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Upgrading Flat R.C. Slab with Haunch Using F.R.P

Dr. Eiad Hafiz. Zahran
Lecturer, Department of structural Engineering, Higher institute of engineering and technology, New Cairo Academy, Egypt.

ABSTRACT:- This work presents a method to improve the punching shear resistance of flat RC slabs that develop cracking at regions between the slab and haunch. The work examines the effect of the punching shear capacity of using glass fiber and carbon fiber at slab haunch interface to enhance. The study consists of an experimental phase and a theoretical study. The experimental work includes testing five specimens of reinforced concrete slabs having a concrete compressive strength (30MPa) and specimens rest on haunch. The first specimen was loaded until failure and used as reference .Four specimens were loaded up to 80% and 50% of the failure load. After being unloaded, two specimens were repairing using glass fiber then loaded to failure and two specimens were repairing using carbon fiber then loaded to failure.

The deflection, cracking, failure modes, strain in steel reinforcement and relationship between load deflection and load-strain were recorded and discussed. Results show that repairing using GFRP and CFRP enhanced the shear capacity of the tested specimens. Enhancement was significant for two specimens after repairing by glass fiber it improved resistance about (11%-15%) and two specimens after repairing by carbon fiber it improved resistance about (17%-30%).

In the analytical study, the specimens were modeled using (ANSYS) computer program based on finite element analysis system. Fair agreement was found between the experimental and the theoretical results.

Keywords:- Glass Fiber Reinforced Polymers, Carbon Fiber Reinforced Polymers, Slab-Haunch connections, Punching Shear and Repairing.

I. INTRODUCTION

Punching shear failure is caused by the vertical shear and unbalanced moment borne by the slab-column connection, which makes the flat-slab connections a weak link in the whole flat-slab structure, and then leading to serious damage or even collapse. Unbalanced moments commonly occur in buildings with flat slabs, caused by unequal spans or loading on either side of the column. Differences of temperature or differential creep between two adjacent floors results in differential displacements of the top and bottom of the columns, which induce moments in the slab-column connection, even if the columns, as is assumed for this study, do not participate in the horizontal load resisting system. In the presence of such moments, the phenomenon of punching becomes unsymmetrical, and the punching strength of the slab decreases as shown in Fig.(1)

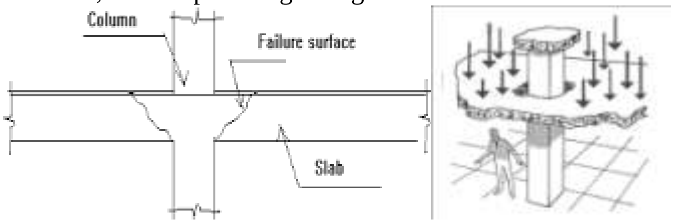


Fig (1): Punching Failure of Slab-Column Connection

II. EXPERIMENTAL PROGRAM

Details of the Test

The experimental work includes testing five specimens flat RC slabs with plan dimension (1250x1250) mms and thickness of 120 mm and rest on square haunch (570 /330/180) . Specimen (SH) is loaded until failure and is considered as reference. Specimen (SH80) is loaded up to 80% of the failure load specimen (SH), (SH50) is loaded up to 50% of the failure load specimen (SH). After that, two specimens (SH80 and SH50) of were repairing by using glass fibers then reloaded until failure. Specimen (LH80) is loaded up to 80% of the failure load specimen (SH), (LH50) is loaded up to 50% of the failure load specimen (SH). After that, two specimens (LH80 and LH50) of were repairing by using carbon fibers then reloaded until failure.

III. MATERIALS PROPERTIES AND CONCRETE CASTING

The flexural reinforcement for all slabs consisted of 15 ϕ 10 each direction, plus 8 ϕ 10 each direction as add reinforcement. The Stub haunch was casted monolithically at the slab center with a cross section of (570 x 570) x (330 x 330) and 180 mm height. The reinforcement of the stub haunch as shown in Fig (2).

