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Behavior of Shear Connectors in the Connection between Old and New R.C Slabs

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ملخص البحث

نظرا لانتشار ظهور العديد من العيوب الانشائية فى البلاطات الخرسانية المسلحة المختلفة واعتماد طرق التدعيم لهذه العناصر على زيادة سمك البلاطات . وتعتمد الطريقة المقترحة على قوة الترابط بين الخرسانة المسلحة القديمة والجديدة. ولقداثبتت الدراسات ان هناك عدة عوامل تؤثر على قوة الترابط بين الخرسانة القديمة و الجديدة والتي يجب أخذها في الاعتبار منها الخلطات الخرسانية المستخدمة و تخشين سطح الخرسانة القديمة و تأثير المواد الرابطة و وجود موصلات القص....الخ).وفى هذا البحث تم إختبار عدد ١٠ بلاطات تم تقسيمهم الى مجموعتين رئيسيتين تحتوى كل مجموعة على اربعة بلاطات . فى المجموعة الاولى تم صب الخرسانة الجديدة فى ناحية الشد و تم استخدام اربع طرق لربط الخرسانة الجديدة بالخرسانة القديمة و هى روبة الاسمنت فى البلاطة الاولى و مادة ايبوكسية للربط فى البلاطة الثانية و بلاطتين تم استخدام المادة الايبوكسية بالاضافة الى زرع اشاير فى البلاطة القديمة . و المجموعة الثانية مماثلة للمجموعة الاولى و لكن تم صب الخرسانة الجديدة فى منطقة الضغط. و تم اختبار بلاطتين بدون تدعيم كعينات مرجعية.وتم إجراء مقارنة بين سلوك جميع البلاطات التى تم إختبارها من حيث قيم الانحناء وحمل التشرخ وحمل الانهيار عند جميع مراحل التحميل .

Abstract

Studies have shown that there are several factors that affect the strength of the connections between old and new reinforced concrete slabs that must be taken into consideration including: (concrete strength–roughening of the surface of old concrete - the impact of the bonding material - the presence of shear connectors .... etc.)
This research aims to study the effect of roughening of the surface of old concrete, the bonding materials and the importance of the presence of shear connectors at the link between the old and new reinforced concrete slabs on both tension and compression side of the old slab.

Key words: Repair – Strengthening –RC slabs – Shear connectors – Epoxy – Dowels

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1. Introduction

Duarte Faria, et al. (1) stated that strengthening of concrete slabs by means of post-tensioning is a very effective method regarding ultimate and serviceability limit states. **Eduardo N.B.S. Ju´lio, et al. (2)** declared that the highest value of bond strength was achieved with sand-blasting; pull-off tests are adequate to estimate the bond strength in situ; and pre-wetting the substrate surface does not seem to Influence the bond strength. **Everaldo Bonaldo, et al. (3)** mentioned that Near-Surface Mounted (NSM) is one of the most promising strengthening techniques, based on the use of carbon fiber-reinforced polymer (CFRP) laminates

Hak-Chul Shin and Zhifu Wan (4) discussed the silica fume in new concrete significantly increases not only the compressive strength of new concrete but also the shear bond strength at the interface.
Catherine Papanicolaou, et al. (5). Found that the load-carrying capacity of the strengthened slabs was increased by 26%, 53%, and 20% over that of the control specimen for slabs with one (carbon), two (carbon) and three (glass) textile layers, respectively.
Waleed A. Thanoon, et al. (6) observed that the efficiency of different repair and strengthening techniques and their effects on the structural behavior of cracked one-way reinforced concrete slab had been analyzed. It was observed that the type of repair technique used will affect the load carrying capacity of the slab and will lead to a redistribution of the strains and hence stresses in both concrete and steel reinforcement. All repair techniques are found to be able to restore or enhance the structural capacity of cracked concrete slabs.
K. Behfarnia, et al. (7) declared the bond between repair materials and concrete substrate was evaluated based on slant shear test method.

