Effect of Interface Position and Percentage of Shear Connectors on the Behavior of One-Way Composite Pre-Slabs

Ahmed Shaban Abdel-Hay

Structural Engineering Dept. Faculty of Engineering, Beni Sueif University, Egypt
ahshaban2005@yahoo.com

Abstract: One of the most common types of the composite concrete elements is the pre-slabs which are used extensively in the construction of both buildings and bridges. It consists of a pre-cast concrete layer serves as a form or skeleton for the cast-in-place concrete slab. The problem of shear transfer is a major item in the study of the behavior of pre-slabs to achieve the composite action between two layers [1 to 8]. Many researches had been carried out to study the shear transfer between two concrete layers; few of them concerned with the behavior of pre-slabs with variable interface position. In this investigation, the behavior of one way simply supported composite pre-slabs with variable interface position and different percentage of shear connector was studied. The experimental program contains testing of nine Pre-Slabs and one reference monolithic slab. The studied pre-slabs composed of two layers cast at different ages with variable thickness using different percentage of shear connectors. Finally, the slabs are modeled with the finite element computer program.

[Ahmed Shaban Abdel-Hay. **Effect of Interface Position and Percentage of Shear Connectors on the Behavior of One-Way Composite Pre-Slabs.** Journal of American Science 2012;8(9):325-332]. (ISSN: 1545-1003). http://www.jofamericanscience.org.47

Key Words: Pre-Slabs, One way, Shear transfer, Composite, Concrete.

1. Introduction

Concrete-concrete composite flexural members are widely used in the building and bridge construction as well as strengthening. The common types of the composite concrete-concrete sections are composite slabs with deck floor and composite slab with prefabricated beams.

To achieve the composite action between old and new part, different types of shear connection between the two concrete surfaces may be used, such as rough surface connection, shear keyed connection, steel doweled shear connection and using of Epoxy binding materials.

The strength of each shear connection depends on many factors. Such as, concrete compressive strength of new and old part, span to effective depth ratio, slip between two parts, dimensions and reinforcement of the tested specimens, differential shrinkage, type of loading, position of composite interface with respect to neutral axis, aggregate size and shape, direct stresses acting parallel to the shear plane, casting position.

Saemann, et al. [13] and Nawy, et al. [12] tested beams having composite interface at different levels with respect to neutral axis. The results indicated a little effect on the shear transfer capacity. The shear transfer capacity of interface below the neutral axis was 10 to 20% greater than that of interface above the neutral axis.

Abd El-Hay [2] tested nine composite continuous one way pre-slabs 2.36x0.8x0.1 m. under the action of distributed load, he concluded that the tested pre-slab with rough interface or uniform distributed dowels or concentrated on the outside ¼ of clear span and minimum dowels in other parts, gave good results of both ultimate and working loads.

Zaky,W. and M.Rabie.[1] tested six composite one way simply supported pre-slabs 106 x80x10 cm, the results showed that, the design of the tested specimens successes to change the mode of failure from flexure failure to shear failure also, the changing of loading type from uniformly distributed loads to concentrated one line load led to achieve the ultimate shear strength .

M.Rabie [14] tests four composite two way-simply supported pre-slabs 2x2x0.1 m under the action of distributed load, the results showed that the ultimate load for the composite slab with rough interface only was about 87% of that of monolithic one, and also a slightly higher values of both deflection and concrete compressive stress was measured up to the complete separation of the two layers. Also, pre-slabs with distributed dowels 1ϕ8 every 40 cm gives higher ultimate load than pre-slab of concentrated dowels over the outside perimeter of width (0.25 span) with the same area. While the use of concentrated dowels decreased both deflection and stress in dowels until the separation of the two layers in the interior zones which led to sudden increase in both deflection and dowels stress.

Waleed , et al.[3],Dong, et al. [6], Abdel-Wahab, et al.[4] , Abou El Matty [5], and Easterling , et al. [7], El-Behairy, et al. [8] were discuss the behavior of composite slabs.

El-Zanaty [9], Hussien [10], and El-sayed [11] were concerned with the problem of shear transfer.

The objective of the experimental work in this study is to investigate the behavior of one way simply supported pre-slabs of variable interface position and percentage of shear connectors under the effect of two line load applied through 1/3 of clear span.