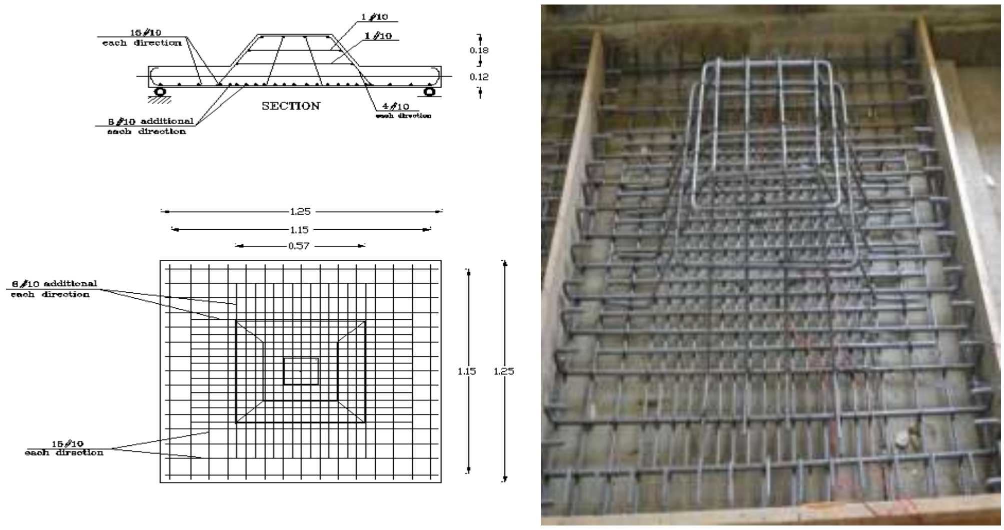


Fig (2): Detail of Reinforcement of Slabs

Table (1): Concrete Mix Constituents (30N/mm2).

Constituents	**Contents (kg/m^3)**	**Proportions**
Cement	325	1.00
Sand	600	1.60
Crushed stone grade (1)	600	1.60
Crushed stone grade (2)	600	1.60
Water	170	0.45

All the specimens of the experimental program were cast in the reinforced concrete laboratory of the Faculty of Engineering, Ain Shams University. Custom designed wooden formwork was used to cast the specimens. Before pouring the concrete the forms were cleaned with a wire brush and treated with a releasing agent and then the reinforcing cages were introduced. A mechanical vibrator was used in placingthe concrete around the reinforcing bars together with the hand tamping and rodding to ensure full compaction as shown in Fig (3), Fig (4).

Slabs were left in forms for 24 hours after which the sides of the forms were stripped away. The specimens were sprinkled with water for a week. Then they were left in the ordinary atmosphere of the laboratory for 28 days before testing.


Fig (3): Details of Specimens Casting Forms **Fig (4): pouring concrete in slabs**

IV. TEST SETUP AND LOADING SCHEME

Two days before testing, Slabs were painted with a white lime solution to facilitate cracks detection. The slab specimens were mounted in a horizontal position in the loading frame and the load was applied to the stub-haunch in a vertical direction fig (5).The load was applied using an hydraulic jack of 100 ton or 200 ton capacity provided with and electrical transducer attached with a digital screen for the load reading. Load was applied on successive increments. Slab deflection, steel strain of shear reinforcement elements and cracking condition were recorded after each load increment and up till slab failure.

Fig (5): Test setup

V. CONCRETE DEFLECTION DEVICES

The deflection of the slab was measured with a linear voltage differential transducer (LVDT). Special arrangement was designed for each dial gauge to fix it in the desired position at the bottom face of the slab (tension side) to ensure proper readings and verticality. The LVDTs positions of the control specimen as shown in Fig (6). To record specimens' concrete vertical deflections, vertical LVDTs were used below slab-haunch specimens at two different locations measured from centerline of the slab as shown in Fig (7).

Fig (6): Locations of vertical LVDT'S

Fig (7): Locations of vertical LVDT'S

The deflection was measured at two locations as shown in Fig (8)

1-At the center of the specimen (D1)

2- At distance of 30 cm from the center of the specimen (D2).

Location (D1) Location (D2)

Fig (8): location of deflection

Electrical Strain Gauges

For each slab, the electrical strain gauges were connected to a strain indicator device. At each load increment, the reading of each strain gauge was recorded until slab failure. The positions of the electrical strain gauges on the main reinforcement as shown in Figure (9).The strain gauge locations were the same for all specimens. (Steel strain was measured before strengthening only but not after).