2- Parameters of the study:

The main objective of this research is to study the best method to strengthen concrete slabs with different techniques various and materials as follows:

1. To study the effect of the concrete surface preparation on the efficiency of the link between old and new concrete.
2. To study the effect of different materials used as a link between old and new concrete slab such as cement mortar and epoxy materials.
3. To study the effect of using shears connectors as a link between old and new concrete.

3. Experimental program

3-1 Specimen Details: As shown in Table (1) and Fig. (1),ten reinforced concrete slabs were tested in this research having dimensions of 100x100 x12 cm. They were reinforced with longitudinal reinforcement 6ø10 mm upper and lower in two directions.
First Group of Slabs: The first group of slabs consists of two slabs as reference samples. They was casted as one unit with 12 cm thickness.
Second Group of Slabs: The second group of consists of two slabs. These slabs were casted as two layers. The thickness of the first slab casted was 7 cm and after 7 days the surface of slab was crushed with thickness 1 cm then a new concrete slab was casted with thickness 6 cm by using cement liquid as linked material . One of these slabs was casted on compression side while the second slab was casted on tension side .
Third Group of Slabs: This group consists of two slabs. These slabs were casted as a two layers. The thickness of the first slab casted was 7 cm and after 7 days the surface of slab was crushed with thickness 1 cm then a new concrete slab was casted with thickness 6 cm by using an epoxy as linked material. One of these slabs was casted on compression side while the second slab was casted on tension side.
Fourth Group of Slabs: The fourth group consists of four slabs. These slabs were casted as two layers. The thickness of the first layer was 7 cm and after 7 days the surface of the slab was crushed with thickness 1 cm then a new slab was casted with thickness 6 cm by using an epoxy and shear connectors as linked material. Two of these slabs were casted on compression side while the other two slabs were casted on tension side.

The slabs were tested at the reinforced concrete laboratory of the housing and building research center, Cairo, Egypt. In order to investigate the ultimate load carrying Capacity, linked materials effects versus deformation as well as load versus strengthening techniques are presented.

3-2 Materials and Mix Proportions

All the tested specimens were cast from locally available materials in Egypt. The concrete used in casting the specimens consisted of ordinary Portland cement, natural sand and coarse aggregate with maximum size 10 mm. The mix resulted in cube strength of approximately 250 Kg/cm² at the age of 28 days. High grade steel bars of an average yield stress 3600 Kg/cm² were used in reinforcing the slabs.

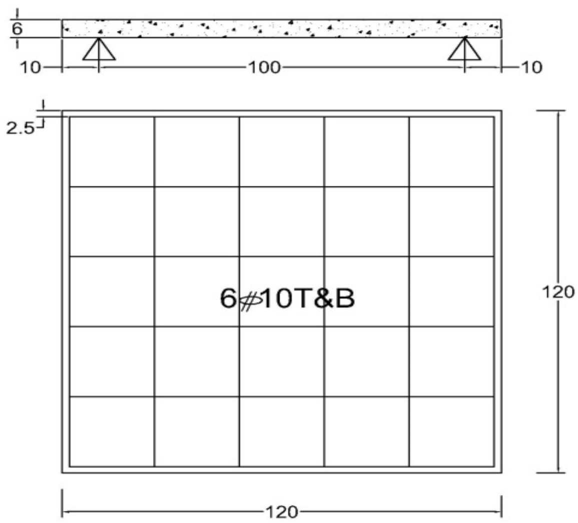

Fig (1) Details of slabs

Table: (1) Details of experimental program.

Slab No.	Kind of Sample	Linking Material	Side of new slab	Reinforcement of old and new slab
S_1	usual	without	Tens.	6ø10 mesh
S_2	usual	without	Comp.	6ø10 mesh
S_3	Sandwich	Mortar	Comp.	6ø10 mesh
S_4	Sandwich	Mortar	Tens.	6ø10 mesh
S_5	Sandwich	Epoxy	Comp.	6ø10 mesh
S_6	Sandwich	Epoxy	Tens.	6ø10 mesh
S_7	Sandwich	Epoxy + Shear connectors	Comp.	6ø10 mesh
S_8	Sandwich	Epoxy + Shear connectors	Comp.	6ø10 mesh
S_9	Sandwich	Epoxy + Shear connectors	Tens.	6ø10 mesh
S_{10}	Sandwich	Epoxy + Shear connectors	Tens.	6ø10 mesh

Deformation Measurements and Loading Arrangement

Two days before testing, the slabs were painted with a white lime solution to facilitate cracks detection. The slabs specimens were mounted in a horizontal position in the loading frame. Both faces of the slab could be easily observed for the development of cracks.

