Assessment of longitudinal shear strength of Composite deck slab

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ABSTRACT: In the modern construction sector, steel-concrete composite deck slabs have emerged as an alternative to conventional concrete slabs nowadays. The composite construction is lighter, stronger and economical when compared to conventional construction method. The longitudinal shear capacity of the slab determines the ultimate load of the composite slab and is the most prominent failure type in composite slab construction. The profile steel sheeting acts as an external tensile reinforcement in the slab. In this experimental investigation, three types of embossments viz., chevron, rectangular and inclined penetrated are introduced for predicting the m-k curve. Totally six numbers of steel-concrete composite deck specimens are used for the study. For each type of embossments, two numbers of specimens were chosen with two different shear span conditions. The specimens are cast using M25 grade of concrete and using 1 mm thickness of profiled steel sheeting to avoid the shrinkage and creep of the concrete, 8 mm diameter of secondary reinforcements are provided (on top of the profiled sheet). The specimens are subjected to static loading and load capacity was found. As per the regulations of Euro-code 4, the m-k method is used to determine longitudinal shear capacity of the deck slabs. The linear regression analysis was plotted using experimental tests data to predict the m-k value.

KEYWORDS: Embossment, slip, deflection, trapezoidal, profiled sheeting, concrete.

1 INTRODUCTION

In the construction industry, composite decks slabs are widely accepted due to its higher structural performance with minimum utility of materials. The composite deck slab construction involves two materials-concrete and cold form profile steel sheet. The concrete being good in compression and steel being good in tension combine together to act as a single unit to enhance the structural ability of the whole structure. The cold form profile steel sheet is available in many size and shapes of which trapezoidal profiled sheet is one of the popularly used profile in the construction. The shear strength of the composite slab mainly depends upon the longitudinal interfacial shear between the concrete and the cold form profiled sheet. The main type of failure in the composite slab is the longitudinal shear failure. To overcome this longitudinal shear failure, three methods are used. They are mechanical interlocking, frictional interlocking and end anchorage method. In the mechanical interlocking method, embossments or indentation on the profiled sheet are widely used to increase the shear interaction between steel and concrete. Embossments are placed in the crucial portion of the profiled sheet such as web or flange, wherever there are higher chances of slip occurrence between the concrete and the profiled sheet. Embossments are formed in the profiled sheet by press breaking method.

The experimental studies conducted by Ong and Mansurt [1] to determine the shear and capacity of the composite slab with locally available profiled sheet. Under three point loading, ten numbers of one way slab specimens were tested. To predict the empirical relationship between the concrete and steel sheeting, slabs were cast with and without end anchorage method. The author also reviewed the existing design method to find the shear bond capacity and proposed a new empirical relationship.

Marimuthu et al. [2] and Saravanan et al. [3] experimentally investigated the trapezoidal profile steel sheet with embossments. The embossments were provided at the web and flange to enhance the shear capacity of the profiled steel sheet. To evaluate the shear strength of the composite slab, eighteen numbers of composite slabs were cast and tested using two different shear span conditions. The experimental study aimed at improving the longitudinal shear strength of the composite slab by analyzing the optimum m-k value.

Pentti Makelainen and Ye Sun [4] discussed the behavior of particular type composite slab using push out tests. Totally twenty seven numbers of push out tests were carried out with different shape, size and location of embossment. The embossments were provided in the profiled sheet by two methods, one by rolling method and other by punching method. The experimental study concluded that the depth of the embossment is an important factor in determining the shear capacity of the composite slab. Finally the author proposed a new method of profiled sheet with embossment which provides higher longitudinal shear.

Namedo Adkuji Hedaoo et al. [5] analyzed the failure mechanism of the composite slab using static and cyclic loading. The trapezoidal profiled sheet of thickness 0.8 mm is used in this study. The dimensions of the composite slab were 3.0 x 0.83 x 0.12 m. the depth of the profiled sheeting (h_p) and the depth of concrete above profiled sheeting (h_c) was 52 mm and 50 mm respectively. To determine the load carrying capacity and structural behavior of the simply supported slabs, both the static and cyclic loads were imposed. The experimental results were compared and the failure modes were analyzed.