2. EXPERIMENTAL WORK

Tests were carried out on nine composite pre-slabs and one control specimen. All slabs were supported on two edges, to represent the case of one way simply supported pre-slabs. Each composite slab consists of two layers, the first layer was pre-cast slabs [100 x 80 x t_b cm] with main bottom reinforcement of 12 ϕ 6 and secondary steel of 6 ϕ 6, while the second layer of dimensions [100 x 80 x t_t cm] and without reinforcement, as shown in fig. (1).All tested slabs had a different percentage of shear connector but same treatment for preparing the interface between the two layers of each slab. Table (1) shows the details of tested slabs and concrete compressive strength of each one.

Fig (1) Pre-Slabs first layer before casting the second layer.

Table (1): Details tested pre-slabs

Specimen		f cu (first layer) kg/cm^2	f cu (second layer) kg/cm^2	t_b (cm)	t_t (cm)	A_{sd}/A_{sh}% (Dowel percentage)
M	**Monolithic**	310		12		………
SD11	**Group 1**	348	315	6	6	0.1
SD12		348	315	6	6	0.12
SD13		348	315	6	6	0.15
SD21	**Group 2**	340	328	8	4	0.1
SD22		290	328	8	4	0.12
SD23		340	328	8	4	0.15
SD31	**Group 3**	345	325	4	8	0.1
SD32		340	325	4	8	0.12
SD33		290	325	4	8	0.15

TEST SET-UP AND LOADING ARRANGEMENT

The tested slabs were supported on two edge support and loaded by two line loads using a hydraulic jack with increment equal to 0.5 ton as shown in figure (2). Demic mechanical strain gages of 20 cm gage length were used to measure the concrete strains. Also, electrical strain gages were used to measure the strain in steel dowels.

Dial gages having an accuracy of 0.01 mm were used for deflection measurements. Also, a horizontal dial gage of an accuracy of 0.01 mm was fixed at the end of pre-slabs to measure the occurred slip between the two layers.

Fig (2) Loading Set-up for tested Pre-Slabs.

3. Experimental Results

The results of tested pre-slabs include mode of failure and cracking pattern, cracking and ultimate loads, maximum induced slip, maximum deflection and deflection pattern, tensile strain in concrete and dowel strains.

The effect of studied parameters on the behavior of tested pre-slabs will be discussed in the following:

CRACKING PATTERN AND MODE OF FAILURE:

The initiation and pattern of cracks of tested pre-slabs can be explained as follows:

The first crack was observed on bottom surface parallel to the supports at middle third of span which was the part of maximum positive moment. This crack was observed at cracking load, Table (2).

After this load level, another bottom cracks was observed on the same part of specimen, part of maximum positive moment, then deflection increased rapidly up to ultimate load. At this load, the reading of load cell dropped slightly and it was not possible to maintain the load constant because of excessive deflections. So, this load was considered as the maximum attained load (ultimate load). Fig. (3) Throw (12) shows the cracking pattern of bottom surface of all specimens. Comparing this figures one can observed the following:

1. In some specimens, few of cracks appear outside the middle third at failure stage.
2. Comparing the crack pattern of group (2), {SD21,SD22,SD23},it can be noticed that increasing the percent of dowel affect the cracking behavior of specimens by concentrate the cracks in middle third, so we can achieved the composite action by increasing the dowel percent to 0.15%.
3. Increasing the dowel percent has a little effect in cracking behavior of specimens of group (1).
4. Comparing the crack pattern of group (3), {SD31,SD32,SD33},it can be noticed that increasing the percent of dowel cause an increase in cracks, but in slab SD33, random cracks was occurred and local failure at support was happened ,that caused by use of bottom layer with low compressive strength ,fig(12 a and b).