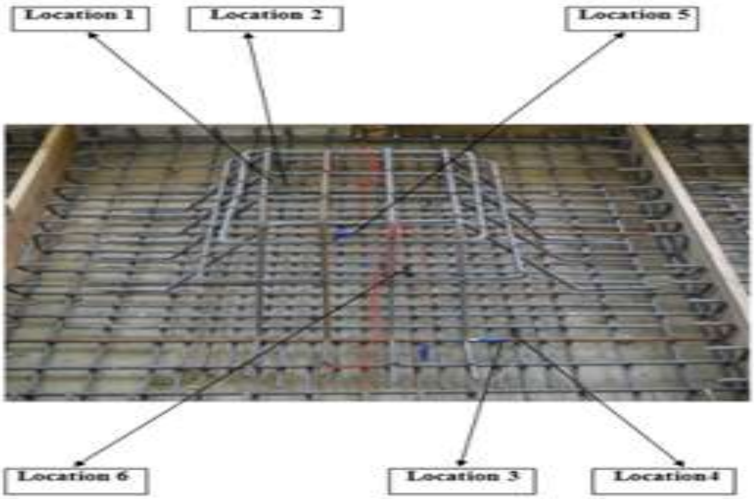


Fig (9): Steel Strain Gauges Positions

VI. EXPERIMENTAL RESULTS AND DISCUSSION

Test Observations

In this section, the cracking pattern and the cracking behavior of the tested slabs during loading is discussed and compared. Final failure in specimen (SH) took place when the haunch was pushed into the slab locally around the connection area. In this part cracking and ultimate loads in the specimens. From results of failure load of the specimens (SH , SH80,SH50,LH80 and LH50) it can be observed the failure load in the slab reference (SH) was (520 KN) but specimens which had been repaired by glass fibers (SH80) its failure load after it was repaired by glass fiber was (580 KN) ,(SH50) was failure load after repairing by glass fiber was (600 KN) , specimen (LH80) which had been repaired by carbon fiber was (610 KN) and (SH50) was failure load after repairing by glass fiber was (680 KN) as shown in fig (10) and fig (11).

Fig (10): Cracking Pattern for Specimens

Table (2): Experimental Results for Specimens

Notations	Concrete Compressive Strength (N/mm2)	Type of Repair	Ultimate Load (KN)	Specimen after Repair/Ref
SH	30	No	520	1
SH80	30	GFRP	580	1.11
SH50	30	GFRP	600	1.15
LH80	30	CFRP	610	1.17
LH50	30	CFRP	680	1.30

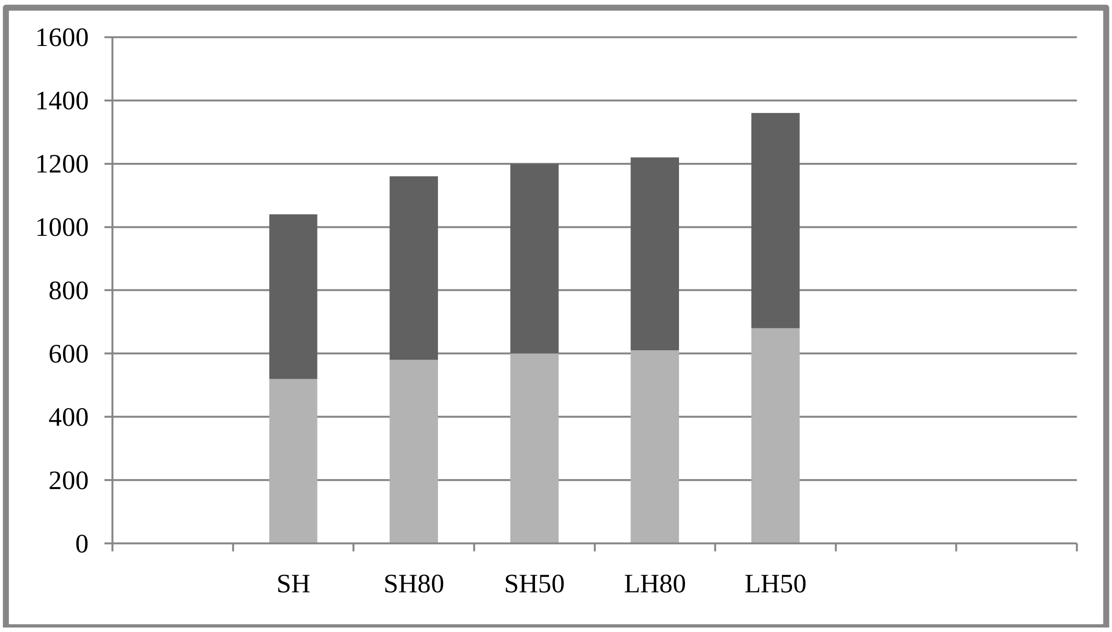


Fig (11): Ultimate load in Specimens.