Holomek and Bajer [6] investigated the behavior of composite slabs under different types of loading conditions. The specimens were tested with four point loading and vacuum test. In addition to the full scale testing, small scale testing were performed to analyse the shear behavior of embossed profiled sheet which forms the basis of numerical modelling. The point of loading is the main factor which influences the load carrying capacity.

A.Gholamhoseini et al. [7] conducted experimental and numerical investigation of composite slabs with four different types of deck profile. Two types of loading schemes applied on the composite slab on the slab. It was concluded that the bond slip between concrete-steel interfaces contributes to the failure and flexural capacity of slabs. Comparison of both numerical and experimental test results was satisfactory.

Hajir Satin Abbas et al. [8] experimentally investigated the shear capacity and load carrying capacity of composite slabs. The profiled sheet was corrugated with steel embossments provided on it. Additionally in order to avoid shrinkage and creep in the concrete, mesh reinforcement was provided. Four number of shear studs were anchored in each side of the rib. The experimental study concluded that the load carrying capacity was increased with the addition of shear studs and mesh reinforcement minimized the concrete cracking.

K.N.Lakshminadhan et al. [9] experimentally investigated the shear connection of composite slabs with three schemes of shear connectors provided on the specimen. Three specimens of each type were tested under two point loading conditions. Experimental results were compared with the load vs slip value of composite slab without any shear connectors. The study concluded that the slabs with shear connector exhibited failure mode in ductile manner whereas the slab without shear connector exhibited failure mode in brittle manner.

2   EXPERIMENTAL PROGRAM

2.1   MATERIAL PROPERTIES OF CONCRETE

In the composite slab, the concrete is cast above the cold form profiled sheet. The grade of concrete used in this experimental study is M25, which is prepared using Indian Standards 10262:1982 [10]. To avoid the shrinkage or creep in the concrete, minimum reinforcement of 8 mm diameter is provided on the top surface of the concrete. The composite slab cast is represented in the Fig.1.
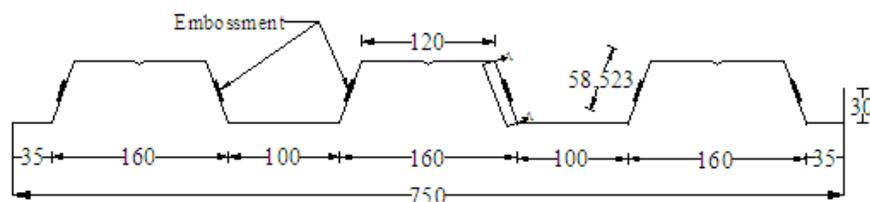

Fig.1.   Schematic view of composite slab

2.2 RECTANGULAR BOX TYPE EMBOSSMENT

The rectangular type embossment was punched onto the profiled sheeting as shown in the Fig. 2. The center spacing between the each embossment is maintained as 65 mm. The embossment also looks like box shape and the dimensions of the embossments are 21 mm x 25 mm is shown in the Fig. 3.
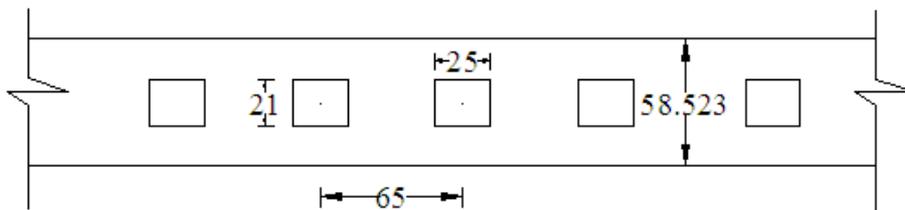

Fig.2.   Rectangular Dishing Type Embossment

Fig.3.   Detailed view of Rectangular Dishing Type Embossment

2.3 CHEVRON TYPE EMBOSSMENT

The chevron type embossment was punched onto the profiled sheeting as shown in the Fig.4. The center spacing between the each embossment is maintained as 85 mm. The embossment also looks like inverted V shape and the dimensions of the embossments are 31 mm x 60 mm is shown in the Fig.5.