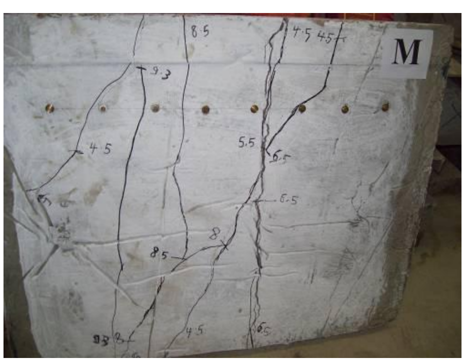


Fig (3) Cracking pattern of Slab M

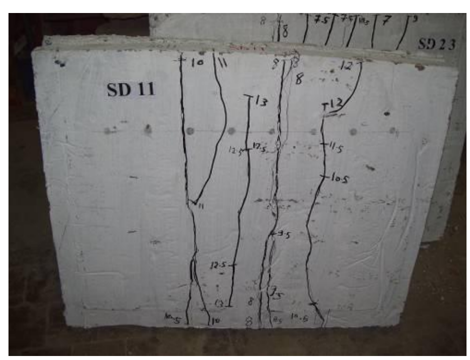


Fig (4) Cracking pattern of Pre-slab SD11

Fig (5) Cracking pattern of Pre-slab SD12

Fig (6) Cracking pattern of Pre-slab SD13

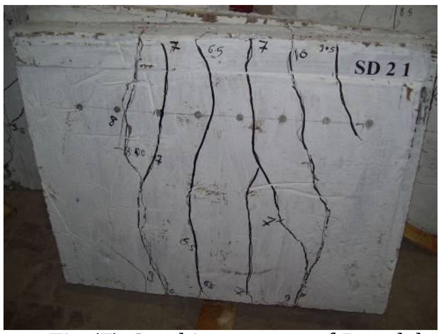


Fig (7) Cracking pattern of Pre-slab SD21

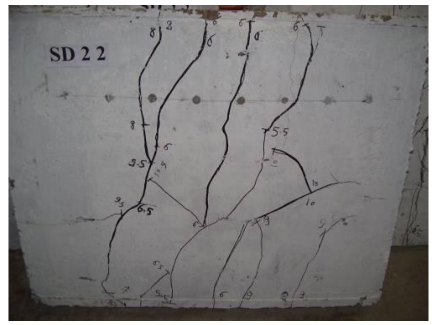


Fig (8) Cracking pattern of Pre-slab SD22

Fig (9) Cracking pattern of Pre-slab SD23

Fig (10) Cracking pattern of Pre-slab SD31

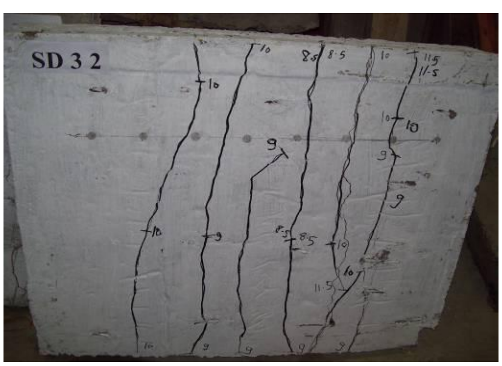


Fig (11) Cracking pattern of Pre-slab SD32

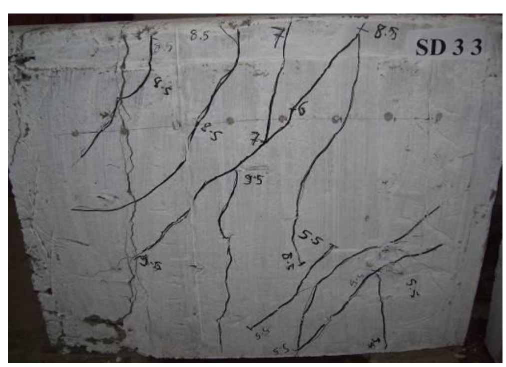


Fig (12-a) Cracking pattern of Pre-slab SD33

Fig (12-b) Local failure at support of Pre-slab SD33

Cracking and Ultimate Loads

Table (2) and fig (13) shows the values of cracking loads of the tested pre-slabs (P_{cr}) and the ultimate loads (P_u) for the tested pre-slabs. Also, table (2) shows the value of maximum deflection of slabs. It is clear that increasing the percentage of dowels for both group (1) and group (3) causes a little effect on the maximum ultimate load obtained except SD33 which have a local failure, as mentioned before. While increasing the percentage of dowels of group (2) causes a great effect on the ultimate load. Also, it can be noticed that the good results of ultimate load obtained in group (1) which have an ultimate load as monolithic.

So, it can be concluded that in case of higher depth of first layer we must use a higher percent of dowels not less than 0.15%, but 0.1% was enough in other cases. Also in case of lower depth of first layer we must prevent using a poor concrete.