The concentrated load was applied using a hydraulic jack of 50 tons. Five LVDT were used for deflection measurements at the bottom of the slab (tension side) and arranged as shown in Fig (2). The load was applied in successive increments. Slabs deflection and cracking propagation were recorded after each load increment up till slabs failure.

Discussion of Experimental Results

The behavior of the different tested reinforced concrete slabs was investigated under different stages of loading up till failure. The main parameters in the test specimens were the type of link materials. The effect of these parameters on deflection, cracking load, crack pattern and ultimate load was investigated. The main findings of this work can be summarized as follows.

Deflections

Table (2) and Figure (6,7) shows that the deflection of slab $S_{1,2}$ under successive loading is slightly higher than that of all slabs at all stages of loading and up till the failure. At maximum recorded load deflection of slabs S_3, S_5, $S_{7,8}$, S_5, S_4,$S_6$and S_9,S_{10} were 84%, 88.21%, 89.4%, 62.2%, 74.33% and 80.65% of that recorded for slab$S_{1,2}$ respectively. They indicate that the strengthened slab in compression side by using epoxy and shear dowels lead to the close deflections close with those of control slabs.

Crack Initiation and Propagation

The total number of cracks up to maximum recorded load for each slab was recorded. Figure (3) Shows that the total numbers of cracks are considerably the same for all slabs with respect to the total number of cracks of the control beam$S_{1, 2}$.

Ultimate Resistance of Reinforced concrete slab

Table (2) and Figure (5, 7) show the ultimate strength recorded experimentally for the tested reinforced concrete slabs. The ultimate load for slabs S_3, S_5, $S_{7,8}$, B_5, S_4,$S_6$and $S_{9,10}$were 86.9%, 90.56%, 97%, 74.5 %, 80.84%and 89.91% of that recorded for slab $S_{1,2}$ respectively. They indicates that the ultimate load for the slab strengthened in compression side by using epoxy and shear dowels lead to the close ultimate strength for control slab.

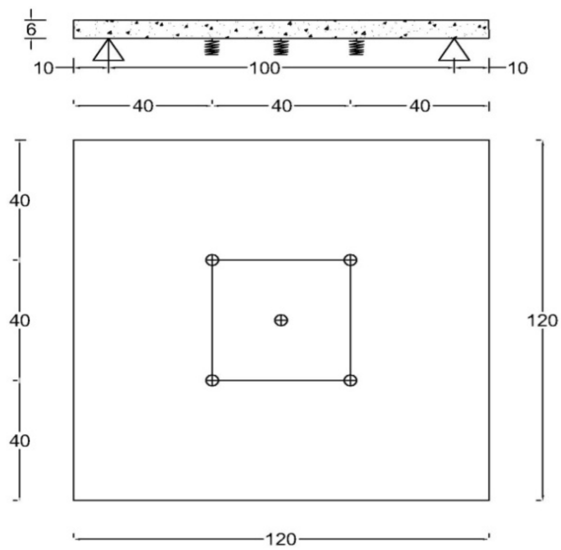

Fig (2): LVDT arrangement

Fig (3): Mode of failure

Table (2): Test results of all specimens

Symbol	Type	P_{crack} (ton)	$P_{ult.}$ (ton)	Deflections (mm)	Deflections / $Deflections_{control}$ (%)	P_{crack} / $P_{control}$ (%)	$P_{ult.}$/ $P_{control}$ (%)
S1-S2	control	11	44.78	21.7	-	-	-
S3	Mortar- Comp.	8.7	38.91	18.23	84	79.1	86.9
S5	Epoxy- Comp.	9.3	40.50	19.14	88.21	84.55	90.56
S7 – S8	Epoxy+Dowels Comp.	10.4	43.42	19.29	89.4	94.6	97
S4	Mortar – Tens.	8.4	33.36	13.51	62.2	76.36	74.5
S6	Epoxy – Tens.	8.5	36.20	16.13	74.33	77.36	80.84
S9 –S10	Epoxy+Dowels Tens.	9.5	40.26	17.51	80.65	86.36	89.91

