Performance of Precast Thin Panel as Permanent Formwork for Precast Composite Slabs

Yavuz YARDIM

[1]Department of Civil Engineering, EPOKA University, Albania

ABSTRACT

This study investigates the performance of precast thin panel as permanent formwork for precast composite slab. The two-way inverted ribs in the thin panel are placed to enhance its flexural stiffness, as well as providing link between the precast layers. Flexural behaviors of two precast panels are investigated under two line load and distributed load. Test results indicate that the thin panel with suitable ribs layout and support distance can be used as permanent formwork. Typical load from construction worker and in situ elements could be sustained by the panel.

Introduction

Precast slab system take place in the construction with temporary prop for longer span. most precast companies eliminate the props during construction to speed up the construction. however, it causes heavier structure, more steel to support the wet concrete before the composite action take place. in addition, heavier precast units are more expensive to handle, transport and erect. they also require large and more expensive foundation and column to support them. therefore alternative ways have been suggested by researchers to overcome these shortcomings. temporary supports for precast slab reduce temporary bending moments in the element due to wet weight of the cast in situ concrete thus resulting of a substantial reduction in the quantities of concrete and steel required in the precast unit. (Alfred a. 2001). key elements for precast slab system are to be stiff structure at the same time light weight. composite precast slab have been practicing as an efficient system to achieve a light, thin, and stiff structure.

Composite structures combine two or more materials in a unit structure to provide tangible benefits and a versatile solution to suite different applications. A composite system reduces the unnecessary material properties, such as weight, without sacrificing required capacity. The composite idea applications with precast solution have been rapidly increase with development of construction techniques. There are five different capacity criteria to be considered for the full precast flooring units; (1) bearing capacity, (2) shear capacity, (3) flexure capacity, (4) deflection limits, (5) handling restriction (Kim S. Elliott, 2002). The concept is more or less the same with composite precast slab system. Generally, usage priority will be taken by the composite system which is light, stiff, thin and able to joint well to the cast in situ layer.

Existing half precast slab systems are widely used all over the world as precast composite slab system. Although the systems are one of the widely used systems among the precast slab systems, very limited studies have been found. The system is similar to the composite slab system, which is a combination of a profiled steel deck and topping concrete. In the half-precast slab system, a thin concrete precast element, which is sometimes called as permanent formwork, is used in place the profiled steel deck.

As an alternative, ferrocement with its versatile properties is an efficient system available to achieve a light, thin, and stiff structure. Many investigations have been carried out about ferrocement as permanent formwork to be used in composite slab system (M. Sulaiman 1985). Ferrocement panel have also been proposed as an alternative material for profiled decks in composite slab construction M.A. Mansur (1986). System connection behavior was observed in the study and it is concluded that system connection is as good as steel deck slab connection. Moreover permanent ferrocement formwork is cheaper and fire resistance is more than steel deck.

A new system was developed by Waleed et al., consisting of a bottom ferrocement skin and top light weight masonry, in-situ mortar ribs. The ferrocement layer is the precast part of the composite slab, which consists of a wire mesh and steel reinforcement, required to resist the tensile stresses. The two layers are interconnected using interlocking connection. The advantages of this system, amongst others, are its relatively lighter weight compared to R.C which will reduce the load transferred to the beams/walls. The masonry units act as light (especially voided brick and AAC), natural, cheap effective insulation material and at the same time partially resist the compression forces developed due to bending of the composite. On site, the construction of the composite slab does not require heavy equipment to handle the ferrocement layer. Furthermore, the construction does not need any formwork since the bottom layer of ferrocement is a precast unit that can be easily fixed in position, using simple crane, to provide a platform that acts as a formwork for the brick layer and the in situ concrete ribs (Thanoon Waleed A,2010). This study demonstrates that the weight of the slab structure may be reduced 20 to 35 percent without sacrificing load-carrying capacity. The study proves that the ferrocement precast composite technology has wide practical application with many advantages, and also inspired the effort in this study to find an even more efficient design for ferrocement composite panels.

The aims of this study were to experimentally examine the flexural behavior of half precast slab which is part of composite slab units and suggest suitable propping during construction stages. Therefore two ferrocement half slabs with different span length were investigated under two line and distributed flexural load. In addition, mechanical properties of ferrocement were studied to explain ability of the structure under different loading conditions.

Preparation of Test Specimens and Test Setup

Ordinary Portland cement and natural sand were used for concrete in the ratio 1:3 with water/cement ratio of 0.5. The mortar mix was designed to give 28-day cube strength of 30 N/mm². The ferrocement reinforcement used in all slabs consisted of high tensile steel bars and galvanized welded square wire mesh of 0.9 mm diameter and 12 mm openings. The tensile strength of the mesh was found 321 N/mm². Two one-way ferrocement panels were cast and tested as ferrocement panel. The slab specimens tested under two line loads and distributed load. Details of specimens are given in Table 1.

