BOND SLIP CHARACTERISTIC STUDY ON COMPOSITE SLAB USING COLD FORMED PROFILED STEEL SHEETING

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ABSTRACT

In the construction sector, cold formed profiled steel sheeting can be employed in place of hot rolled sections due to their excellent advantages such as quality, aesthetic appearance and savings in construction time, material and cost etc. Composite slab comprises of cold-formed profiled steel sheeting with concrete core at top portion or surface. Although it was originally conceived for use as precast slabs, it has lot of potential to be used in conventional slab also. Previous studies revealed that adequate load transfer devices in the form of embossments or other mechanical connections between sheeting and concrete are necessary to effectively utilize the composite action and improve the slab performance. The present investigation aims to develop a new composite slab by using cold formed sections and appropriate interconnection devices. Thus, these composite slabs may serve as an alternative to conventional slabs and therefore, low rise buildings can be constructed using these cold formed profile steel sheeting. The composite slab is designed to take the horizontal shearing forces. The bending action leads to vertical separation between steel and concrete. At present limited experimental studies are available on this subject both at National and International level. Hence, it is necessary to carry out a series of laboratory tests augmented with analytical/numerical studies on the composite slabs to adjudge its reserve strength under various loading conditions.

Keywords: Shear Connectors, Embossments, Shear Bond and Cold Formed Profile.

1. INTRODUCTION

In the construction sector or industry, now a day composite slab have gained popularity as they lend themselves to faster, lighter and economical construction in buildings. Recently, composite sections like composite slab, composite beam and composite column have gained momentum all over the world and therefore many researchers have been carried out on composite members throughout the world. The two generic types of profile used in practice consist of the re-entrant or dovetailed rib and the trapezoidal shape. Stud shear connectors are encased in concrete to transfer maximum load. If not**,** entire slab will fail due to the longitudinal shear between the concrete component and sheet component.

One way to achieve the efficient interlocking between the concrete and steel deck is by means of embossments and shear connectors on the profiled sheets. Generally, two values are used as an indicator to the mechanical bonding between the concrete and the steel sheeting. These values are called shear-bond values (m–k), where 'm' represents the mechanical interlocking and 'k' represents the friction between concrete and the steel deck.

2. EXPERIMENT PROGRAM

The experimental investigation was divided into two groups; each group consisted of three slabs. One group was tested with re-entrant or dovetailed ribs shape and the other group was tested with trapezoidal ribs shape. All the tests were carried out in accordance to BS 5950: Part 4: 1994 and Euro code 4: Part 1.1. The composite slab specimens were simply supported with two equal line loads placed symmetrically at varied distance from the centre line of support. In each group, all the specimens were subjected to static loading until failure occurred. Although, monotonic loading is required to be implemented in the tests prior to the static loading, according to Marimuthu et al., there is a negligible effect of the cyclic loading on the load carrying capacity of the composite slabs. Therefore, cyclic (monotonic) loading was omitted in the testing.

The length of the specimens (L) was 1200 mm, overall depth of the composite slab (ht) was 90 mm and the width (b) was 750 mm. The thickness of the concrete above the ribs (hc) was 45 mm while thickness of the profiles steel sheet (hp) was 1mm. Tests were performed on 2- line supported loading conditions. A nominal reinforcement of 0.1% of the cross-sectional area of the concrete was used for the longitudinal and transverse reinforcement. Mild steel bars with 6 mm diameter and of 250 mm c/c spacing in length wise and 150 mm c/c in width or transverse directions were used in the fabrication of the composite slabs. The rebar was placed at a distance of 25 mm from the surface of the composite slab to allow for proper compaction of concrete.

Uniformly distributed load was applied by a 500kN hydraulic jack via transverse and longitudinal spreader bars. The effective span of composite slab specimens was 1000 mm. For strain measurements, one strain gauge was installed in the composite slab, at the bottom flange of the steel sheeting. For deflection and end slip measurements, two transducers were attached to each end of the composite slab in order to measure the relative slip between the concrete and the steel deck. Mid-span deflection was measured by one transducer placed at the centre of the span in the central trough of the profiled sheeting. Load was applied and measured through a load cell placed at the centre of the specimen.

2.1. CONTACT MECHANISM OF STEEL CONCRETE COMPOSITE SLAB

The shear bond connection between the concrete and the profiled steel deck in composite slabs is highly nonlinear problem as far as boundary conditions, material and geometrical shapes are concerned. The shear bond resistance of the steel to concrete interface is provided by profiled steel sheet, embossments and end anchorage of the composite slabs. Suitable shape of the profiled steel deck and embossments can provide resistance to the vertical separation and the horizontal slippage. End anchorage and similar construction measures would also increase the shear bond resistance of the composite slabs.

