Upgrading Of Reinforced Self Compacting Concrete Flanged Deep Beams Containing Voids In Web By Strengthening With CFRP Sheets

Dr. Qasim Mohammad Shakir, Yahya Mohammed Yahya, Dr. Ali Talib Jasim

Abstract: In the present work, a non-linear finite element (FEM) analysis has been conducted in order to investigate the performance strengthening of reinforced self-compacting concrete T-deep beams with rectangular openings by CFRP sheets. five beams have been considered with different opening location (size of openings 150 *250)mm. To improve the performance of beams with rectangular openings, the most commonly used methods in strengthening have been adopted which is CFRP sheets. This comparison was based on the of load-deflection curves, ultimate loads and cracking patterns the result obtained are compared with those experimentally recorded at failure. The comparison result between the results of the experimental program and the F.E. analysis showed the validity of the result model adopted in the present work to simulate the behavior of the flange deep beams have openings strengthening by CFRP sheets in the present work. The analysis results showed that when the introducing openings with size of (150*250) mm led to a reduction in the load capacity by (64%) when located flushed to the flange and (70%) when bottom location.

Index Terms: Non-linear analysis, R.C. T- deep beams, rectangular openings, strengthening with CFRP

1 Introduction

A major challenge in a tall building structure is to reach suitable column free space in the lower most floors either for storing or parking. To achieve sufficient residence room size as a design for architectural in the upper stories. It terminal level which acts as point load have to rest on a transmission deep girder which is categorized by load distributing structure element beam with small span/depth ratio such member transfers loading diagonally to support and mostly fails in others rather than flexural(Yousif,2016). In practical life, it is repeatedly required for passing services like electrical installations, pipe lines and networks, telephone and heating or cooling ducts (Yang and Ashour, 2007; Saeed and Yousif, 2013). Usually, these pipes and ducts are placed underneath floors, then are covered by a suspended ceiling. This leads to create a dead load and increase the building height. This results in an added dead load and a reduction in lateral stability. Thus, incorporating openings in floor beams will reduce such problems (Mansur, 2006). However, existence of opening in the web of a deep beam could be the reason to happened of unexpected weakening in the capacity of shear as a result to concentrate of stress at the opening corners and intermission of the path of the load of compressive strut. An opening may be small or large. Most of previous works considered small openings (Mansur, 2006; Rashwan et al., 2014). But sometimes, such openings may not satisfy the utility requirements. Therefore, it is necessary to adopt larger openings (Mansur, 2006; Sahoo, 2012; Qasim2010).

- *Dr. Qasim Mohammad ShakirCivil Engineering Dept.University of Kufa, qasimm.alabbasi@uokufa.edu.iq*
- *Yahya Mohammed Yahya Civil Engineering Dept. University of Kufa yahyaalsahlawy@gmail.com*
- *Dr. Ali Talib Jasim Civil Engineering Dept. University of Kufa, alit.albozwaida@uokufa.edu.iq*

FRP has been used as a reinforcing material for many structures around the world for retrofitting and rehabilitation of structures(Lee, 2008). The application of FRP composites spread dramatically with increased attractor in the last few years in strengthening rather than be as a reinforcing material due to their several advantages such as corrosion resistance, high strength to weight ratio(Yuan, 2004).

2-Experimental Program

2.1 Details of the test specimens:

Five T-deep beams specimens were designed and manufactured. dimensions of a typical specimen were web of 160 mm width, flange width of 440 mm, a flange thickness of 100 mm, overall depth of 450 mm, and clear span 1400 mm with a total length of 1600 mm, the size opening have been studied with two location. Fig.(1) and table (1) shows the dimensions and the location openings details of the T-deep beams. Compressive strength values of concrete with a 28 day have been 48.5 MPa. The test of the specimen beams were done under monotonically increment of load and up to the failure. The beam was loaded at the upper face with vertical load, then it was recorded the first reading a dial gage. The load was applied at a constant rate on the specimen beams and gradually was increased up to the failure. For each stage of increment of load, The reading of deflection (vertical displacement) in the mid-span of beam. Also, for each step of load the patterns of crack were checked, as well as the load of the first crack and failure of the beam was recorded.