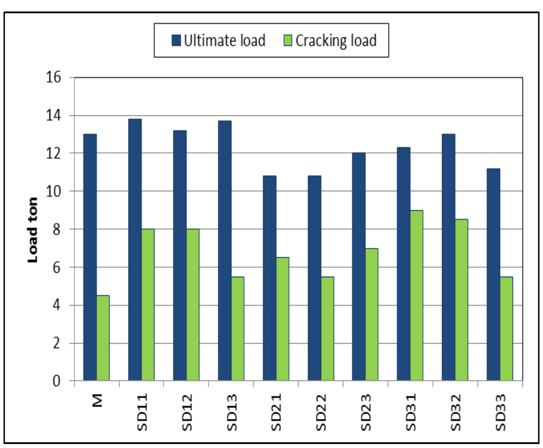


Fig (13) Cracking and Ultimate loads for tested Pre-Slabs.

Table (2): Pre-Slabs test results.

slab	P_{cr}(ton)	P_u (ton)	Pu / Pum	Δ max	Notes
M	5.0	13.00	---	5.70	Monolithic
SD11	8.0	13.80	106%	2.39	Group 1
SD12	8.0	13.20	101%	3.98	
SD13	5.50	13.70	105%	4.85	
SD21	6.50	10.80	83%	3.61	Group2
SD22	5.50	10.80	83%	4.31	
SD23	7.0	12.00	92%	2.67	
SD31	9.0	12.30	95%	2.99	Group 3
SD32	8.50	13.00	100%	6.00	
SD33	5.50	11.20	86%	5.29	

Δ max: Maximum deflection of slab.

Load-Deflection Diagrams

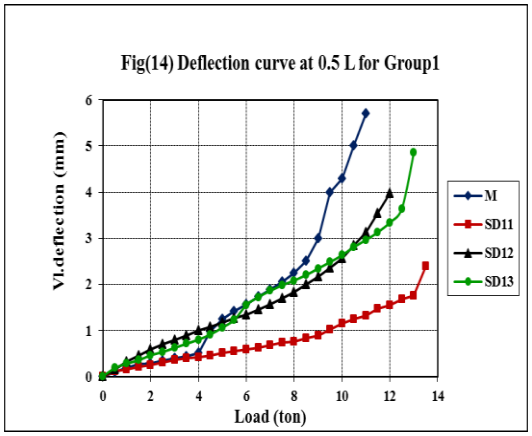
Deflections of pre-slabs at bottom surfaces measured at x/L equal to 0.25, 0.5 and 0.75 were plotted against the load up to failure, where x was the distance measured from the support and L was the span. The trend was the same for tested groups in the three measured points. Fig. (14) Through fig. (16) Show the deformation curve for the tested groups at mid span point.

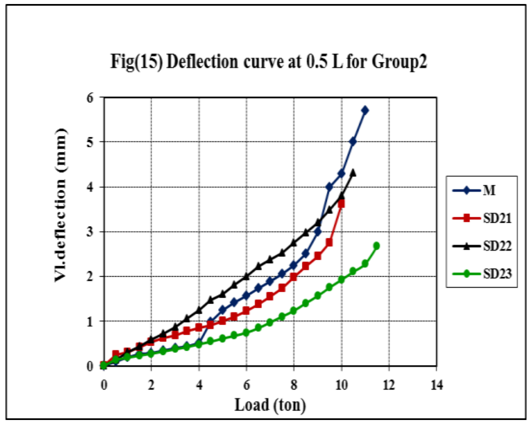
All curves indicates that the relation between load and deflection was nearly linear up to cracking load, then excessive cracking in concrete leads to excessive deformations and nonlinear distribution of deflections.

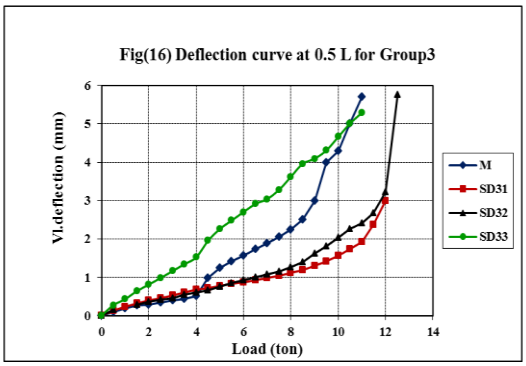
Comparing the load-deflection curves of pre-slabs of group (1), it can be noticed that, increasing the dowel percent cause the specimen having nearly the same behavior as monolithic unless at failure, while in group (3), slab SD33 having a higher deflection than monolithic. Group (2) having a different behavior than above, therefore increasing the dowel percent made the behavior same as monolithic up to cracking only.

