Enhancement in the Load-Carrying Capacity of Reinforced Concrete Corbels Strengthened with CFRP Strips under Monotonic or Repeated Loads

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ABSTRACT:
The present research investigates the effectiveness of using unidirectional carbon fiber reinforced polymer as an external strengthening technique to increase the load carrying capacity of existing reinforced concrete corbels subjected to monotonic or non-reversed repeated loads.
20 normal weight reinforced concrete double-sided corbels were cast for this purpose, 15 of them were strengthened with carbon fiber strips. The variables studied were: the width and orientation of carbon strips and the load history schemes used to apply the non-reversed repeated loading. It was found that the external strengthening with carbon strips improved the capacity of corbels. The enhancement in the load carrying capacity for the corbels strengthened with 50 mm strips and tested under monotonically loads were 11%, 15% and 27% for the horizontal, inclined and mixed orientations respectively. While for the non-reversed repeated loaded corbels, the enhancement in the load carrying capacity was about 11%, 18% and 21% for the horizontal, inclined and mixed orientations respectively.
Keywords: Normal Reinforced Concrete Corbels, External Strengthening, Unidirectional Reinforced Carbon Fiber Fabric (CFRP), Epoxy Bonding.

INTRODUCTION:

Brackets or corbels are short structural members that cantilever out from a column or a wall to support a load. Those members are generally built monolithically with the column or wall; the term "corbel" is generally used for cantilevers having shear span-to-depth ratios, a_v/d, less than or equal to 1[1].
In ACI-318, corbels are considered as simple trusses or deep beams, rather than flexural members designed for shear [2].
The small ratio of (a_v/d), less than unity, changes the state of stresses of the member into a two-dimensional one. Shear deformations would affect their nonlinear stress behavior in the elastic state and beyond, and the shear strength becomes a major factor. Therefore, it is widely assumed that reinforced concrete corbels are principally shear transfer devices [3].
Conventional design procedures provide horizontal stirrups throughout the corbel depth to improve their shear capacity and reduce the sudden catastrophic failure; examples of such failure are called diagonal splitting failure modes [4 and 5].
To improve the strength of corbels, some researchers recommended the use of different kind of fibers, such as steel or polypropylene fibers to replace the conventional stirrups or a combination of both. It was observed that steel fiber reinforced corbels achieved high strengths, had smaller cracks

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and failed in a more controlled manner [6, 7, 8, 9, 10, 11, and 12]. Moreover, it was also concluded that the combination of fibers and stirrups have led to a higher reduction in deflection [13].
The addition of steel fibers is different from using CFRP as a strengthening technique to improve the capacity of existing reinforced concrete members. Previous studies, regarding strengthening, concentrated on the effectiveness of using CFRP or GFRP in increasing the shear capacity of deficient reinforced concrete members in general and corbels in particular, but most of these studied were related to structures subjected to monotonic loads [10, 14, 15, 16, 17, 18, 19, 20 and 21].
The use of this technique to improve the behavior of deficient reinforced concrete corbels subjected to repeated loadings are rare in literature. The main objective of the present study is to investigate the effectiveness of using CFRP as an external strengthening technique to increase the load carrying capacity of existing corbels subjected to monotonic or non-reversed repeated loading regimes.