Conclusions:

1. The crack load of slabs strengthened by using Epoxy in compression side increased by 111.88% than the crack load of slabs strengthened in tension side.
2. The crack load of slabs strengthened by using Epoxy and shear dowels in compression side increased by 107.85% than the crack load of slabs strengthened in tension side.
3. The ultimate load of slabs strengthened by using Epoxy in compression side increased by 104.9% than the ultimate load of slabs strengthened in tension side.
4. The ultimate load of slabs strengthened by using Epoxy and shear dowels in compression side increased by 107.8% than the ultimate load of slabs strengthened in tension side.
5. The ultimate load of slabs strengthened by using Epoxy and shear dowels in compression side increased by 107.2% than the ultimate load of slabs strengthened by using Epoxy only.
6. The ultimate load of slabs strengthened by using epoxy and shear in tension side increased by 111.21 % than the ultimate load of slabs strengthened by using Epoxy only.
7. The ultimate load of slabs strengthened by using epoxy and shear dowels in compression side approximately equal the design slab.

8. In case of study the strengthening of slabs by using epoxy and shear dowels in tension side we must be take into consideration that the ultimate load of strengthened slabs less 10.10 % than the design slabs.

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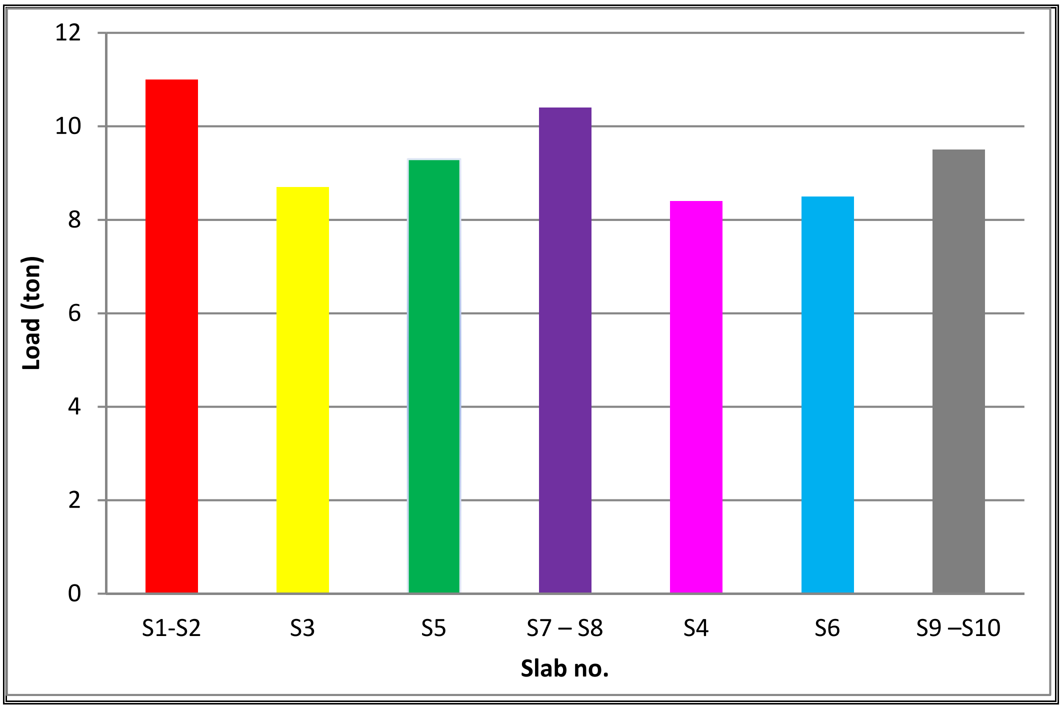

