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Experimental Study on Profiled Deck Composite Slab (PDCS) Fitted with Steel Bolt Stud Shear Connectors

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Abstract: *This paper investigates the shear transfer between the sheeting deck and concrete in profile deck composite slab (PDCS). This usually depends on bonding adhesion and/or the use of mechanical interlock for friction enhancement at the interface between concrete and the deck, this can be in form of provision of adequate embossment on the sheeting deck or by use of end anchorage. This study adopt the use of series of stud shear connectors across the entire span of the slab. This was to ascertain the improvement in shear bond failure load, deflection and slip, the result obtained indicates a high potential in shear bond failure load improvement and deflection, slip was not ascertain due to limited number of LVDs. Author recommends further investigation by using various slab thickness.*

Key words: Stud shear connectors; composite slab; profiled metal deck; longitudinal shear

1. Introduction:

Profiled deck Composite slab is a floor system that comprises of normal or lightweight concrete placed permanently over profiled cold-formed steel deck so that they can act as a combined unit. This floor system is now widely used in buildings all over the world, on account of various advantages such as light weight construction, easy handling, speedy construction work, convenient transportation, more strength than the conventional slab and excellent ceiling finished surface. Another advantage of this construction system is the elimination of formwork erection and their subsequent removal (Abbas *et al.,* 2015; Chen, 2003). Upon attainment of full strength, the decking sheet also perform the function of tensile reinforcement, hence the use of positive reinforcement has also been eliminated.

For composite action to take place, the slab and profile deck sheet must transfer longitudinal shear through the interface for which proper interlocking arrangements are required. Several studies (Abbas *et al.,* 2015; Burnet and Oehlers, 2001; Chen, 2003;

Tenhovuori and Leskelä, 1998; Tsalkatidis and Avdelas, 2010) shows that the behavior of profiled deck composite slab is affected by shear bond failure between the decking sheet and the concrete.

Apart from known concerns that influences the PDCS shear bond capacity such as section slenderness Abdullah *et al,* (2015), Metal deck embossing and shear connectors provide shear resistance characteristics for effective composite action between sheeting deck and hardened concrete. However, one vital factor is known to affect the longitudinal shear capacity for this composite construction system; slip at the interface between the decking sheet and the concrete, which is attributed to ineffective bonding between the two material, which always resulted to a lower flexural strength.

2.0. Literature review:

The use of the steel-concrete composite slab system is a common practice especially in the steel framed buildings. The system comprises normal or lightweight concrete placed permanently over a profiled cold-formed steel deck. Compared to the construction of ordinary reinforced concrete slab, the steel-concrete composite slab offers more advantages because the system is lighter and the handling of the steel deck is easier since laborious preparation and placement of reinforcement bars in the slab can be circumvent (chen, 2003; Marimuthu et al., 2007; Degtyarev, 2012; Gholamhoseini et al., 2014; Abdullah et al., 2015). During construction, the deck acts as the mold for the fresh concrete, hence no temporary form is needed. When the concrete hardens, the deck acts as reinforcement for the composite slab system, hence, eliminating the need for positive reinforcement bars.

In general, ultimate strength governs the design of composite slab (Mariukaitis et al., 2006), but shear bond strength defines its capacity. Shear bond failures is one of the three known failure modes associated with composite slabs (Marimuthu et al., 2007; Gholamhoseini et al., 2014), flexure and shear at support are the other failure modes. The formation of tension cracks at the concrete surface characterizes shear bond failure, and this is followed by loss of bonding between concrete and profiled deck because of slippage (Marimuthu et al., 2007).

Composite construction method is faced with several challenges. For instance, the longitudinal shear failure happen before reaching the plastic bending capacity of the composite slab, and this is as a result of inadequate shear connection between the profiled sheeting deck and the hardened concrete. This is primarily due to the fact that ultimate load associated with shear bond loss between the steel sheeting and concrete is low (Tzaros et al., 2010). The attainment of longitudinal shear transmission between steel sheeting deck and concrete depends on either the bonding adhesion or the use of mechanical interlock for friction resistance enhancement between them.

