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IMPROVEMENT IN LONGITUDINAL SHEAR CAPACITY ESTIMATIONS DIFFERENCE FOR PROFILED COMPOSITE SLAB

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Abstract
Slope-intercept and partial shear connection methods are two known methods for the determination of the longitudinal shear capacity of profiled composite slab (PCS). The shear value estimations from these two methods shows conflicting values with a very high difference (26%), and this constitutes a serious challenge coupled with the lack of a simplified PCS strength determination approach devoid of the costlier experimental procedure. These drawbacks have led to the development of rational-based numerical technique for the two longitudinal shear estimation methods. Hence, this paper presents improvement in the performance of the two the methods in determining the longitudinal shear capacity of PCS. The consideration of the section compactness and the decking characteristics in the formulation of the modified strength determination functions resulted in reducing the estimation differences between those methods to about 12% from 26%, with an average deviation of about 3%. Certainly, this work contributes to the existing knowledge for composite slab strength determination by providing a simpler and effective method for its strength evaluation.

Keywords: Slope-intercept; Partial connection; Longitudinal shear; Profiled Composite slab

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 serves 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 (Abdullah *et al.*, 2015; Chen, 2003; Degtyarev, 2012; Gholamhoseini *et al*, 2014; Marimuthu *et al*, 2007). However, the composite slab design and strength verification process in *Eurocode* is complex and largely uneconomical because of the mandatory laboratory procedures that are necessary in determining its strength parameter (Gholamhoseini *et a.*, 2014; Marimuthu and Seetharaman, 2007). These parameters are determined either through the slope-intercept (m-k) or partial connection methods, and the results from these methods are always conflicting (Abdullah *et al*, 2015; Hedaoo *et al*, 2012). Literature shows several studies aimed at simplifying the complex strength verification and improvements in the estimation difference between the two methods (Abbas *et al*, 2015; Abdullah *et al*, 2015; Crisinel and Marimon, 2004). However, because of a number of factors that affect the longitudinal shear capacity estimation for this composite construction system, it greatly hampers the much-needed development in simplifying the strength test methods variations through deterministic approach. These drawbacks have led to the development of a rational numerical technique for the two longitudinal shear estimation method (Mohammed, 2016; Mohammed *et al*, 2017). Hence, this paper presents improvement in the performance of the two methods in determining the longitudinal shear capacity of composite slab.

2. Literature Review

Ultimate strength governs the design of profiled composite slab (PCS), but shear bond strength defines its capacity (Marčiukaitis *et al*, 2006). The shear bond strength analysis is from shear bond failure (Figure 1) that constitutes one of the three known failure modes associated with composite slabs, while flexure and shear at support are the other failure modes (Gholamhoseini *et al*, 2014; Marimuthu and Seetharaman, 2007). The determination of PCS shear capacity is with the use of shear bond equations that requires an experimental test results. Such procedures include the slope-intercept and the partial shear connection (PSC) methods. Despite the several studies (Abdullah *et al*, 2015; Tsalkatidis and Avdelas, 2010) on the complex shear characteristics of PCS, the un-economical laboratory performance testing is still a reliable factor in the determination of composite slab strength. Additionally, significant literature have shown a wide strength load variation (about 26%) as well as conflicting results in longitudinal estimation from those two methods (Abdullah *et al*, 2015; Hedaoo *et al*, 2012). A potential consequence may arise in selecting the wrong strength estimation method between those two methods that may lead to PCS strength load underestimation.

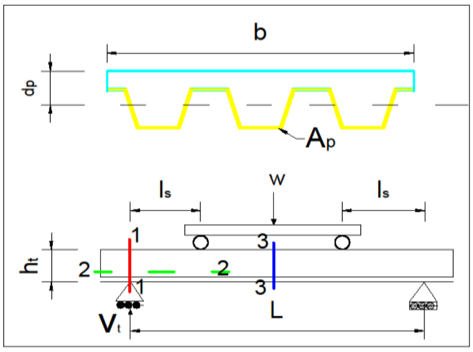

Figure 1: PCS Failure Regions (Mohammed, 2016)

Similarly, a number of issues are known to affect the longitudinal shear capacity; for example, the type and level of embossment, the steel strain, shear span length, among others (Tzaros *et al*, 2010). These issues have greatly constraint the development of deterministic-based strength capacity for PCS that will replace the current challenge of uneconomic strength determination method and bridging the wide difference in its strength determination using the two aforementioned methods. Therefore, the capital-intensive, time-consuming PCS strength test and its longitudinal shear capacity determination method became a major issue.