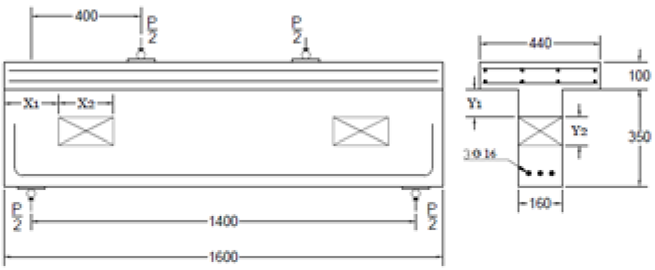

Fig. (1) *Detail control beams*

Table (1) *Details of control beams opening*

Beam designation	Beam type	X1	X2	Y1	Y2
C solid	control	-	-	-	-
CRBO	control	175	250	75	150
CRTO	control	175	250	0	150

2-2 Mix Constituents

The mix has designed according to the (ACI R237-07). Table (1) lists the proportion of the final SCC mix .

Table (1) *SCC mix proportion.*

Material	Cement	Coarse Aggregat (kg/m3)	Fine Aggregate (kg/m3)	Water (L/m3)	Limestone (kg/m3)	Glenum 54 (L/m3)	W/c
Amount	400	780	962	128	75	4.8	0.3218

3-Finite Element Modeling:

By benefit from the symmetry, a quarter of the beam is modeled. This approach significantly reduces the required computer disk space and the time computation of the mesh density. Mesh description and boundary condition are shown in Fig. (2) and Fig. (3).

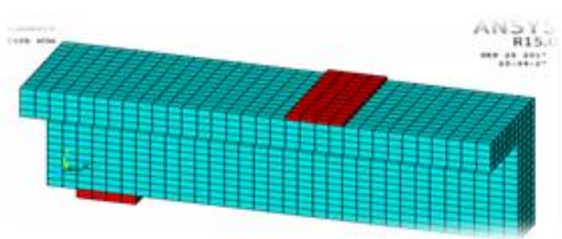

Figure (2) *simulation of boundary conditions*

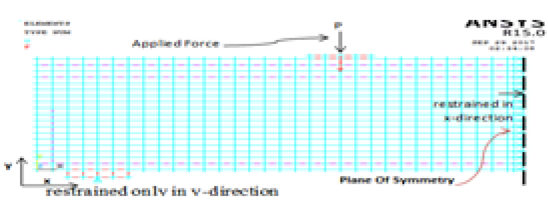

Figure (3) *Sketch for a quarter of the beam*

The concrete was modeled using Hexahedral element (SOLID65). This element was defined by eight nodes and each node has three degrees of freedom. The (SOLID65) has ability to creep, plastic deformation, cracking in tension zone and crushing in compression zone. The bearing plates and strengthening were modeled using brick element (SOLID185). This element was defined by eight nodes and each node has three degrees of freedom. The (SOLID185) has large deflection, creep, large strain, plasticity, stress stiffening and hyper-elasticity. The longitudinal steel bars and ties were modeled using (LINK180). This element was defined by two nodes and each node has three degrees of freedom. Its characteristics were no bending, pin-jointed structure and uniaxial compression-tension. The (LINK180) has large deflection, creep, large strain, plasticity and rotation. A four node SHELL 41 element was used to model CFRP sheet.

4-Test result

4-1 Load-Deflection Results

The load mid-span deflection curves for the tested beams are shown in Figs. (4) to (8). It can be seen that the results of numerical analysis for most of the beams including openings seem to be Identical than experimental , the theoretical results tend to be closer to those obtained. This agreement gives high dependability of the theoretical analysis and it can be used in study the behavior of specimens of full scale or with complex geometry that difficult to be tested experimentally. In general, the load-deflection curve for all beams from the F.E. analysis appears that there is a good agreement with results of the experimental work as shown in Table (2).

