Journal of Building Engineering 9 (2017) 1–9

Contents lists available at ScienceDirect

Journal of Building Engineering

journal homepage: www.elsevier.com/locate/jobe

Composite slab strength determination approach through reliability analysis

Kachalla Mohammed[a,b,*], Izian Abd Karim[a], Rasheed Abed Hammood[a]

[a] Civil Engineering Department, Universiti Putra Malaysia, 43300 Serdang, Selangor, Malaysia
[b] Civil and Water Res. Engineering Department, University of Maiduguri, Maiduguri, Borno State, Nigeria

ARTICLE INFO

Keywords:
Partial shear connection
Reliability
Composite slab
Longitudinal shear
First order reliability method
Strength test

ABSTRACT

The economic use and ease of construction of profiled deck composite slabs faces the challenge of complex and costly strength determination procedures. This is through the longitudinal shear strength determination that shows the level of composite action between the decking sheet and concrete, and a number of methods are available for its determination; the partial shear method is one such method. The Eurocode design provision requires experimental procedures in establishing the shear strength parameter. However, the cost and time constraint associated with the strength verification is a critical issue of major concern that is currently receiving attention. This study proposes to address these challenges by implementing a rational based approach in developing a numerical function for profiled composite slab strength devoid of experimental procedure. The developed methodology is from reliability-based analyses of longitudinal shear load carrying capacity of profiled deck composite slab from partial shear connection method to Eurocode provision. The proposed methodology results indicate good agreement with the performance of full-scale experimental tests.

1. Introduction

The use of profiled deck composite slab in the construction industry has many advantages including the simplicity in construction compared to other flooring system. The profiled sheeting serve's as shuttering by shouldering wet concrete during construction stage, for example. This composite construction method gained popularity for eliminating time-consuming erection and subsequent removal of temporary forms [1–3]. The composite action between the profiled sheeting deck and the hardened concrete will come into play with effective development of longitudinal shear at the steel-concrete interface. Several studies [4–7] shows the behaviour of profiled deck composite slab is affected by the bond failure in the longitudinal direction. Intuitively, longitudinal shear capacity determines the ultimate strength of profiled deck composite slab. [8].

The use of bonding adhesion or mechanical interlock greatly enhances the shear resistance between steel sheeting deck and concrete [9,10]. The metal deck embossing provides equivalent shear resistance characteristics for effective composite action between sheeting deck and hardened concrete similar to those mentioned previously [9,11]. A number of factors are known to affect the longitudinal shear capacity; for example the type and level of embossment, the steel strain, shear span length, etc..[10], and these hinders the deterministic based strength capacity model development for profiled composite slab (PCS). Besides those factors, the shear strength parameters are determined only after the capital-intensive laboratory procedures, and this could be through the slope-intercept, the partial shear connection (*PSC)* methods amongst others. These drawbacks constitute a serious challenge in developing a numerical strength determination model considering the associated random variabilities [12]. Despite several research attempts [13–15], the complex interface between profiled sheeting deck and the concrete hinders the much needed breakthrough in the development for simplified procedure for strength determination of profiled deck composite slab using PSC method. The objective of this probabilistic study is to define the safety bounds, and develop a simplified numerical model for determining the shear strength parameters for PCS devoid of expensive laboratory works.

2. Reviews on alternate means to laboratory test of composite slab strength determination

Several numerical approaches were developed in order to replace the uneconomical and complex strength verification of composite slab. The strength behaviour of PCS depends on the horizontal shear bond, and it is influenced by the steel deck shape, embossing frequency, load arrangement, shear span length, mechanical friction and type of end

* Corresponding author at: Civil Engineering Department, Universiti Putra Malaysia, 43300 Serdang, Selangor, Malaysia.
E-mail addresses: engrkachalla@gmail.com (K. Mohammed), izian_abd@upm.edu.my (I.A. Karim), Rasheed_eng2000@yahoo.com (R.A. Hammood).

http://dx.doi.org/10.1016/j.jobe.2016.11.002
Received 28 June 2016; Received in revised form 4 November 2016; Accepted 4 November 2016
Available online 10 November 2016
2352-7102/

anchorage [16]. Literature finding shows the difficulties in providing strength determination function applicable to all composite slabs because of those strength-influencing factors. Hence, the need to depend on full-scale experimental test is unavoidable. Abdullah and Samuel Easterling [16], proposed new method for modelling composite slab horizontal shear capacity that takes in to account the slab slenderness as a major shear influencing parameter. The author's uses force equilibrium method in determining the shear bond-end slip behaviour of the composite slab in bending. The result shows that the shear bond varies with the slenderness in bending. Furthermore, the authors use finite element analysis with the aim of replacing uneconomical and time-consuming full-scale test on composite slab, but those factors affecting the shear bond capacity hinders in getting effective results due to lack of quantitative information on them.

Furthermore, in a related numerical finite element modelling study, the simulation results for long slab resembled true slab performance. However, comparative behavioural analysis using short span shows significant variations between modelled and the real slab behaviour [14,17]. Generally, in the critics of FE analysis application for shear bond capacity determination for PCS (geometry dependent) requires full scale experimental test data before utilizing for the modelling, as such FE modelling is still considered uneconomical [16]. To augment this drawback there is a need to use a different numerical approach in finding solution to the problem, and reliability method is one good option other than finite element approach. Therefore, in this paper, this study focuses on application of reliability method on the load carrying capacity of PCS, and this will steer the direction for the development of numerical strength determination function for PCS.