VII. DEFLECTION

The deflection was measured at two locations for test slab as previously shown in fig (8) during loading and up to failure, and the relation between the load and the deflection was drown as shown in fig(12) and fig (13).

Generally, deflection curves starts more or less straight linear until the cracking load was attained, then, a non linearity is observed because the load increases as a result of cracks propagation.

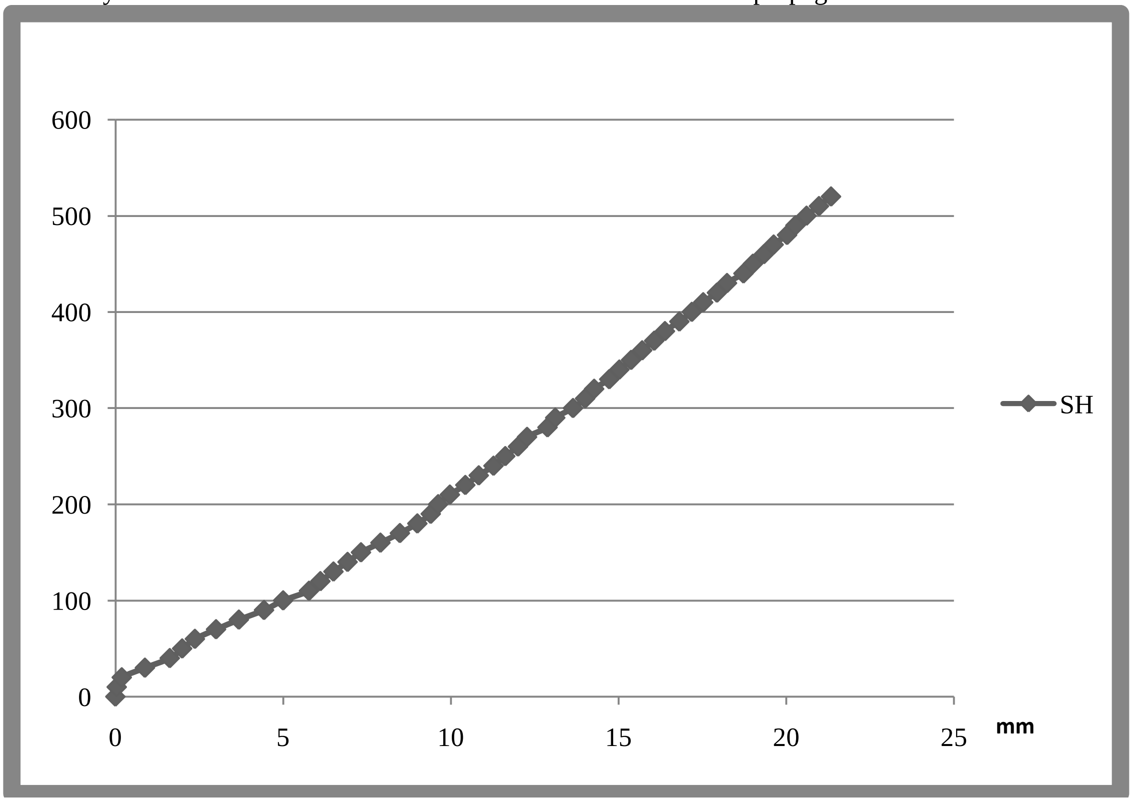


Fig (12): Deflection values at different stages of loading for slabs SH at location (D1).