Fig(4): Crack load for slabs

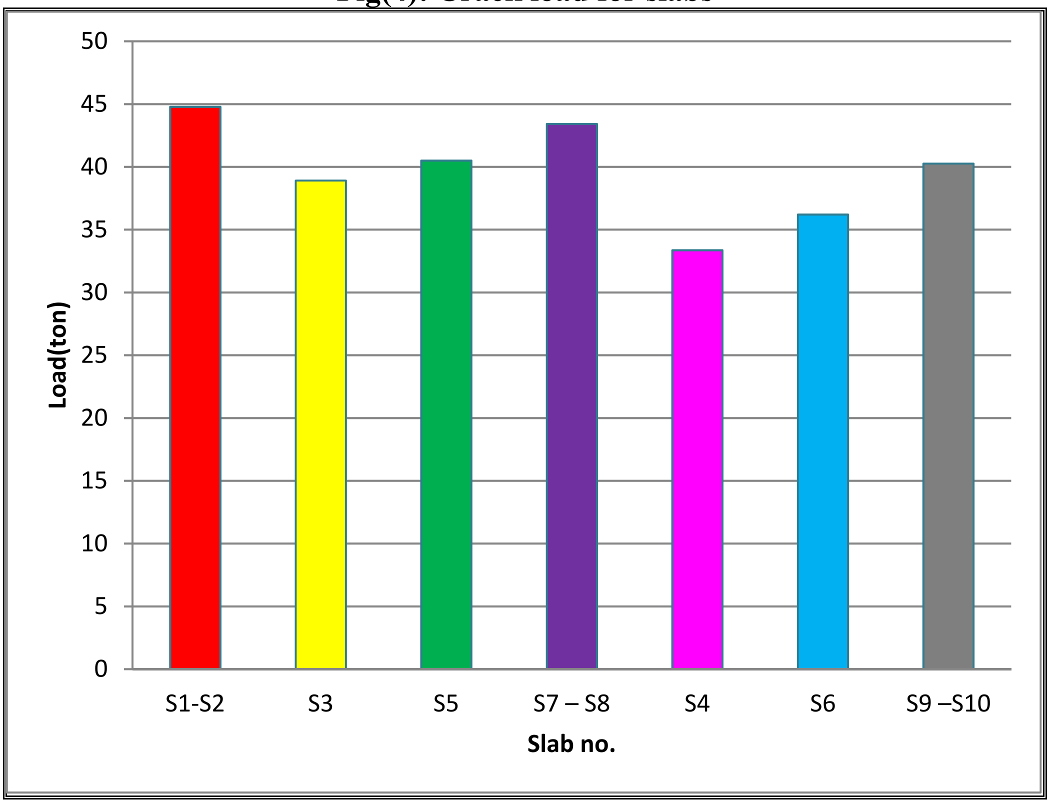

Fig (5): Ultimate load of slabs

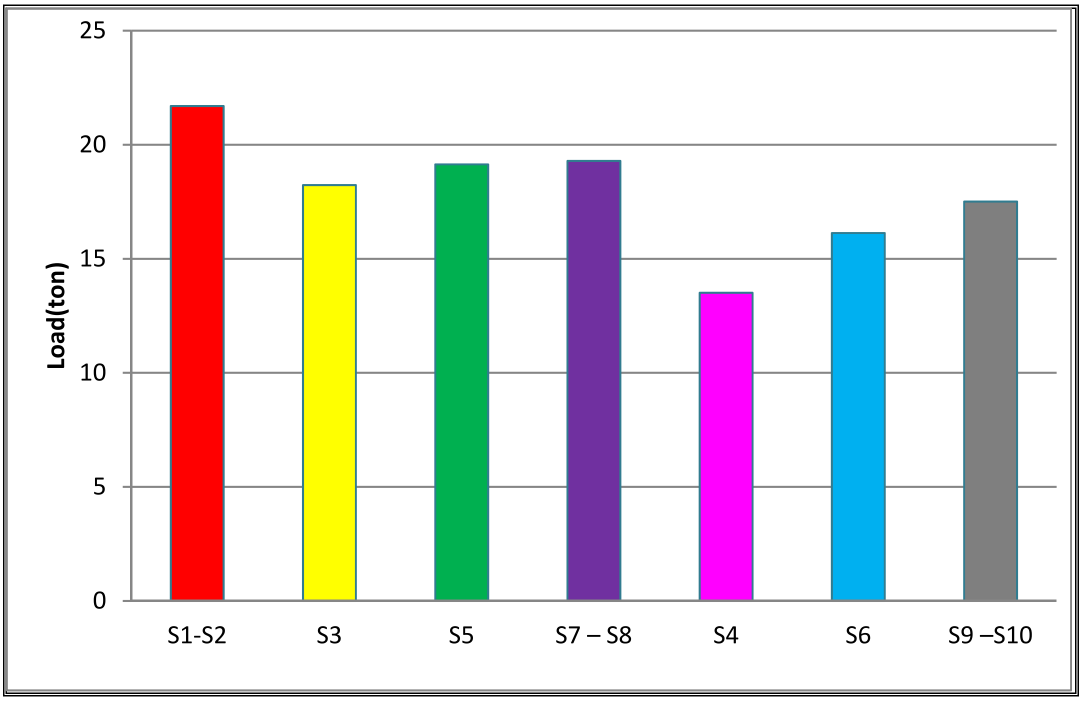