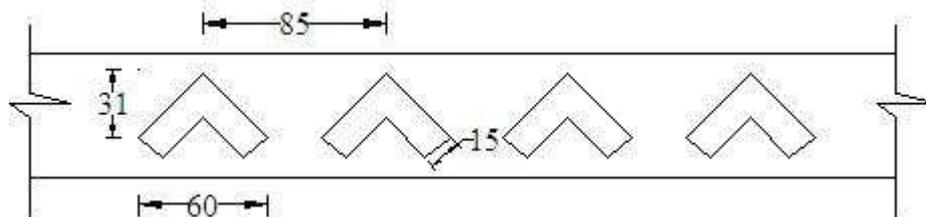

Fig.4.   Chevron type embossment

Fig.5.   Detailed view of Chevron type embossment

2.4   INCLINED PENETRATED EMBOSSMENT

The inclined penetrated embossment is another type of embossment which is punched inclined method represented in the Fig.6. The dimension of the inclined penetrated embossment was 25 mm x 55 mm and distance between the centers of each embossment is 55 mm is shown in Fig.7.
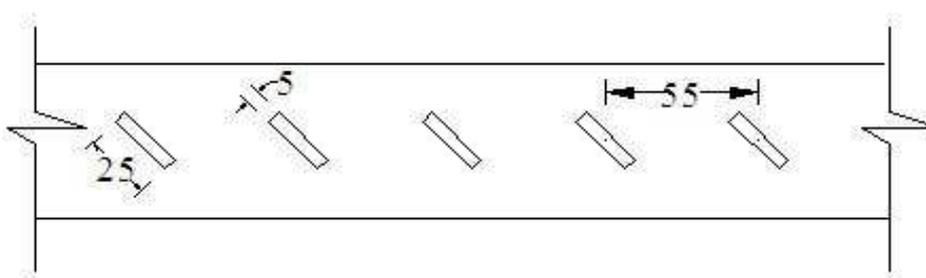

Fig.6. Inclined Penetrated Embossment

Fig.7.Detailed view of Inclined Penetrated Embossment

2.5   APPARATUS SETUP

The composite slab specimens were placed on the loading frame carefully without any damage to the specimen. The loading frame is attached with hydraulic jack of capacity of capacity 500 kN is used to give the static load on the specimen. The schematic view of the loading frame is shown in the Fig.8. The overhanging length of the specimen (l_0) is 100 mm on either sides of the specimen and the effective length (l_e) is 1400 mm respectively. Hinged support is provided on one side and on the other hand roller support is provided to simulate simply supported condition. Along the width of the composite slab specimen the load is given with the help of I section beam. Two line rods are used to distribute the load equally on the composite specimen. The load carrying capacity of the composite slab is recorded through the load cell which is placed at the top of distributor beam. The loads on the composite slab specimen were recorded timely on regular time intervals in the computer. A total of six numbers of specimens were subjected to testing with two numbers in chevron, rectangular dishing