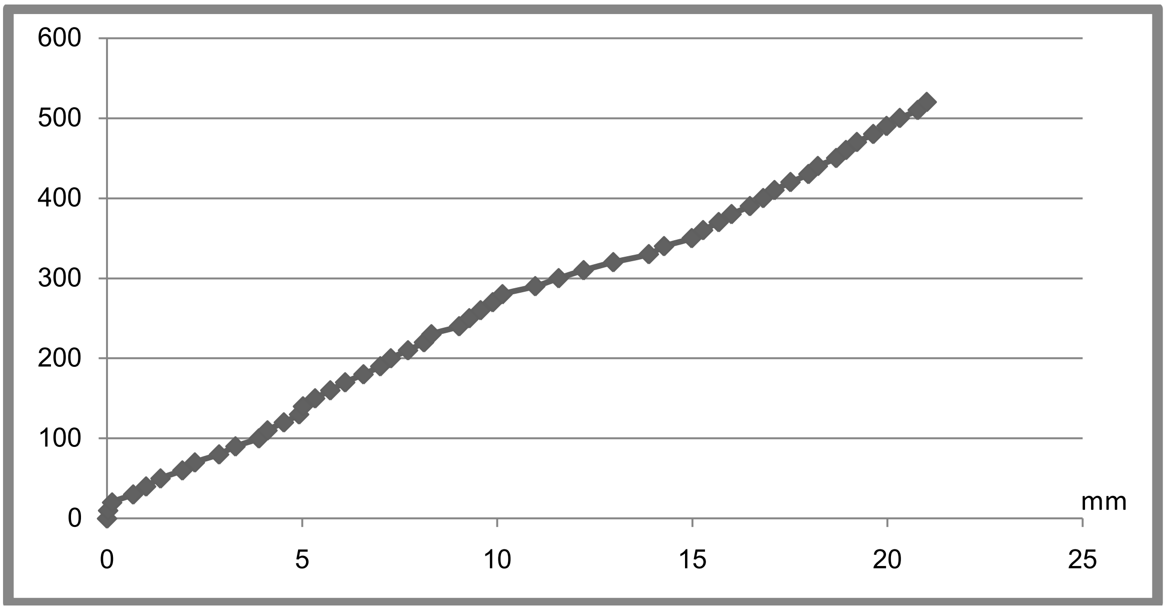


Fig (13): Deflection values at different stages of loading for slabs SHat location (D2).

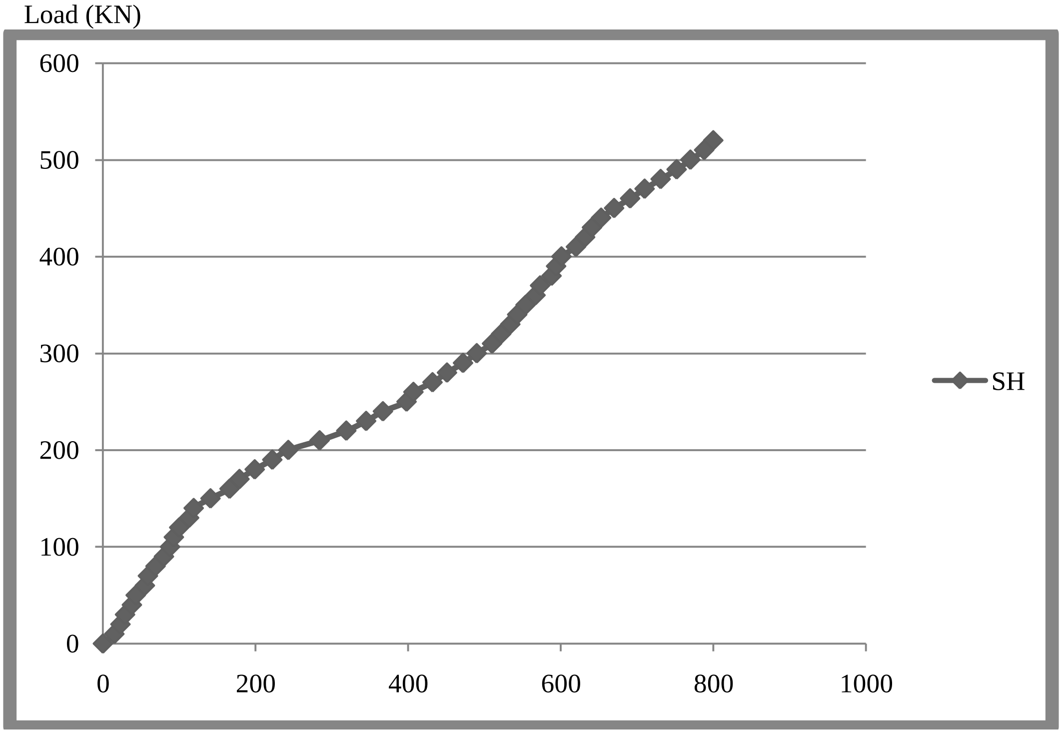
Table (3): Experimental Results Maximum Deflection for Specimen (Reference).