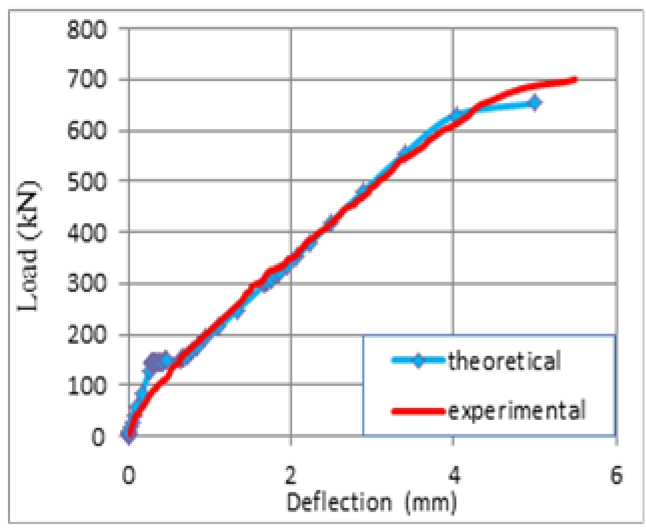

Figure. (4) *load-deflection curves for the specimen csolid*

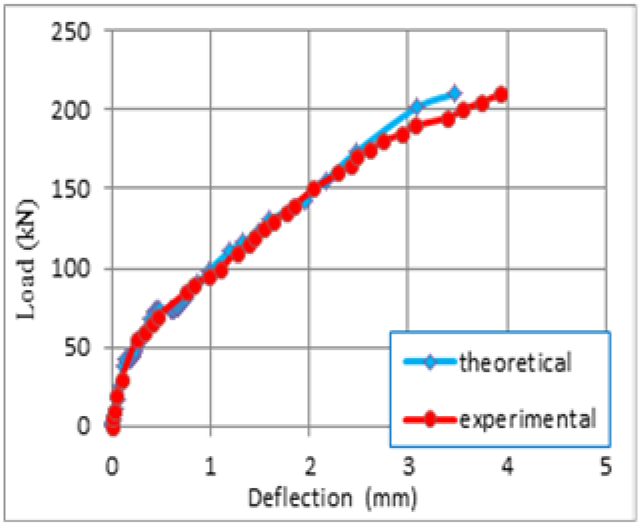

Figure. (5) *load-deflection curves for the specimen crbo*

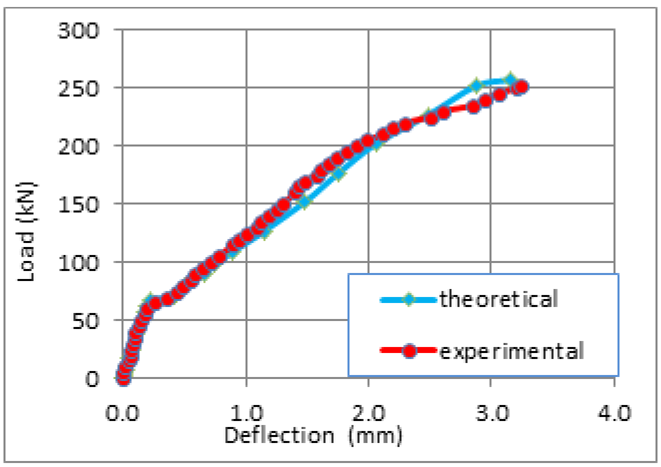

Figure. (6) *load-deflection curves for the specimen crto*

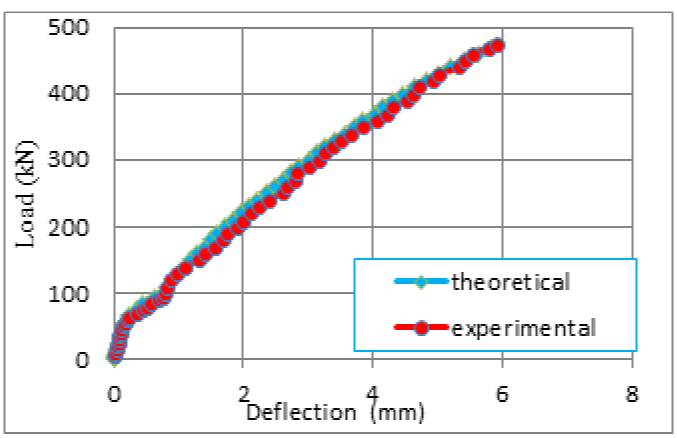

Figure. (7) *load-deflection curves for the specimen R2crto*

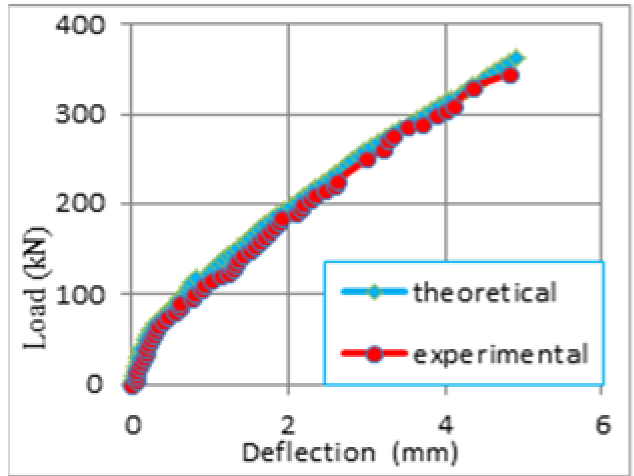

Figure. (8) *load-deflection curves for the specimen R2crbo*

Table (2) shows the value of failure load obtained experimental and theoretical for the tested beam. Also , shown value of deflection at instant of failure .

Table (2) *Ultimate Load and deflection for test beam*

Beam symbol	*Failure Load*		*(Exp./F.E)*	*Deflection (mm)*		*(Exp./ F.E)*
	EXP.	*Ansys*		*EXP.*	*Ansys*	
C solid	*700*	*653*	*1.07*	*5.49*	*5*	*1.21*
crto	*252*	*256*	*0.98*	*3.24*	*3.15*	*1.02*
crbo	*210*	*209*	*1.01*	*3.93*	*3.46*	*1.14*
R2crto	*475*	*470*	*1.01*	*5.9*	*5.82*	*1.01*
R2crbo	*345*	*362*	*0.95*	*4.82*	*4.92*	*0.98*

C:control, r:rectangular, t:top, b:bottom, R:strengthening O:opening

5- Crack Patterns

The results of the comparison between experimental and (FE) results of the crack patterns for the tested beams has presented in Fig. (9). Where, each figure consists of two parts, theoretical and experimental It can be easily noticed that there was a good agreement between the