Existing schemes to mitigate the differences suggest the inclusion of the variables of concrete thickness and shear span considerations to the other method amongst the two methods (Abdullah *et al*, 2015). However, the suggested working framework still lacks the alternate solution to the challenging and costly laboratory procedure required in determining the shear parameters. This necessitates the need for a framework that will improve on the longitudinal shear estimation variations from the two methods and the development of a numerical PCS strength determination function devoid of costly laboratory work. Although, a finite element method is one of the widely used alternate numerical method against the current costlier laboratory procedures for composite slab strength determination but some limitations make its results unsatisfactory. Hence, the main challenges in PCS strength determination are longitudinal shear value differences from the two methods, and the expensive laboratory procedure requirement. Therefore, solving these challenges through a more rational-based numerical approach leads to the development of a numerical strength function within the framework of both longitudinal shear estimation methods.

A recent presentation on a developed numerical strength determination function for PCS under PSC showed promising results (Mohammed *et al*, 2017). The study showed a close agreement between the experimental test values and model estimation values. There is a similar function development for application using the *m-k* method (Mohammed, 2016). Deterministically, evidence in literature shows a clear strength estimation disparity between these methods (Hedaoo *et al*, 2012; Marimuthu and Seetharaman, 2007). Therefore, how are these developed strength functions performing in bridging the strength values estimation difference? This forms the key question that this paper wants to provides the answer.

3. Materials and methods

This study methodology comprised of two major sections. The first section gave an overview of the development of the numerical strength determination function for the two longitudinal methods, while the other section accounts for the literature specimen details considered in this paper. This specimen details are necessary inputs in determining the strength function using either methods.

3.1 PCS Strength function

The development of a PCS numerical strength testing method devoid of the costlier experimental procedure was through implementing a sequential procedural approach highlighted in the following section.

- Safety performance analysis against the load ratio $l_r = f_{tl}/\zeta_{dl}$ function. The parameters f_{tl} and ζ_{dl} represent failure test load and design load, respectively.
- Safety value range determination to upper and lower value guided by the section slenderness d_p/l_s function. These bounds are delineated through $l/6$ and $l/8$. Hence, taking in to consideration the sheeting deck cross section A_p and its yield value f_{yp}, a strength function $\varpi = A_p f_{yp} d_p / l_s$ were formulated, and this is applicable for both longitudinal shear estimation methods.
- Then, the establishing of probabilistic performance function with respect to the defined l_r function led to the definition of new longitudinal based safety benchmark, and the determination of the equivalent load ratio f_{lr} factor.
- A statistical-based numerical relationship analysis between ϖ parameter and ζ_{dl} considering the l_r function would give the strength load function. This contains the deck characteristics by taking in measures that include safety performance and the design load. All judgement and decision leading to the formulation of the numerical strength determination model are supported fully with sound-closed form statistical evidence.

Hence, the above sequence led to the development of numerical strength load functions for predicting PCS performance for both *m-k* and PSC as shown by Eq. (1) and (2) respectively.

$$FTL_{m-k} = 0.001\zeta_{dl} f_{lr} l \qquad (1)$$

$$FTL_{psc} = 0.41\left(\frac{A_p f_{yp} d_p}{l_s} - 3.1\right) \qquad (2)$$

Detailed formulations of these functions are found in literature (Mohammed, 2016; Mohammed *et al.*, 2017).