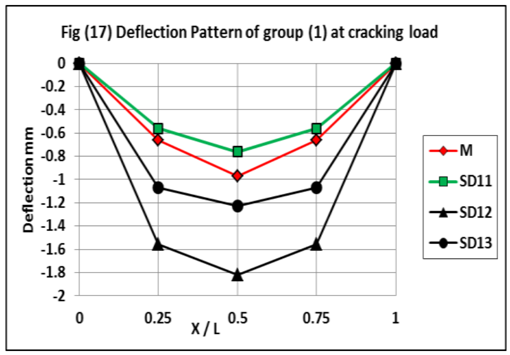
On the other hand, fig. (17) Through fig. (22) Shows the deflection pattern of tested pre-slabs at both cracking and ultimate load respectively. At cracking load, it was found that the deflection of all specimens was more than that of monolithic except SD11. Also deflection of pre-slab SD23 was same as monolithic. This behavior was changed at ultimate load where monolithic slab having a higher deflection than the tested pre-slabs except SD32. Comparing the deflection pattern of group (1) and (3), it can be noticed that increasing the dowel percent cause the specimen having nearly the same behavior as monolithic, but in group (2), there is no one trend of behavior for increasing the dowel percent.

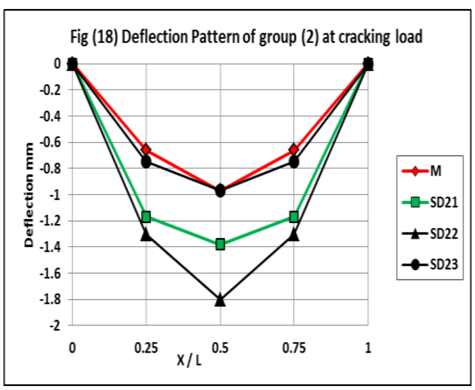
From the above discussions, it is clear that it is not recommended to use concrete with low compressive strength in pre-slabs with bottom layer thickness less than above one.