Notations	Concrete Compressive strength (N/mm2)	Maximum deflection at center (D1)(mm)	Maximum deflection at distance of 30cm from the center (D2)(mm)
SH	30	21.33	21

STRAIN STEEL REINFORCEMENT CHARACTERISTICS

The strain was measured at six locations for test slab as previously shown infig (9) and the relation between the load and the steel strain was drown as shown in fig(14) and fig (15) and fig (16).

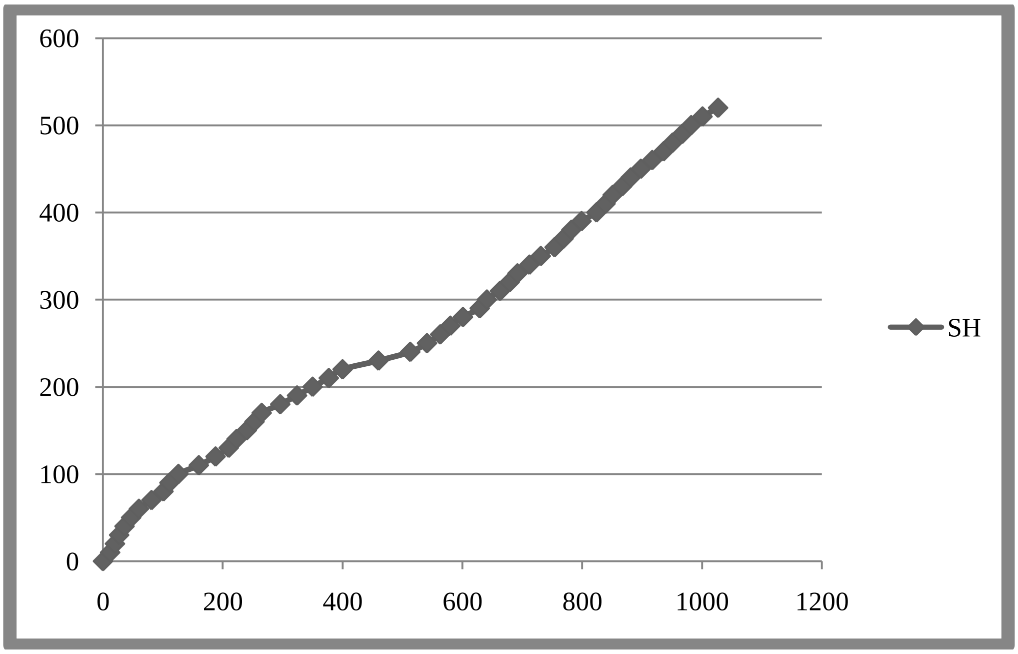
Load (KN)



Micro Strain

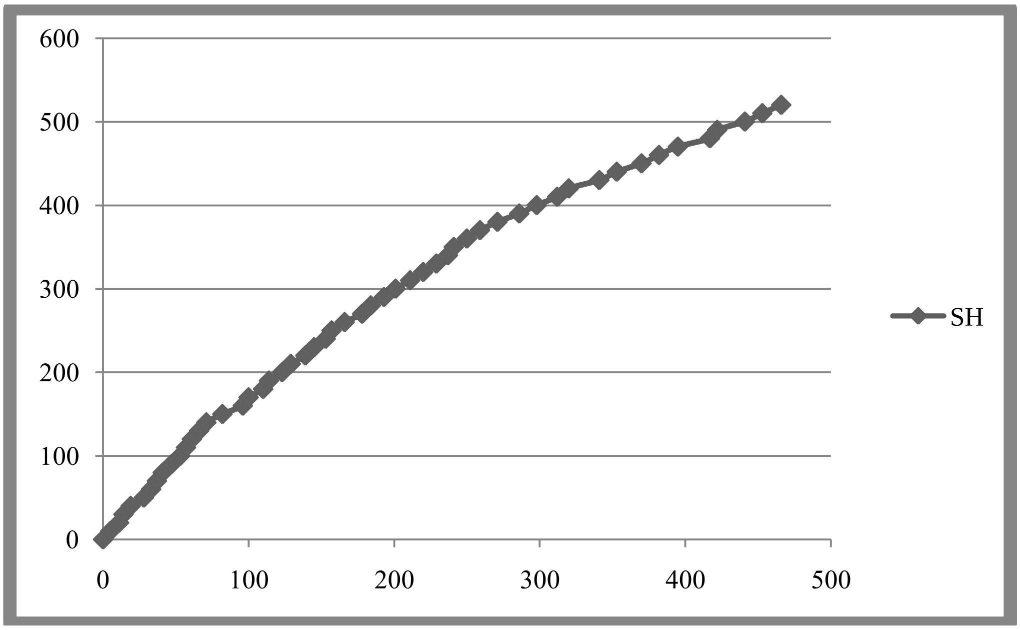
Fig (14): Load- Steel Strain Relationship in average location (1) and (3) for slab SH