3.2 Test specimen details

This study used a literature specimen details (Gholamhoseini *et al*, 2014) in appraising the performance of those developed functions given in Eqns. (1) and (2). Gholamhoseini *et al*, (2014) conducted experimental testing to determine the behaviours of composite slab using four different decking profiles produced by Fielders Australia ltd. The overall slab thickness was 150 mm, and the span lengths (l) were 3.1 m and 3.4 m. The specimen width (b) was 1.2 m and considered two shear span lengths $(l/4$ and $l/6)$ values. Form the aforementioned literature, the notations designated shows ST (short-term) as the first two letters, while the next two numbers indicated the deck type (57, 55, 70 and 40 for KF57, RF55, KF70 and KF40). The literature provides detailed characteristic of other essential specimen parameters. Similarly, Mohammed (2010) carried out experimental testing to determine the structural composite behaviours and *m-k* value while utilizing crump rubber concrete under two shear span lengths (450 mm and 900 mm). Six-specimens (2.7 m long and 0.6 m wide) having overall profile depth of 54 mm and

A_p is 980 mm^2. Hence, the specimens' profiles serves as input variables in determining the PCS strength capacity devoid of an experimental testing, and further statistical assessment of the performance variations between those two methods.

4. Results and Discussion

A rational approach led to the development of functions capable of predicting PCS behaviour after taking into consideration several issues that hinders the solution through deterministic approach. Hence, Figure 2 shows the PCS predicted strength values under both the *m-k* and PSC methods.

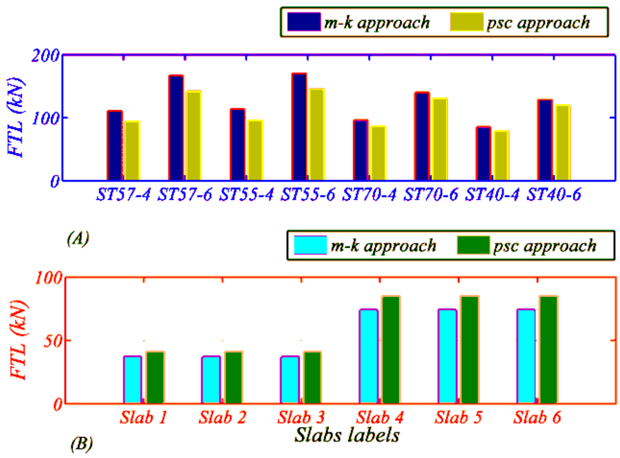

Figure 2 Strength capacity (FTL) values

The literature evidence showed a decrease in load carrying capacity of about 38% with the PSC method, compared with only 12% using the *m-k* approach (Cifuentes and Medina, 2013). Thus, this indicates a difference of about 26% in load carrying capacity between the PSC and *m-k* methods estimations (Marimuthu and Seetharaman, 2007). However, the consideration of the section compactness and the decking characteristics in the formulation of the modified strength determination functions resulted in reducing the estimation differences between these methods to about 12% from 26%, with an average deviation of about 3% (Figure 2).

This shows a significant improvement in reducing the variations in strength capacity determinations between the two methods. The most striking observation to emerge from the comparison was the insignificant difference in the failure test load values $(t = 1.048, dof = 14, p > 0.05)$ and $(t = 0.558, dof = 10, p > 0.05)$. Supportively, a literature similarly demonstrated through a direct comparison of PCS capacity estimates using the two aforementioned, and it showed a near similitude in the estimations from both the improved PSC and m-k methods, respectively (Abdullah *et al.*, 2015). However, use of the improved PSC approach requires two bending test sets, similar to the requirement specified for *m-k* method. On the contrary, this study formulation for PCS strength capacity does not require bending set tests. Yet it can provide quite comparable load carrying capacities from these two methods without the stringent testing. Hence, this paper concludes that the developed numerical strength function will significantly bridge the performance estimation difference between the *m-k* and PSC methods in determining the performance of PCS without the rigors of the costly experimental procedures that posed serious challenges.

5. Conclusion

Lack of simplified strength verification method, and high shear value estimations difference between the slope-intercept (*m-k)* and Partial shear connection (PSC) methods for composite slab constitutes a serious challenge. This paper addresses the challenge by designing a numerical strength testing function for composite slab devoid of the expensive experimental procedure, and evaluates its effectiveness in bridging the high shear value estimations difference between those methods. The developed numerical strength function showed evidence of bridging the significant difference between the *m-k* and PSC methods to 12% from 26% in determining the performance of PCS without the rigors of the expensive experimental procedures that posed serious challenges. However, the result from this study indicates the needs for further improvement on the performance differences between the two methods despite the significant reduction recorded. Certainly, this work contributes to the existing knowledge in determining composite slab strength by providing a simpler and effective method for its strength evaluation.

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