and inclined penetrated type of embossment. To measure the mid span deflection and load slip behavior of the composite slab specimen, Linear Variable Differential transducers (LVDT) and digital dial gauge were used. The LVDT's and the dial gauges were placed at the bottom and middle of the composite slab as shown in Fig.9 Experimental set-up and Fig.10 shows the End-slip of trapezoidal profile sheet. Fig.11 shows the crack pattern of the composite slab.
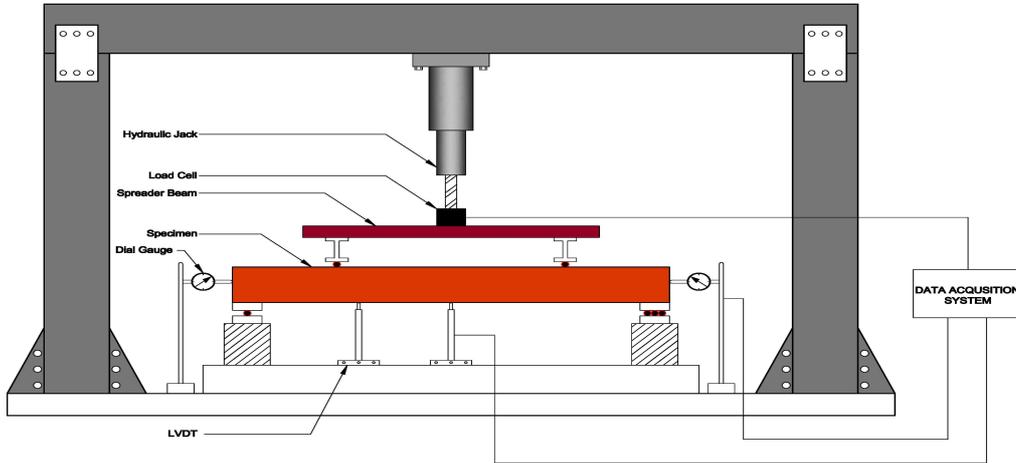

Fig.8.   Schematic view

Fig.9.   Experimental setup of loading frame

Fig.10.   End-slip of Trapezoidal slab

Fig.11. Crack pattern of composite slab

3   RESULTS AND DISCUSSION

For the experimental studies m-k method was adopted from Euro code. As per Euro code recommendations two different shear spans should be considered for the studies. In this experiment two types of loading was given, one short shear span 300mm and long shear span 500 mm was chosen with different embossing sheets. Initially with a propping sound indicated which clearly indicated the delamination of concrete and profiled sheeting. Longitudinal shear continued with the help of embossing in the profiled steel sheeting. The Fig.12 indicates the load- deflection value of the three types of embossed profiled sheeting tested with short shear span. The chevron type of embossment had a higher deflection of 25 mm and higher load was 71 kN. Similarly for long shear spans shown in Fig.13, rectangular profiled sheeting showed higher deflection of 23 mm and higher load was 55 kN.
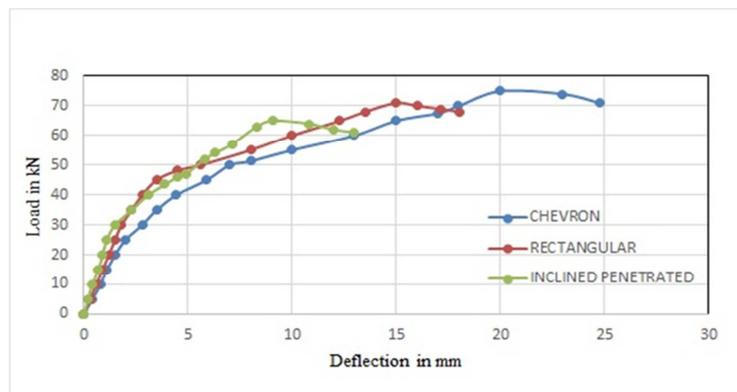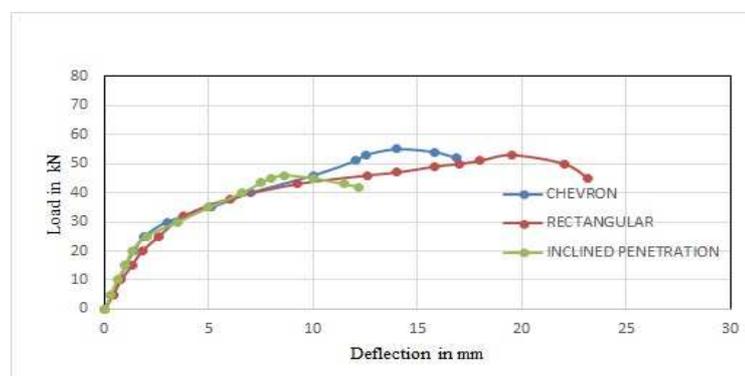