2.1. Longitudinal shear capacity

Several studies show the behavior of profiled deck composite slab is affected by the bond failure in longitudinal direction (Abbas et al., 2015; Burnet and Oehlers, 2001; chen, 2003; Tenhovuori and leskela, 1998; Tsalkatidis and Avdelas, 2010), and steel shear connectors was found to be effective to enhance the shear bond strength of a composite slab (Calixto *et al*., 1998; Chen, 2003; Daniels and Crisnel, 1993; Esterling and Young, 1992). In a conventional design procedure, the longitudinal shear-bond strength of a composite slab is determined based on slabs without end anchorage. Use of studs as end anchorage is normally a construction measure in composite slab systems. Contribution of studs as end anchorage should be considered as an additional contribution to the shear-bond strength of a composite slab and several studies are found on this.

Porter (1984) conducted experimental studies on composite slab with the aim of understanding the behavioral characteristics of studed as distinguished from non studed composite slab, the author tested fifteen specimens. All fifteen specimens were nominally 914mm wide, had an overall thickness of 140mm, and were reinforced with 76mm deep steel deck of either 16 or 20 gage thickness. Specimens were divided into two groups and each consists of studed and nonstuded of various size and corrugation dept. the result shows a significant increase in load-carrying capacity in studed slab. With increase of 8 to 33% in shear-bond strength.

Chen (2003) similarly presented study results on shear bond action in composite slab, where the effects of end anchorage are tested using seven simply supported, one span and two continuous spans. The study shows slab having end anchorage bear higher shear bond strength compared with these slab without steel shear connectors as end anchorage. Its findings further re-affirm that shear bond slip governs the contributions of end restraint than shear stud resistance.

Abbas *et al* (2015) also carried out a study on composite slab using corrugated deck in order to develop new small-scale test method. The author uses two lines of shear connectors welded to both lateral beam and the profiled decking sheet with a view of increasing the contact resistance between decking sheet and the concrete. The test result shows high ductility, and that the end slip is very small compared to composite slab without shear connection.

Though headed stud according to research by Porter and Greimann, 1984; Chen, 2003, Chen *et al.*, 2011 and Abbas *et al*., 2014 was found to be effective in enhancing the shear-bond strength of composite slab, but the authors restricted its use only as end anchorage at the supporting beam. Series of steel bolt stud connectors when placed at the shear span of PDCS is expected to provide additional restrain along the region and therefore improve the bonding effect at the interface, this is considered as the most reliable way of addressing this issue as steel bolts are easier to be fixed on the steel deck without welding. Hence, this research propose to adopt similar model by attaching series of shear connectors along the entire shear span so as to further enhance the shear-bond strength.

When we consider the issue of global warming, erosion, desert encroachment etc. and the volume of timber used as formwork in our present construction practice, This research work when fully explore will provide two efficient solution (in term of cost and environmental issue) to our current challenge of adequate provision of infrastructure to our schools, hospitals and other public places with regard to lower construction cost.

3.0. Materials and methods

The steel sheet deck was attached (welded) with series of 19mm diameter studs, the studs were 750mm in high and placed at the down through of the deck, spaced at 200mm center to center, the slabs were 1000mm in length, 830mm in width, and 100mm in thickness as indicated in fig. 1. The composite Slab was cast with the steel deck as base, and was properly cleaned before concreting. The casting was carried out in fully supported conditions as indicated in fig 2.

The detailing of the steel corrugated deck, and the view of the embossed steel sheet, are shown in fig. 3. All specifications of the model were indicated, see table 1. The concrete was provided using manual mixing (thoroughly mixed) and the proportion of cement, water and aggregate was 1:2:4 respectively. Ordinary Portland cement was used, and the aggregate was fine sand and gravel with maximum grain size of 20mm.Compressive strength and workability were established by conducting compression strength and slump test respectively as shown in fig 4.

The slabs were cast and cured for 7 days as shown in fig 5. After 28 days the slabs were transferred from the casting area to the testing place using adequate supports to avoid flexural deflection.

3.1. Experimental set up

Fig. 6, fig. 7 and fig. 8 shows the view for the experimental set up of the composite deck slab.

The main goal was to measure the maximum load capacity of the composite slab under the limit deflection. Two LVDTs were put under the slab at the mid span as shown in fig 9 and 10.