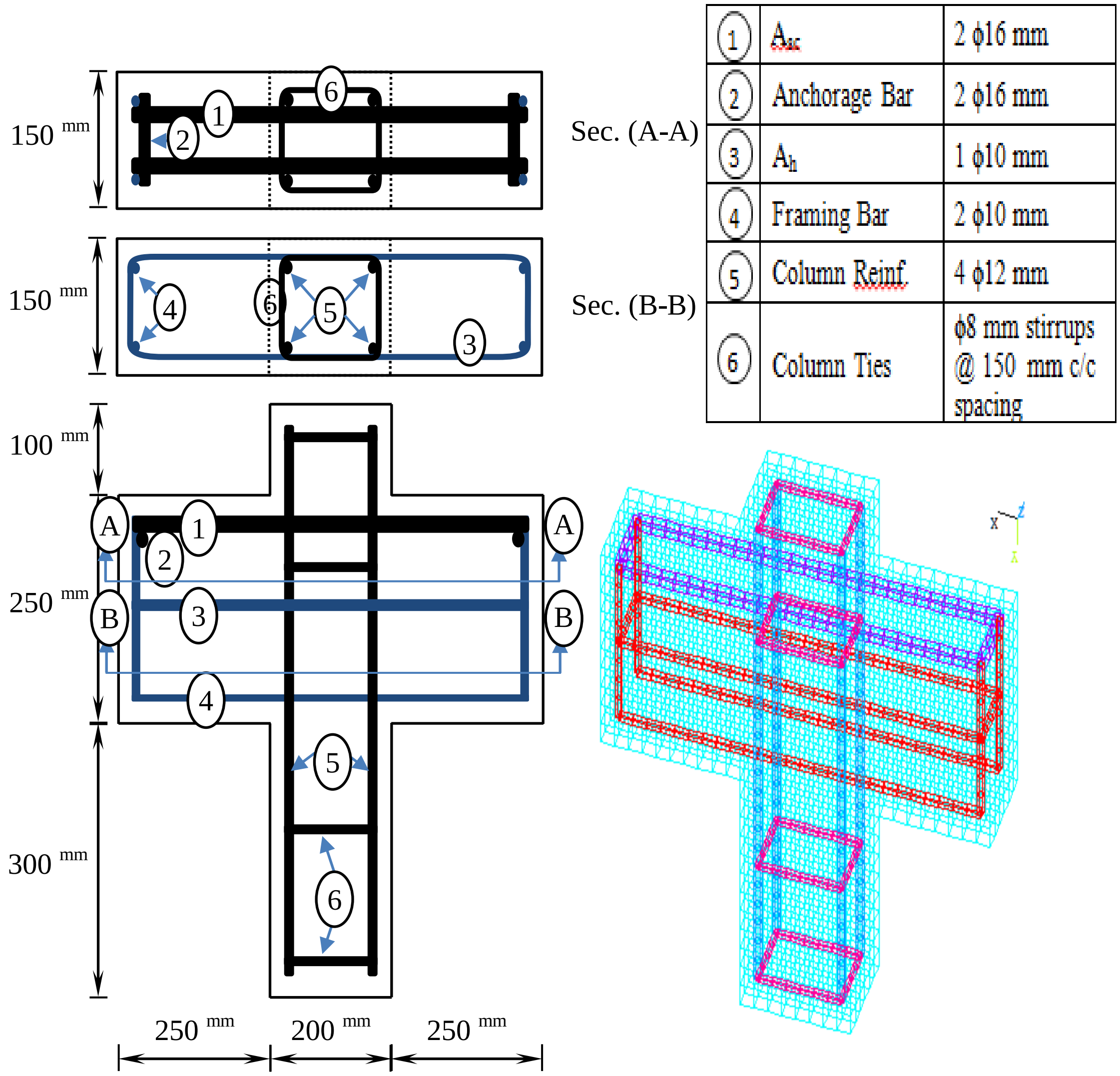
Experimental Work:

Test Specimen

The experimental program consisted of constructing and testing 20 normal weight reinforced concrete double corbels built monolivthically with a short column, as shown in figure (1).
The research specimens were designed following the ACI 318-M-14 procedures, the design included the non-strengthened specimen. The specimens were divided into two groups according to the nature of loading. The first group included six specimens tested under monotonic loading. The second group is divided into four subgroups which included fourteen specimens tested under non-reversed repeated loading. The variables studied were: the width and orientation of the CFRP fabric strips, and the load history schemes used to apply the non-reversed repeated loading, LH1, LH2 and LH3. The test matrix of the research specimens are illustrated in table-1.

Materials Used:

Ordinary Portland cement was used to produce the concrete in this research. The mixture had the proportion by weight of (400:753.5:901), (Cement:Sand:Gravel) with a water/cement ratio of 0.54. All specimens were cast horizontally in five batches.
Four sizes of deformed steel bars were used in this investigation. The modulus of elasticity for all types of steel bars was assumed to be 200000 MPa. The yielding stress for the bars 16, 12, 10 and 8 mm were 497, 655, 756 and 667 MPa respectively.



1	A_{sc}	2 ϕ16 mm
2	Anchorage Bar	2 ϕ16 mm
3	A_h	1 ϕ10 mm
4	Framing Bar	2 ϕ10 mm
5	Column Reinf.	4 ϕ12 mm
6	Column Ties	ϕ8 mm stirrups @ 150 mm c/c spacing

Figure 1 - Details of Research Specimens

The external strengthening reinforcement included a unidirectional woven carbon fiber fabric, CFRP, Sika Wrap®-300 [22], bonded to the specimen using a compatible epoxy resin, Sikadur 330 [23]. The cured CFRP composite sheet (fibers and resin) had a Tensile strength of 3900 MPa, tensile modulus of 230000 MPa and an ultimate elongation of 1.5%, as given by manufacturer.