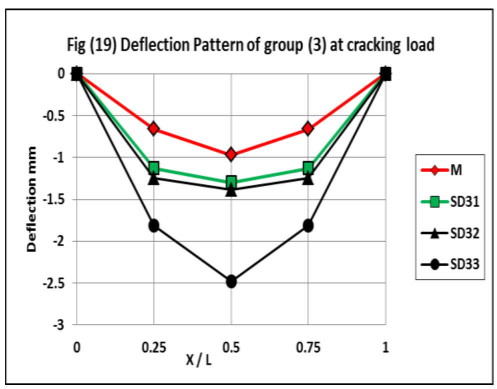


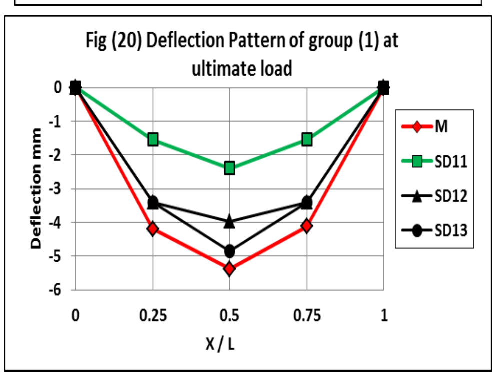


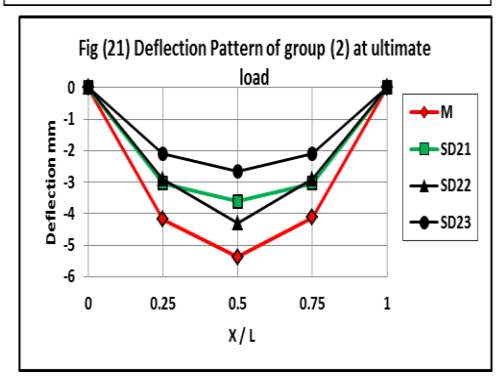


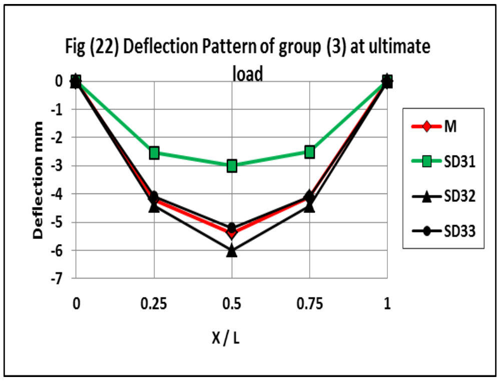


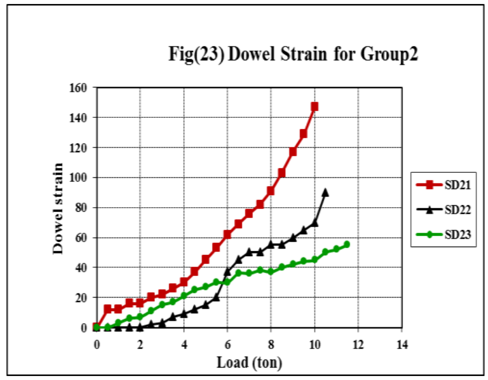












Maximum Induced Slip

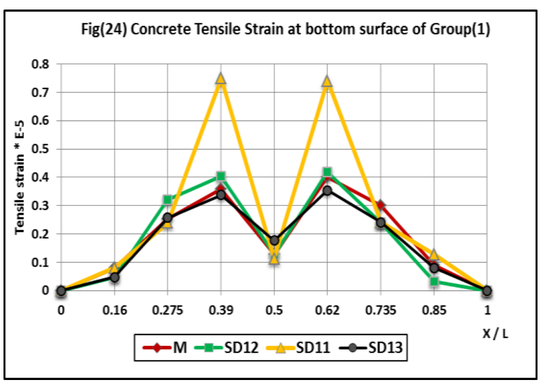
No observed slip occurred in all specimens, which mean that the percentage of dowels used was sufficient to mad a composite action between the two layers.

Strains in Dowels

Dowel's strain was plotted versus load as shown in Fig. (23). It is clear that decreasing the percent of dowels cause an increase in values of dowel's strain of pre-slabs at the same location and load level.

Tensile Strain on Bottom Surface of Concrete:

The distribution of tensile strains at cracking load was plotted along the slab axes as shown in Fig. (24). It is clear that, the strain distributions are similar for all slabs and the maximum value was at point of maximum positive moment. From the figure, it is clear that the tensile strain for SD12 and SD13 was as monolithic but SD11more than that of monolithic, therefore it can be concluded that increasing dowel percent improve the composite action between the two layers.



4. Finite Element Program [NOPARC]

The reinforced concrete composite section is assumed to be made up of system of concrete layers, interface layer and "equivalent smeared" steel layers. The reinforcing steel is converted to a uniform layer with an equivalent thickness determined by:

ts = As / b

Where:

As = Area of one reinforcing bar.

b = Spacing between the bars.

The slab is modeled with the finite element mesh, while the cross section is divided into three layer systems. The first layer system consists of five layers and represents the top layer of the pre-slabs, while the second layer system consists of one interface layer. The third layer system consists of five layers which represent the bottom layer of composite pre-slab.

Correlation between Theoretical and Experimental Results:

The comparison of the ultimate load between the theoretical and experimental values is shown in figure (25). It can be noticed that the theoretical ultimate loads were about (80%: 96%) of that of corresponding experimental results for all slabs. Also, the finite element model gave a good agreement with the experimental results in vertical deflection measurements as shown in figure (26).

It is clear from the above discussion that the experimental and finite element model results of the tested pre-slabs were in good agreement.

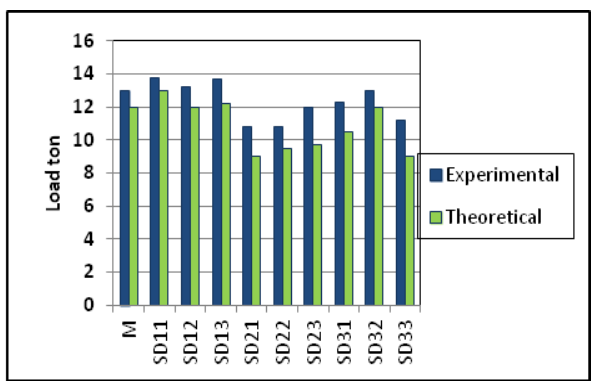
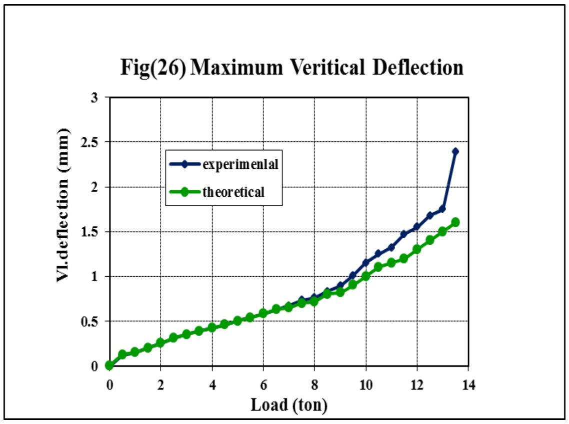