Fig (6): Deflection of slabs

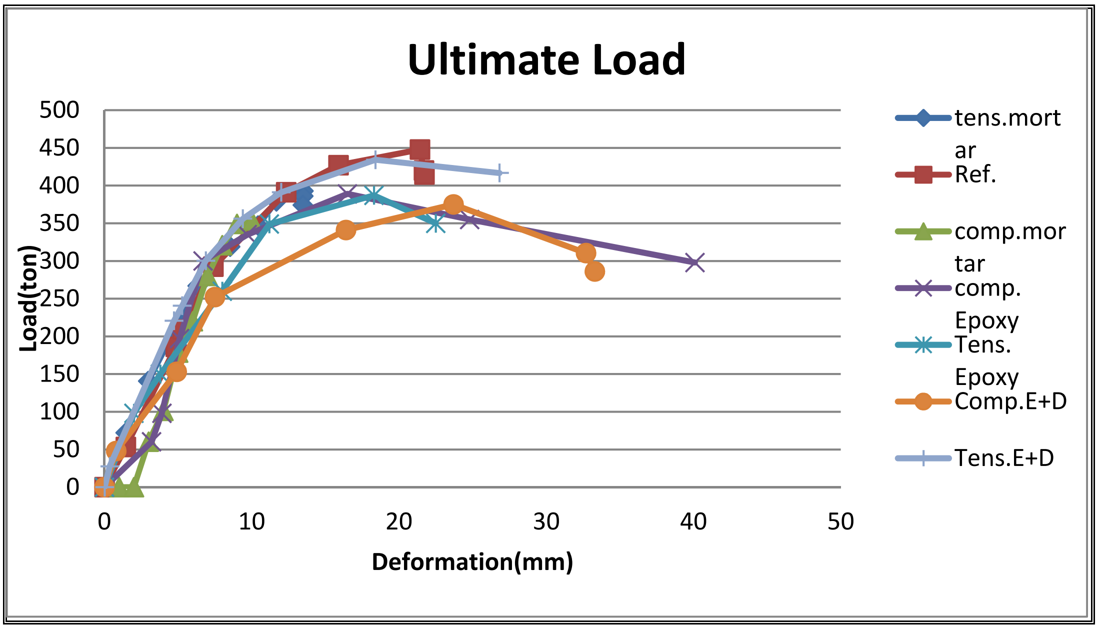

Fig (7): Ultimate Load for Each Slab