Literature related to reliability studies on the performance of composite slab is scant [2], very few areas is indeed covered. Much recently, Degtyarev [2] presented reliability based analysis of composite slab at construction stage to US design provision. The author investigated the failure analysis using allowable stress design and load resistance factor design using First Order Reliability Method (FORM). The results showed high level of conservatism in the US design provision for the composite steel deck design, and this led to proposals for modifications of the construction load requirement for that code. This paper consideration for the PCS performance function is on the longitudinal shear capacity design in accordance with *EC-4* provision employing the use of FORM in determining the safety performance. Similarly, from number of statistical judgement (*p-value*) while analysing this study results, a sequential scheme will led to the development of numerical strength load function. This sequence includes the performance function value, the metal deck strength and dimensions characteristics, for example. Afterwards, this study designed experimental test for the validation of the numerical strength determination function.

3. Longitudinal shear capacity of profiled deck composite slab

Design strength verification for composite slab found in code of practice is complicated and largely uneconomical because of the mandatory laboratory procedures that are required for the determination of its strength parameter [1,3]. The EC4 [18] provides a general guide for the bending resistance calculation for composite slab, the *m-k* or the partial interaction method are widely use. The study explores the use of PSC method in the determinations of longitudinal shear resistance parameter for the PCS.

3.1. Partial connection method

Partial connection method can be used to obtained longitudinal shear strength of PCS, where complete re-distribution of longitudinal shear is assumed between the sheeting deck and the concrete interface [19]. The degree of shear connection, ξ (N_c/N_{cf})defines the level of re-

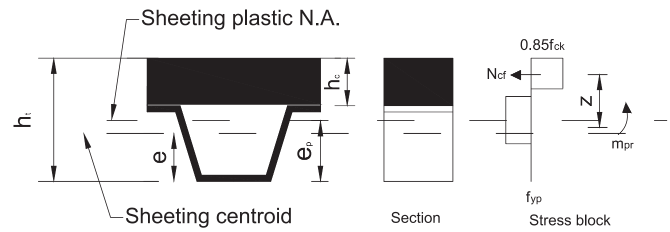

Fig. 1. Typical stress-strain diagram under PSC method.

distribution; $\xi = 0$ signifying no composite action and $\xi = 1$ for full shear connection while slip and strain are assumed to be zero, ξ value between 0 and 1, signifies partial shear connection between the sheeting deck and the concrete.

Johnson [20], developed the formulae for longitudinal shear, τ_u for a given value of bending resistance as shown using Eq. (1).

$$\tau_u = \frac{\xi_{test} N_{cf}}{b(l_s + l_o)} \tag{1}$$

Where l_o and l_s are the overhang and shear span lengths for a given width, b of profiled sheeting deck having a yield force, N_{cf} computed from Eq. (2). The parameter ξ_{test} is the degree of shear connection. The design shear strength $\tau_{u,Rd}$ is from the experimental test results by dividing characteristic strength, $\tau_{u,Rk}$with a partial safety factor of 1.25. The minimum value reduced by 10% gives $\tau_{u,Rk}$ [21].

$$N_{cf} = 0.85 A_p f_{yp} \tag{2}$$

Fig. 1 shows the stress-strain diagram under PSC method where the compressive force, N_c is less than or equals N_{cf}, hence, the bending resistance determination is highly dependent on the neutral axis, $N.A.$ position within the system determined from the stress block depth,x given by the expression in Eq. (3).

$$x = \frac{N_{cf}}{0.85 f_{ck} b} \le h_c \tag{3}$$

In Eq. (3), the concrete thickness, $h_c \ge 40$ mm, aimed at controlling the minimum fire protection requirement. Hence, the design bending resistance, $m_{p,Rd}$ is

$$m_{p,Rd} = N_{cf} z + m_{pr} \tag{4}$$

The plastic moment of resistance, m_{pr} and the lever arm, z in Eq. (4) are as follows

$$m_{pr} = 1.25 m_{pa}(1 - \xi) \le m_{pa}$$
$$z = h_t - e_p - 0.5x + (e_p - e)\xi \tag{5}$$

Where m_{pa} plastic moment of resistance of the profile deck, $e$and $e_p$are the centroid distance and the plastic neutral axis above the base, respectively (see Fig. 2). The EC4 specification for PCS thickness h_t should not be less than 80 mm, and this study experimental specimen thickness value is 120 mm.

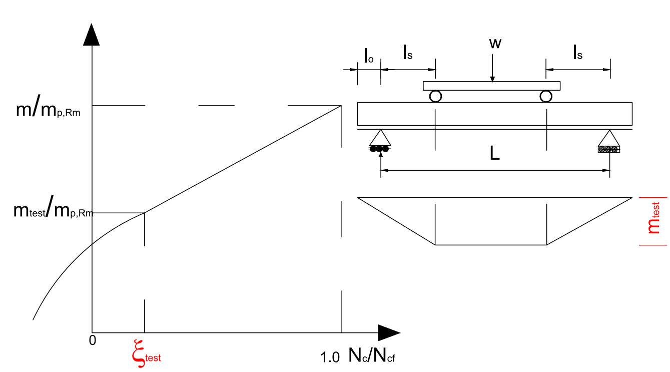

Fig. 2. Typical PSC interaction curve.