Load (KN)



Micro Strain

Fig (15): Load- Steel Strain Relationship in average location (2) and (4) for slab SH



Micro Strain

Fig (16): Load- Steel Strain Relationship in average location (5) and (6) for slab SH

MODELLING USING ANSYS

Introduction

This paper introduces the finite element modeling (FEM) and the FEM by ANSYS in particular. In the next section the required general background to the finite element modeling is presented. Then an introduction to the use of ANSYS in FEM modeling is given. The main phases in modeling by ANSYS are reviewed; these are the preprocessing phase, the solution phase and the post processing phase. Afterwards a complete review of the element types -that will be used in this work- out of the ANSYS element-library is given. These elements are the SOLID65, and link180 element. The model presented in this work is completely explained by the end of this paper; this includes the geometry of the model the used data, the loading conditions and the boundary conditions.

FINITE ELEMENT MODELLING CONCRETE ELEMENT

To be able to account for the failure modes of concrete cracking in tension and crushing in compression, a special brittle finite element material model should be used. This material model could be accessed only with the three dimensional solid element (SOLID65) which was used to model concrete.

The element SOLID65 is defined by 8 nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. A 2x2x2 lattice of integration points is used with Gaussian integration procedure. This means that for each element there are eight integration points. The geometry, node locations, and the coordinate system for this element as shown in fig (17). The element material is assumed to be isotropic and the most important aspect of this element is the treatment of nonlinear material properties where concrete is capable of directional cracking and crushing besides incorporating plastic and creep behavior.

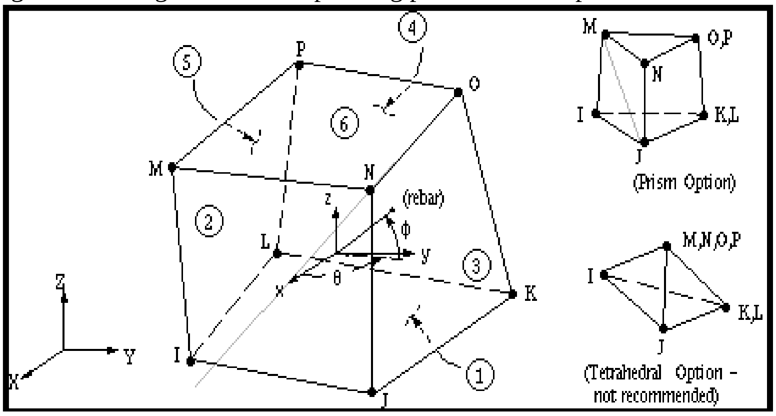


Fig (17): Solid65- 3-D Reinforced Concrete Soil Element (ANSYS Ver.14, 2012)

REINFORCEMENT ELEMENT

A link180 element was used to model the steel reinforcement. Two nodes are required for this element. Each node has three degrees of freedom, translations in the node in x, y and z directions as shown in fig (18).