Fig.12. Short shear span of 300 mm

Fig.13. Long shear span of 500 mm

4   PREDICTION OF M-K VALUE

Table 1 Experimental value for m-k

Embossment type	Shear span, L_s (mm)	Ultimate load, P (kN)	Vertical shear force, Vu = (0.8xP) / 2 (kN)	$\dfrac{V_u}{bd_p}$ (N/mm^2)	$\dfrac{A_p}{bL_s}$	Experimental value for m-k method
Rectangular	500	50	40	0.376	0.00278	0.266
Rectangular	300	71	56.8	0.535	0.00463	0.382
Chevron	500	55	44	0.414	0.00278	0.294
Chevron	300	75	60	0.565	0.00463	0.402
Inclined	500	46	36.8	0.346	0.00278	0.243
Inclined	300	65	52	0.489	0.00463	0.348

The regression analysis is performed to predict the m-k method According to Euro code 4 Part 2, the mathematical equation to estimate the m—k value is given below

$$\frac{V_u}{b.d_p} = m.\frac{A_p}{b.L_s} + k$$

Where A_p represents the area of profiled sheeting, b represents the breadth of the specimen, L_s is the shear span of the specimen, d_p is the depth of the profile sheet. The linear regression analysis was used to estimate the m-k values for the different embossing profiled sheets. The value m represents the slope and k represents the co-efficient of friction. The Fig.14 represents the linear regression analysis for estimating of m-k value.
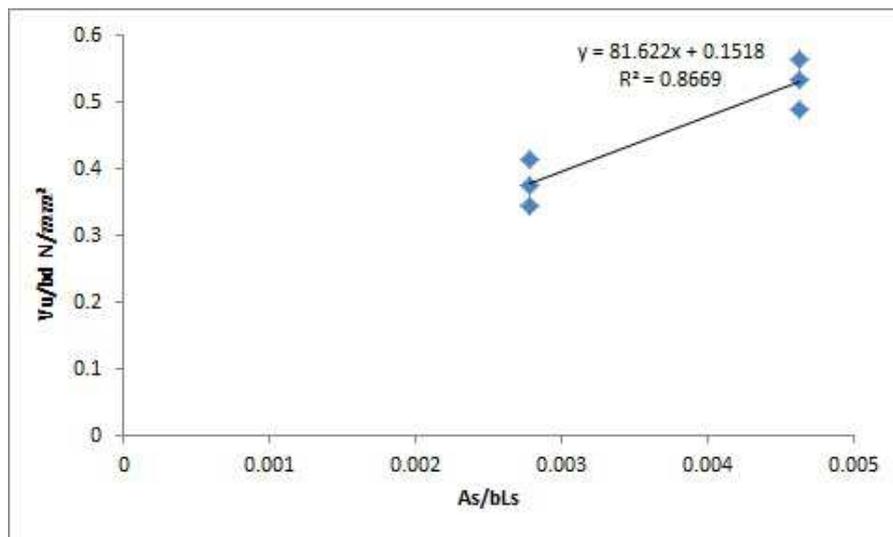

Fig.14.   Estimation of m-k value

5   CONCLUSION

The following conclusions were arrived from the experimental studies. They are

- The specimens with the shorter shear span showed more load bearing capacity than the longer shear spans
- The longitudinal shear capacity of the specimen can be increased by depth of the embossment and orientation of the embossment.
- A simple regression analysis was created. The linear regression constants 'm' and 'k ' values are: m = 81.662, k = 0.1518.
- The shorter shear spans failed in shear mode whereas the longer shear spans failed in flexural mode.
- Up to initial crack the deflection was greater in chevron type of embossment in short shear span and deflection was greater in rectangular type of embossment in longer shear spans.

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