Table 1: Details of specimens' dimension and loading type.

No	Dimensions	Load type
FP1	3mx1.3mx75mm	Two line load
FP2	1.75mx0.78mx75mm	Distributed

Two formworks with the dimension of the precast slab specimens were prepared. In order to shape the ferrocement decking with main and secondary ribs as specified in design, blocks of polystyrene was made and pasted in the formwork. The wire mesh is cut according to the required dimension. Then, the steel bars were tied on top of the mesh with a specified spacing using spacers. Strain gauges were welded in the middle of each steel bar. Then, the mesh together with the steel bars was placed in the formwork on top of the polystyrene with a specified spacing using spacers. The mortar was poured into the formwork to fill the voids between polystyrene blocks. The specimens were cured for six days. On the seventh day, the specimens were demoulded. The polystyrene blocks were removed leaving empty spaces for cast in suite toping.

Typical set-up of two-line load test is shown in Figure 1. Precast layer (FP1) tested under two line loads. Second specimens (FP2) of the composite system tested under uniformly distributed load by using 50 kg cement bags. Deflection, strain on steel bars and strain tension and compression zone of concrete monitored by dial gage, strain gage and demec points respectively. First crack and cracks width was monitored by crack measurement instrument. Cement bags are added on top of slab as uniformly disrupted load, bags are placed one by one and symmetrically to avoid uneven loading.

Figure 1: set-up of test for two line load test

RESULT AND DISCUSSION

Structure's behaviors were observed and recorded carefully for every steps of load increment. The ferrocement plates had considerable ductility and behaved in composite manner throughout the entire loading process. The results of Precast (FP) specimens were also tabulated in Table 2 and the load deflection characteristics are shown in Figure 2.

Table 2: Summary of Theoretical and Experimental results

Spec.	First Crack Load (kNm^2)		Ultimate load (P_{ULT}) (kN/m^2)		Ultimate Moment, M_U (kNm/m)		M_U (Expt) / M_U (Theor)
	Theor.	Exper.	Theor.	Exper.	Theor.	Exper.	
FP1	2.2	2.9	5.4	6.5	5.5	6.6	1.20
FP2	5.8	7.5	10.8	13.7	3.7	4.5	1.21

Similar to most of the ferrocement slab structure (A.W.Hago 2005, S.K. Kaushik1991); three different behaviors were recorded during entire loading history. Therefore load deflection curves have different slope at three different zones. The first zone represents the load deflection relationship for uncracked stage of testing and the curve is linear. Along this zone, both the concrete matrix and reinforcement behaved elastically, whereby the load is mainly carried by the concrete matrix. Load deflection curve show linear attempt until first crack load which is around $2.8kN/m^2$ for FP1. The plate shows large deflection of 8 mm (L/ deflection = 350) with load of $2.8kN/m^2$ which is less then total topping and construction load. Systems behave in ductile manner and first crack appear at the load of $2.9kN/m^2$. Crack numbers are increased with increasing of load and large deformation is observed. At the deflection of 55 mm system fails by crashing of ribs.

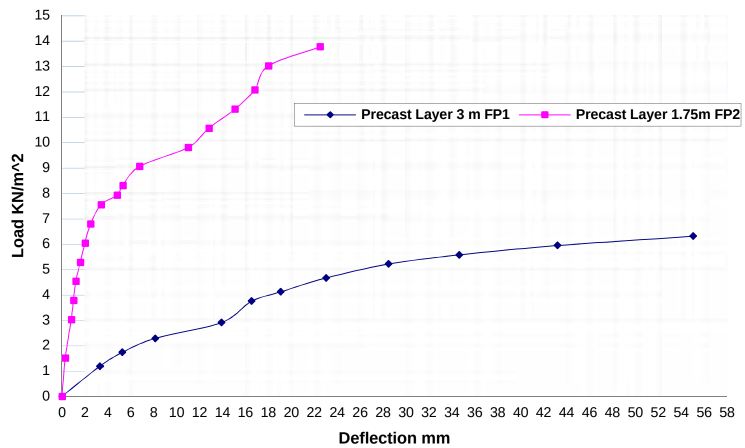

Figure 2 : Load Deflection Curves for Precast Layers

FP2 specimen is representing propped structure with it is short span. Every loading stages of the specimen are carefully investigated. Total load during construction is considered as 4.5 kN/m^2, which includes self weight of precast panel, topping load, construction load of 1 kN/m^2 and safety factor.