When the loading of a composite slab which is transferred to concrete exceeds the tensile strength of the concrete, the concrete will initiate cracks and result in the mechanical interlock mainly due to the embossments of the profiled steel sheeting, to hold the concrete and steel deck together. When a critical loading is achieved, the shear bond is broken and sliding would occur at the interface of the two materials. Further increase of the load will lead to shear bond failure of the composite slab, normally characterized by the development of an approximate diagonal crack under or near one of the concentrated load, followed by an observable end slip between the steel deck and the concrete. Mechanical bond exists due to the physical interlocking between the profiled steel sheeting and the concrete.

2.2. GEOMETRIC VARIATIONS

There were 6 specimens in series 1 as shown in the figure1. The geometric parameter b_r/b_f is shown in the figure1. This parameter was varied over a wide range from 0.25 to 2.00 such that the transition from a dovetailed or re-entrant to a trapezoidal shape factor. Cold formed steel sheet of 1mm thick as a base and with embossments and bolted shear connector was used. Where has b_r, width of opening in bottom was varied, b_f width of sheet in top was not varied and overall height of concrete also not varied.

2.3. DETAILED CROSS-SECTION OF PROFILE SHEETING

Figure 1 depicts the detailed cross-section of profiled sheeting. In this, both the cross-section of the profiled sheeting and the width of opening of bottom (br) were varied whereas the width of the top flange (bf) was not varied. Length of the sheet is 1200mm, breadth of the sheet is 750mm and depth of the concrete is 90mm. Bolted shear connector was used at regular intervals and their height was 45mm.

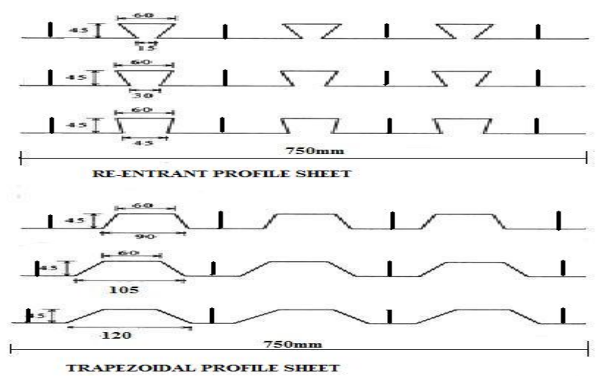

Figure1. Detailed cross-section of profiled sheeting

3. INSTRUMENTATION AND TESTING PROCEDURE

A servo-controlled hydraulic machine of 500 KN was used and the rate of loading was controlled by a constant rate of increment of vertical displacement. The load was applied accurately on the specimen. The boundary conditions at both ends of the slabs were hinged. Each slab was instrumented with LVDTs, for deflection calculation. Strain Gauge was fixed at bottom of the profiled sheets.

3.1. EXPERIMENTAL SETUP

The experimental setup for the slab is shown in the figure 2. The support conditions are hinged support condition and Roller support condition is shown in the figure 3(a) and 3(b) respectively and the strain gauge setup shown in figure 4.

Figure 2. Experimental Setup

Figure 3(a). Hinged Support Condition

Figure 3(b). Roller Support Condition

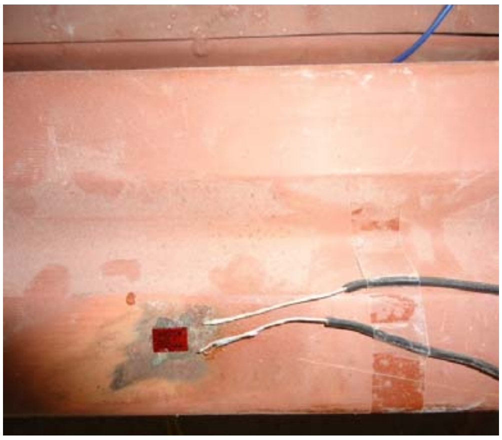

Figure 4. Strain Gauge at bottom of Profile Steel sheet

4. RESULTS AND DISCUSSION

4.1. CRACK PATTERN

The following figure shows the crack patterns which were observed from the composite deck slab testing, Crack pattern for the re-entrant profile steel sheet slab, midspan and slip failure of trapezoidal profile steel sheet slab are shown in figure 5, 6 and 7 respectively.

Figure 5. Crack Pattern of Re-entrant Profile sheet slab

Figure 6. Crack at mid span of Profile sheet slab

Figure 7. Slip of Trapezoidal Profile sheet slab

4.2. MODES OF FAILURE

The following Modes of failure were observed for the composite deck slab testing,

1. Slip was found after the shear connector failure.
2. First crack was formed after the shear connector failed.
3. After the first crack load, the strain drastically varied.
4. Shear Cracks were formed from the flange of profile steel sheet to the top concrete face of the slab.
5. Mid span deflection is more in Re-entrant profile steel sheet slab than the Trapezoidal profile steel sheet slab.
6. Slip is more in Trapezoidal profile steel sheet slab than the Re-entrant profile steel sheet slab.

