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

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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 load-deflection curves, ultimate loads and cracking patterns. The results obtained are compared with those experimentally recorded at failure. The comparison shows that 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 sheets.
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.

<table>
<thead>
<tr>
<th>Material</th>
<th>Cement Amount (kg/m3)</th>
<th>Coarse Aggregate (kg/m3)</th>
<th>Fine Aggregate (kg/m3)</th>
<th>Water (L/m3)</th>
<th>Limestone (kg/m3)</th>
<th>GIl54 (L/m3)</th>
<th>W/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount</td>
<td>400</td>
<td>780</td>
<td>962</td>
<td>128</td>
<td>75</td>
<td>4.8</td>
<td>0.321</td>
</tr>
</tbody>
</table>

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).

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 studying 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).
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

<table>
<thead>
<tr>
<th>Beam symbol</th>
<th>Failure Load</th>
<th>(Exp./FE)</th>
<th>Deflection (mm)</th>
<th>(Exp./FE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>700</td>
<td>1.07</td>
<td>5.49</td>
<td>5</td>
</tr>
<tr>
<td>crbo</td>
<td>252</td>
<td>0.98</td>
<td>3.24</td>
<td>3.15</td>
</tr>
<tr>
<td>crto</td>
<td>210</td>
<td>1.01</td>
<td>3.93</td>
<td>3.46</td>
</tr>
<tr>
<td>R2crbo</td>
<td>475</td>
<td>1.01</td>
<td>5.9</td>
<td>5.82</td>
</tr>
<tr>
<td>R2crto</td>
<td>345</td>
<td>0.95</td>
<td>4.82</td>
<td>4.92</td>
</tr>
</tbody>
</table>

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 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.
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 of 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.

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 solid, R2crto and 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 (fc') from (30 to 50) showed enhancement in load capacity about (59)%.

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.

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

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.
8-REFERENCES