Deflection was observed less than 0.5 mm from 0 to 2kN/m2 loading. Average deflection until the 4.5 kN/m2 load is 1 mm (Deflection/L =0.0006). Strain in tension and compression zone was observed as 0 at the load of 1.5kN/m2. First recorded strain at tension zone is 0.0004 at the load of 3 kN/m2. Until the first crack load 7.5kN/m2, average strain increment is 0.0003 for every 0.7-0.8 kN/m2 load. Total strain observed before first observed crack is 0.0023 at tension zone and 0.001 at compression zone.

First observed crack was measured at 0.15mm width and it extended until 15 mm from the bottom part of specimen FP2. The crack was appeared at left side of slab. Possibly some other hair cracks was occurred at bottom part of slab but because of access difficulties, that much small crack could not monitored at bottom part of slab. At the load of 7.9kN/m^2 the crack extended with same width towards bottom of slab and second crack appeared at right side of the slab. Increment on the steel strain is accelerated with last 0.4kN/m^2 the load and stain along the depth graph show sudden increase of 0.002 strains. Furthermore, sudden deflection was observed 1 mm, on the load deflection cure at this stage of load. This increment is the biggest deflection increment so far for 0.4 kN/m^2 load increment. Cracks are remained as it is at the loading of 12 kN/m^2, however, maximum crack width was observed as 3 mm.

At the load of 13kN/m^2 cracks got wider and branches' numbers and length of side cracks were increased. Some crushing symptoms (like local spoiling on concrete surface) were observed at top surface of side ribs. Largest deflection was recorded at this load as 18 mm (Deflection /L= 0.011). Strain was recorded as 0.0023 for compression and 0.00645 for tension on concrete surface. Steel strain was exceeding the limit of 0.002 strains. All the result was showed that next loading will be the fail load for system. Three stages load deflection curve were also observed for this specimen. At the load of 18.25 kN the system fail by flexural fail. Behaviors of the FP2 ferrocement panel structure shows that, system enable to carry topping plus construction load safely without any mid support.

Conclusion

This study introduces a new invert ribbed precast ferrocement slab system for composite slab. Tests were complied for precast layer of composite slab system and composite slab system under two line loads and uniformly distributed loads. Precast layer achieves its required tasks which are working as formwork, forming interlocking connection and carrying temporary loads such as toping and construction loads. System was carried out the load which was more than theoretical estimation. Test results shows that the precast layer is able to carry temporary loads and light enough to handle with simple crane. Ferrocement layer creates high modulus of rupture so that first crack load was observed at 40% of ultimate loading, provides strong protection against spalling and most of others surface distress and Eliminate cost of formwork.

REFERENCE

[1] Thanoon Waleed A, Yardim Yavuz, MS Jaafar, Noorzaei J (2010). Structural behaviour of ferrocement–brick composite floor slab panel, Construction and Building Materials, 24 : 2224–2230.

[2] Thanoon Waleed A, Yardim Yavuz, Jaafar MS, Noorzaei J (2010). Development of interlocking mechanism for shear transfer in composite floor, Construction and Building Materials 24 : 2604–2611.

[3] Mansur MA, KCG Ong (1986). Composite Behavior of Ferrocement –Deck Reinforced Concrete Slabs, J. of Ferrocement 16 (1) : 13-21.

[4] Alfred A. Yee, P.E. Hon. D. Eng. ,2001, "Structural and Economic benefits of Precast/Prestressed Concrete Construction" PCI Journal, July – August 2001 Vol 46, No 4, Page 34-42.

[5] Kim S. Ellitott, 2002, "Precast Conceret Structure", Butterworth Heinemann An imprint of Elsevier Science Linacre house , jjordan hill, Oxford OX2 8DP 225 wilwood Avenue, woburn , MA01801-2041.

[6] M. sulaiman, AMaher , P.Brohi, " Ferrocement Hollow Box Roof Slab " Journal of Ferrocement Vol. 15, No 1 , January 1985 Page 35 -39 .

[7] M. A. Mansur , K.C.G. Ong. Composite Behaviour of ferrocement –Deck-Reinforced Concrete Slabs. J. Ferrocement 1986; 16(1): 13-22.

[8] S.K. Kaushik, V.K. Grupta and M.K. Rahman, 1987, "Efficiency of Mesh Overlaps of Ferrocement Elements", Journal of Ferrocement, Vol. 17, No. 4, Page 329-336.
[9] A. W. Hago, K.S. Al- Jabri, A.S. Alnuaimi, H. Al- Moqbali, M.A. Al-Kubaisy, 2005, Construction and Building Materials 19, Page 31-37.