/250* for the self -weight of the slab plus, when props are used, the deflection due to prop removal.

Vertical shear capacity and punching shear

The vertical shear capacity, Vv of a composite slab over a width equal to the distance between centers of ribs should be determined from either of the following expressions, as applicable:

(a) for open trough profile sheet

$$V = b_a\, d_{\$ €s}\, v_c \quad (1)$$

(b) for re-entrant trough profile sheet

$$Vv = b_b\, d_s\, €s\, v_c \quad (2)$$

where from, *ba* is the mean width of il trough of open profiles, *bb* is the minimum width of a trough of re-entrant profiles, ds is the effective depth of the slab to the centroid of the sheet and from CP 110: Part 1 : 1972, €s is the depth of slab factor, *Vc* is the ultimate shear stress in concrete or for lightweight concrete, The punching shear capacity *V*p of a composite slab at a concentrated load should be determined from *V*p = Cp *(Ds - D) € s vc*, Where, Cp is the critical perimeter. If the design shear or concentrated design load exceeds the above values, the composite slab should be increased in depth.

Moment capacity: composite slab

The moment capacity M_{es} of any cross section should be determined assuming rectangular stress blocks for both concrete and steel sheeting. The stresses should be taken as $0.4f_{eu}$ for concrete. P_y for the sheeting and O.87fy for any bar or mesh reinforcement. Unless the slab has compression reinforcement, the depth of the stress block for the concrete should not exceed 0·5ds.

B) Euro code 4[2]

Euro cade uses both M-K method and partial interaction method for analysis and design. The profiled steel sheet shall be capable of transmitting horizontal shear at the interface between the sheet and the concrete.

Slab thickness, reinforcement and Aggregate

The overall depth of the composite slab shall not be less than 80 mm. The thickness of concrete slab above the flat surface of the top of the ribs of the sheeting shall not be less than 40mm. If the slab is acting compositely with the beam or is used as a diaphragm, the total depth shall be not less than 90 mm and concrete depth above concrete shall not be less than 50 mm. Transverse and longitudinal reinforcement shall be provided within the depth he of the concrete. The amount of reinforcement in both directions should not be less than $80mm^2/m$. The spacing of the reinforcement bars should not exceed 2h or 350 mm, whichever is the lesser. The nominal size of the aggregate depends on the smallest dimension in the structural element within which concrete is poured, and shall not exceed the least of 0.40 h_c , or $b_o/3$, where b_o is the mean width of the ribs (minimum width for re-entrant profiles) or 31.5 mm.

Deflection limit

The deflection may be determined using the following approximations: The appearance and general utility of the structure could be impaired when the calculated sag of a beam, slab or cantilever subjected to quasi-permanent loads exceeds span/250. The sag is assessed relative to the supports. Upward deflection in the formwork should not generally exceed span/250. Deflections that could damage adjacent parts of the structure should be limited. For the deflection after construction, span/500 is normally an appropriate limit for quasi-permanent loads. For external spans, no account need be taken of end slip the initial slip load in tests defined as the load causing an end slip of 0.5 mm exceeds 1.2 times the design service load. Where end slip exceeding 0.5 mm occurs at a load below 1.2 times the design service load, then end anchors should be provided.

Vertical shear and Punching shear

The vertical shear resistance $V_{v,Rd}$ of a composite slab over a width equal to the distance between centers of ribs The design value for the shear resistance $V_{Rd,c}$ is given by:

$$V_{Rd,c} = [C_{Rd,c}\, k(100\, p1\, f_{ck})^{1/3} + k1\, \sigma_{cp}]\, b_{wd} \quad (3)$$

with a minimum of

$$V_{Rd,C} = (V_{min} + k_1\, \sigma_{cp})\, b_{wd} \quad (4)$$

where: f_{ck} is in MPa , $k = 1 + \frac{\sqrt{200}}{d} \leq 2.0$ with d in mm , $p_1 = \frac{Asi}{bwd} \leq 0.02$, Asi = the area of the tensile reinforcement, which extends 2 (I_{bd} + d) beyond the section considered, B_w

is the smallest width of the cross-section in the tensile area [mm], $\sigma_{cp} = \frac{Ned}{Ac} < 0.2\ f_{cd}$, N_{ed} is the axial force in the cross-section due to loading or prestressing, Ac is Area of concrete., $V_{Rd,c}$ is the design value of the punching shear resistance of a slab without punching shear reinforcement along the control section considered, $V_{Rd,cs}$ is the design value of the punching shear resistance of a slab with punching shear reinforcement along the control section considered, $V_{Rd,max}$ is the design value of the maximum punching shear resistance along the control section considered.

Flexure

In case of full shear connection the bending resistance M_{RD} of any cross section should be determined by plastic theory in accordance with but with the design yield strength of the steel member (sheeting) taken as that for the sheeting fyp,d. In hogging bending the contribution of the steel sheeting shall only be taken into account where the sheet is continuous and when for the construction phase redistribution of moments by plastification of cross-sections over supports has not been used

3. Conclusion

Many researchers have studied the behavior of profiled steel decking composite slab and predicted lots of result on the basis of analytical or experimental investigations. In this paper the literature of such researchers is studied and also the provisions given in Eurocode and British codes are mentioned by which we can conclude that,

1. European code gives the access to design the composite slab by M-K method or partial interaction method for design but British standard is based on the M-K method only.
2. By literature the initial concrete cracking load and ultimate load-carrying capacity of the profiled deck system is greater than the RC deck slab.
3. Codal provisions are based on experimental investigations the finite element analysis of composite deck slab with nonlinear contacts between the profile deck , shear connectors and concrete.

Reference

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