Fig (25) Ultimate Load of Tested Slabs



5. Conclusion

1. The use of pre-slab with bottom layer of thickness less than top layer is not recommended in case of using a concrete with low compressive strength.
2. The maximum ultimate load obtained for pre-slab with bottom layer of thickness higher than top layer was affected by increasing the percentage of dowels, while in other cases; the ultimate load has a little effected by this increase.
3. In case of higher depth of first layer we must use a higher percent of dowels not less than 0.15%, but 0.1 % was enough in other cases.
4. Decreasing the percent of dowels cause an increase in values of dowel's strain of pre-slabs at the same location and load level.
5. Increasing dowel percent was improving the composite action between the two layers.
6. The finite element analysis was in good agreement with experimental results for both deflection and ultimate load for all tested pre-slabs.

Corresponding author
Ahmed Shaban Abdel-Hay
Structural Engineering Dept. Faculty of Engineering, Beni Sueif University, Egypt
ahshaban2005@yahoo.com

References

Zaky,W. and M.Rabie., "Effect of cases of loading and distribution of shear connectors on the behavior of One -Way composite pre-slabs", Life Science Journal, Vol. 9, No. 2, 2012. pp. 435-443.

Abd El-Hay A.S. (2006) Shear transfer in composite continuous one way pre-slabs. PH.D Thesis. Faculty of Engineering, Cairo University.

Waleed A. Thanoon, Yavuz. Yardim, M.S. Jaafar, J, Noorzaei., "Development of interlocking mechanism for shear transfer in composite floor", Construction and Building Materials Journal, Vol.24,2010,pp.2604-2611

Abdel-Wahab, H. M., and Khalil, M. H., "Rigidity and strength of orthotropic reinforced concrete waffle slabs", ASCE, Vol. 126, No. 2, February, 2000. pp. 219-227.

Abou El-Maaty, M. A., "Composite corrugated Pre-cast reinforced concrete deck slabs", PH.D thesis. Faculty of Engineering. Cairo Univ. 1997.

Dong-Uk choi, David, W.F., and jomaso, J., "Interface shear strength of concrete at early ages", ACI structural journal, Vol. 96, No. 3, May-June 1999, pp. 343-347.

Easterling, W. S., and Young, C. S., "Strength of composite slabs", Journal of structural Engineering ASCE, Vol. 118, No. 9, September, 1992. pp. 2370-2389.

El-Behairy, Sh., and Abu El-Enin, A. W., "Behavior of simply supported pre-slab system", Bulletin No. 15-C20, 1984, Faculty of Engineering, Ain Shams Univ.

El-Zanaty, A. (1995), "Shear transfer behavior of initially cracked concrete with compressive stresses normal to the shear plane", Egyptian society of Engineers, Vol. 34, No. 1.

IHAB Abdallah Hussien, "Effect of shear connectors on composite concrete beams", M.sc. Thesis. Faculty of Eng. Cairo Univ. 1991.

Elsayed., "Behavior of simply supported high strength concrete composite T-beams", M.sc. Thesis. Faculty of Engineering Cairo Univ., 2002.

Nawy, E. G., Ukadile, M. M., and Balaguru, P. N., "Investigation of concrete: PMC composite", Journal of the structural division, ASCE, Vol. 108, No. ST-5, May 1982. pp. 1049-1063.

Saemann, J. C., and Washa, G., "Horizontal shear connections between precast beams and cast-in-place slabs", ACI, Nov. 1964. pp. 1383-1404.

M.Rabie., "Shear transfer in composite reinforced concrete sections", PH.D Thesis. Faculty of Engineering. Cairo Univ. 1994.

8/10/2012