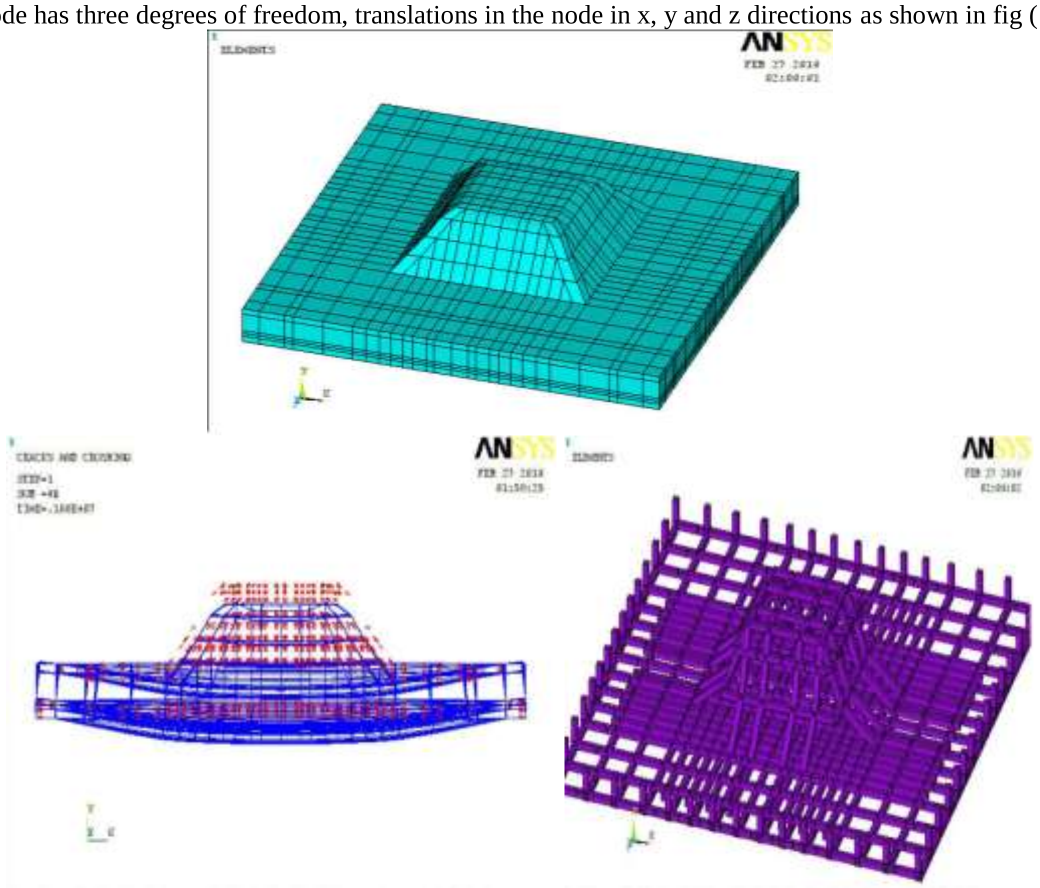


Fig (18): Finite Element Model

COMPARISON BETWEEN ANSYS AND EXPERIMENTAL RESULTS

Table (5): Comparison between ANSYS and Experimental Results

Notations	Compressive strength (N/mm2)	Experimental		Numerical		Exp / Num	
		Ultimate Load (KN)	Ultimate deflection at center (mm)	Ultimate Load (KN)	Ultimate deflection at center (mm)	Load	Deflection
SH	30	520	21.33	570	24.90	0.912	0.856

VIII. CONCLUSIONS

[1]. GFRP and CFRP wraps enhanced the shear capacity.

[2]. Slabs with concrete grade 30 N/mm2 and repairing using GFRP showed enhancement in the ultimate load capacity with ratio 11% (Slabs loaded before repairing to 80% of ultimate load) to 15%(Slabs loaded before repairing to 50% of ultimate load).

[3]. Slabs with concrete grade 30 N/mm2 and repairing using CFRP showed enhancement in the ultimate load capacity with ratio 17% (Slabs loaded before repairing to 80% of ultimate load) to 30%(Slabs loaded before repairing to 50% of ultimate load).

[4]. Repairing of slab-haunch connection using GFRP wraps and CFRP wraps is

[5]. quickand simple to implement.

[6]. Using CFRP in repairing specimens of concrete compressive strength (30 N/mm2)

[7]. give high more than using GFRP.

[8]. In the analytical study, the specimens were modeled using (ANSYS) computer program based on finite element analysis system. Fair agreement was found between the experimental and the theoretical results.

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