4.3. LOAD DEFLECTION

The Slab condition while testing is shown in figure 8. A mechanical bonding between the concrete and the steel was observed which indicates full composite action. This mechanical bonding tends to vanish when the testing was carried on due to the deflection of the slab.

First crack occurred late in re-entrant or dovetailed concrete slab as compared to the trapezoidal concrete slabs. First crack was detected at early load stages for the entire trapezoidal concrete slab. After the total loss of the mechanical bonding, the slippage started to increase because the system lost its composite action and there was no longer transfer of stress from the concrete to the steel sheeting. The loss of mechanical bonding was identified by the sound of propping at the load causing the first crack. After the sound of propping, cracks started to spread indicating a partial shear interaction between concrete and steel. Shear cracks started first in shear zone. Large deflection was experienced by the re-entrant or dovetailed concrete slabs. Cracks started to spread towards the centre of the slab as the load increased.

The cracks beneath the two line loads extended to the surface of the slab to finally separate the concrete in most cases and caused excessive slippage at both ends of the composite slabs. At the end of the test, the mechanical interlock totally failed and the spalling of concrete was noticed at certain locations. Consequently, the end slip became high and the deflection reached maximum.

Figure 8. Modes of Failure

4.4. PARAMETRIC STUDY

Table1 depicts the load vs. Deflection of profile steel sheet. In this the variation of re-entrant to trapezoidal profiled sheet is tabulated. The geometric parameter br/bf was varied from 0.25 to 2.00.

Table 1 Load vs. Deflection of Profile Steel Sheet

SPECIMEN	PROFILED SHEET	br/bf	Load (kN/m^2)	Deflection In mm	Slip in mm
1	Re-Entrant	0.25	77.78	28.50	2.64
2	Re-Entrant	0.50	71.44	32.40	2.70
3	Re-Entrant	0.75	66.10	36.55	2.98
4	Trapezoidal	1.50	61.52	38.65	2.92
5	Trapezoidal	1.75	58.45	42.30	3.26
6	Trapezoidal	2.00	56.25	46.25	3.48

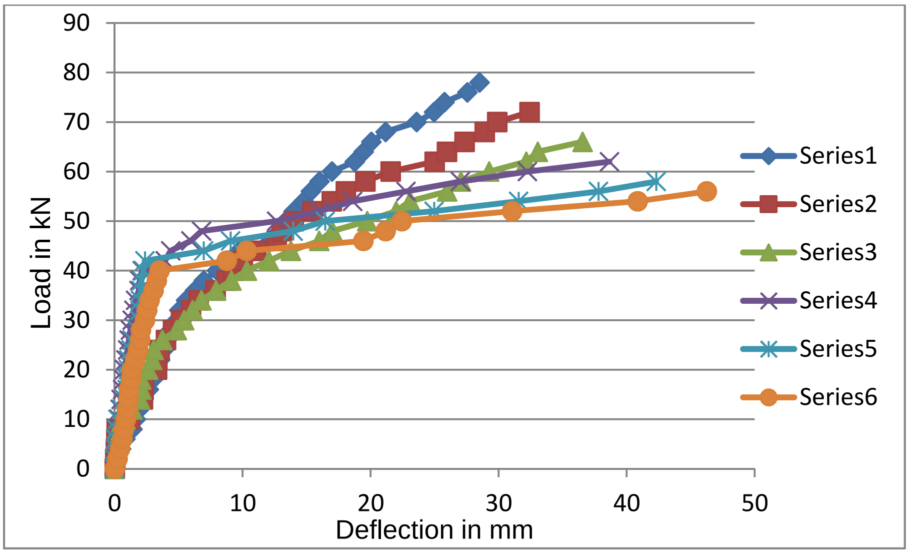

Figure 9.. Load Vs. Deflection

5. CONCLUSION

From the experimental investigation conducted on 6 specimens by varying the profile of the sheeting, the following conclusions are derived:

1. From table1, it can be concluded that the deflection of the trapezoidal profiled sheet is more than the re-entrant profiled sheet. Hence the re-entrant profiled sheet can take more load than the trapezoidal profiled sheet.
2. Considering the shear connector failure of the slab, the re-entrant profiled sheet can withstand more than the trapezoidal profiled sheet after the first stage failure.
3. Comparing the slip failure of the slab, the re-entrant profiled sheet shows lower slip value than the trapezoidal profiled sheet.
4. Finally the ultimate load of the re-entrant profiled sheet is more than that of trapezoidal profiled sheet. So the re-entrant profiled sheet gives better performance than the trapezoidal profiled sheet.

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