End slip between the concrete and steel is important but cannot be determine due to limited number of LVDTs, The two LVDTs at the mid span were connected to a data lodger were readings were taken. See fig. 11. The specimen was placed on strong steel supports and the line loading and shear span were marked, shear span is the distance between the center of supports and point of application of the line load. Two line Loads were applied to the composite deck slab across the width of the slab by using two smaller cylinder sections a transfer beam was used between the point load and the cylinders for load distribution. The load was applied at a steady rate until failure occurs.

4.0. Results and Discussion

4.1. Load deflection

As composite slabs were subjected to vertical loading, they are more likely to suffer from longitudinal shear failure which occurs when diagonal cracks develop in close proximity to concentrated loads. Holmes *et al,* (2014), as with this experiment, composite slab test resulted in shear bond failure with the specimen eventually failed due to horizontal separation of the steel deck from concrete as shown in fig 12 and 13. The maximum load and maximum deflection were 100 KN and 15mm. respectively. Load deflection behavior, and flexural strength for the specimen were indicated in fig 00 and fig. 00 this indicates a slight reduction in shear bond failure load as compared to previous research. Chen *et al,* (2011), Abbas *et al,* (2014) and Holmes *et al,* (2014). This was suspected to be as a result of thickness of the section which is 100mm as against 130, 135 and 140mm being used in Holmes (2014), Chen*,* (2011), and Abbas*,* (2014) respectively. Smaller deflection value was observed, although shorter specimen was used, but the rate of deflection was less compared to previous experiments carried out in the literature indicated above.

4.2. Potential advantages of composite slab with series of stud shear connectors along the span.

From the result obtained from this research, it has shown that Composite slabs with series of shear connectors when properly harness will go a long way in solving the problems such as shear bond failure, deflection and slip which were considered common problem with profiled deck composite slab.

5.0. Conclusion

This paper presents a practical application of composite deck slab with series of stud shear connectors along the entire span. Results from this work indicates a higher potentials of this type of deck slab in terms of shear bond strength and deflection.

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List of figures.

Figure 1. profiled sheets fitted with series of stud connectors.

Figure 2. Casting being carried out in fully supported condition

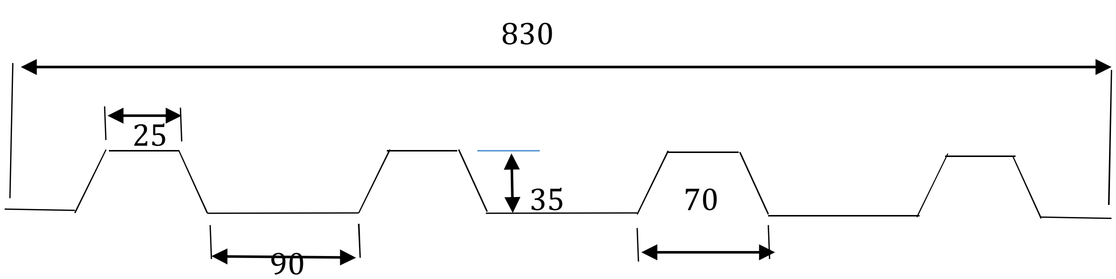

Figure 3. Details of the steel corrugated sheet.

Figure 4. Compressive strength and Slump test

Figure 5. Curing of the slab

Figure 6.

Figure 7.

Figure 8.

Experimental set-up

Figure 9.

Figure 10

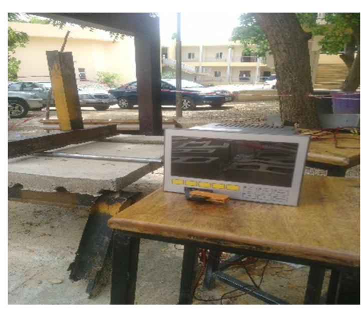

Figure 11.

Taking readings for the load and deflection (LVDs) at the center of the specimen.

Figure 12.

Figure 13.

Shear bond failure of the slab

List of tables

property	symbol	value
Sheet width (mm)	b	830
Slab depth (mm)	h_t	100
Slab length (mm)	L	1000
Nominal thickness (mm)	d_d	0.45
Area of steel (mm^2/m)	A_s	499.14
Stud diameter (mm)	d_o	19
Stud height (mm)	H	75
Stud spacing (mm)	s_s	200