obtained cracks patterns and the at traced when loading of specimens. that the Ansys software can estimate the crack patterns with least difference from experimental tests. The predicted crack pattern for most beams were approximately consistent with the recorded experimental work. This supports the effectiveness of the three dimensional model. A slight difference from the results of the experimental work due to the reasons mentioned previously. It can be obviously seen that cracks are condensed around and close to the corners of openings, which is attributed to concentration of stresses at these points.

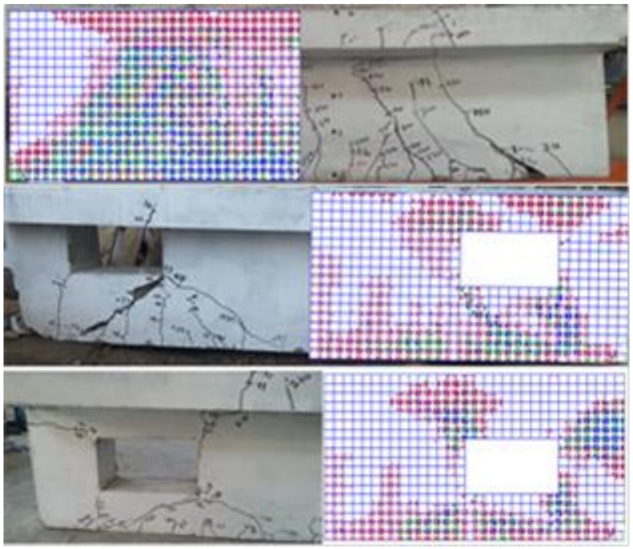

Figure (9) *the experimental and predicted theoretical crack pattern of control specimens*

6- Parametric Study

As of validity of the model adopted in the present study has been some parameters that are expected to have significant influence on the overall behavior R.C. T-deep beam with web opening are studied, which are:

1- Flange width (bf)
2- Concrete compressive strength

6-1 Flange width (bf)

Two values of flange width were selected around the value adopted in the present work. Those namely are 160 mm and 880 mm. In this study, several numerical specimens had been considered (csolid, crto, and Rcrto). The analysis results showed a significant enhancement in load capacity. Fig. (10) shows the influence of flange width on the failure load of the studied beam.

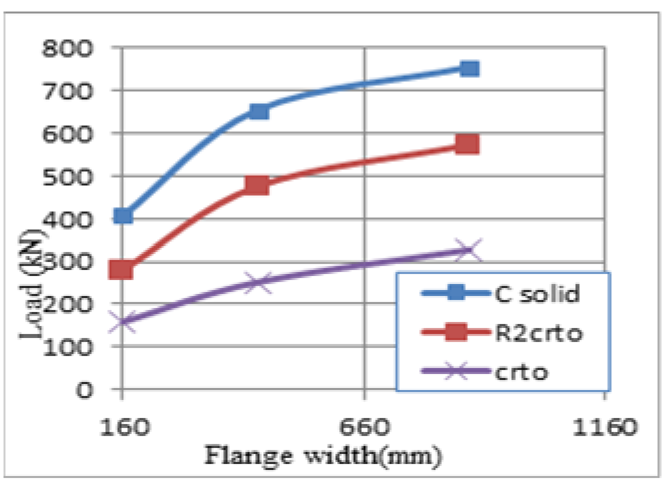

Figure (10) *effect of flange width on the load Capacity*

The results showed that the flange width has a some effect on the shear capacity of R.C T-deep beams to some limits. where the results showed an improvement in the shear capacity of the specimens (C sold, R2crtoand crto) by about (61, 67 and 58) % when considering flange width (440) mm rather than rectangular section, and (15, 20 and 30)% when the flange width increased from (440- 880)mm. In conclusion, the increment of the width of flange of T-deep beam produced a higher capacity of the shear, where the area of concrete in the upper flange of the T-deep beam may provide a supplementary area for the compression zone. So this may result in reducing the average stress at failure and improve the shear capacity of the T-beam.

6-2 The Concrete Compressive Strength

The significant major variables that may affect the capacity of deep beams is the concrete compressive strength. Result of Csolid specimen showed that when the compressive strength increased from (30-90) MPa, lead to an increment in the ultimate load (stiffness) of the beam. Fig (11) shows the effective of change compressive Strength. increasing the (f'c) from (30 to50) showed enhancement in load capacity about (59)%. But when increased (f'c) (50 to 90), a slight improvement can be seen of about (11)%.

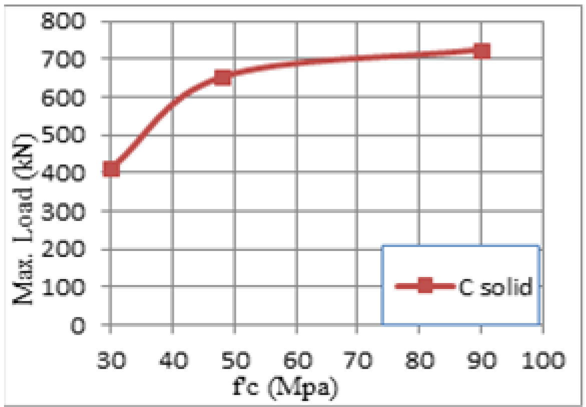

Figure (11) *effective (compressive Strength) on the specicen csolid*

7-CONCLUSIONS

Based on experimentally analysis conducted in the present study, the following conclusions can be drawn:

1- Incorporating openings within reinforced concrete beams results in reduction in ultimate load capacity by (64%) when located flushed to the flange and (70%) with bottom location.
2- It was noticed a considerable influence in the general behavior of the beam specimens when the CFRP sheets were used as a method of the external strengthening, where it was recorded a maximum increment of the ultimate load with a ratio of (88) % in specimen R2crbo.
3- The strengthening with the CFRP sheets led to an improvement in structural capacity by (64%), when located flushed to the flange while bottom location, was found the improvement in capacity by (87%).
4- The comparison result between the results of the experimental program and the F.E. analysis showed the validity of the result model adopted in the present work to simulate the behavior of the flange deep beams have openings strengthening by CFRP sheets in the present work.

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