Table 1 – Test Matrix of Research Specimens

Groups	Sub Groups	No. of Specimens	Specimens	Orientation of Strips	Width (mm)	$f'_{c-28\ days}$* (MPa)	Loading History Scheme
Monotonic	M	1 and 2	M-0-W	-	-	31.3	-
		3	M-50-H	Horizontal	50		-
		4	M-50-I	Inclined	50		-
		5 and 6	M-50-HI	Mixed	50		-
Repeated	R_W	7	R-0-W-1	-	-	30.9	LH1
		8	R-0-W-2	-	-		LH2
		9	R-0-W-3	-	-		LH3
	R_{LH}	10	R-50-H-1	Horizontal	50	30.9	LH1
		11	R-50-H-2	Horizontal	50		LH2
	R_H	12	R-50-H-3	Horizontal	50	31.3	LH3
		13	R-100-H-3	Horizontal	100		LH3
		14	R-150-H-3	Horizontal	150		LH3
	R_I	15	R-50-I-3	Inclined	50	30.5	LH3
		16	R-100-I-3	Inclined	100		LH3
		17	R-150-I-3	Inclined	150		LH3
	R_{HI}	18	R-50-HI-3	Mixed	50	30.5	LH3
		19	R-100-HI-3	Mixed	100		LH3
		20	R-150-HI-3	Mixed	150		LH3

* The average value of $f'_{c-28\ days}$ for all batches = 30.9 MPa

Casting and Curing:

The casting and curing of all specimens were performed under laboratory conditions at the Concrete Laboratory of the Building and Construction Engineering Department at the University of Technology.

After 28 days of curing all specimens were left to dry for a week, and then the strengthening materials were applied.

Strengthening System:

To ensure a correct application of the external strengthening materials, it was necessary to improve the concrete surface which should be freshly exposed and free of loose or unsound materials. This improvement was done according to the manufacturer's instruction [22 and 23]. The corners of the specimens, where the fibers are wrapped, were rounded to a minimum (13 mm) radius in order to prevent stress concentrations in the FRP system and any voids between the FRP system and the concrete [24]. Finally the fabric strips were applied to the specimens using the relevant glue, Sikadur 330, after two weeks the specimens were ready for testing.

The CFRP strips were applied on the specimens in three orientations as follows:

1) Horizontal orientation performed by wrapping the fabric around the edges of the specimen with an overlap of 100mm at the end as means of anchorage.
2) Inclined orientation performed by applying the fabric at the center of the inclined strut path and perpendicular to it at both sides of the corbels; small strips were applied perpendicularly at the ends of the inclined strips as means of anchorage.
3) Mixed orientation performed by applying the horizontal orientation first and then the inclined one.

Photos of the plain and 50 mm strengthened specimens are illustrated in figure 2.

Figure 2 - Photos of Plain and 50-mm Strengthened Specimens

Test Setup and Instrumentation

All Specimens were tested by a 1000 kN (100 Ton) testing frame system, one of the apparatus of the structural laboratory of the Civil Engineering Department at Al-Nahrain University.

The corbels were tested in an inverted position, as shown in figure 3; the vertical load, P, applied to the top end of the column, while the corbels were seated on two end supports. The reactions of the supports, V, represented the loads applied to the corbel. The support reaction was located at a distance of 100 mm from the face of the column, providing a shear span to depth ratio of, a_v/d, of 0.461.

The specimens were cast and strengthened in June-July 2015 and tests were performed in Dec-2015 through Jan-2016.

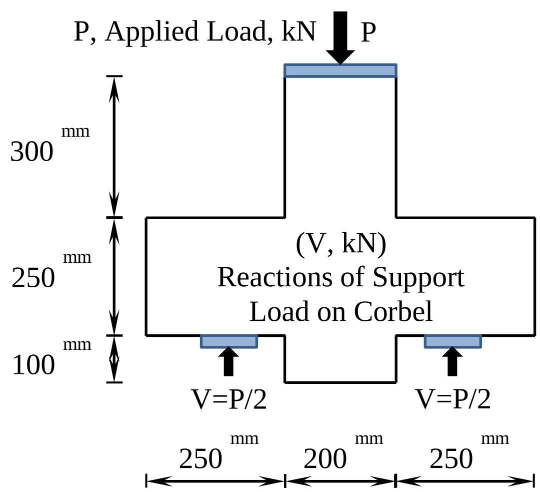


Figure 3 - Test Set Up, Inverted Position

Results and Discussions

Results for Monotonically Loaded Specimens

The monotonic loading test was very important to decide the number and amplitude of the non-reversed repeated loading cycles used throughout this research. Six specimens were tested under monotonic loading regime and acted as control specimens for the rest specimens tested under non-reversed repeated loading regime.

Crack Pattern and Failure Mode

All specimens tested under monotonic loading regime, behaved in an elastic manner at low load levels and were free from cracks at early stages of loading. As the load was increased, diagonal cracks were developed. The first crack was observed at regions close to the bottom corbel-column joint, in its inverted position, propagating along the corbel-column interface. At load levels close to

failure, the inclined cracks became wider and propagated towards the upper corbel-column joint. Further increase in the applied load caused the formation of other cracks until failure occurred.
The mode of failure of all the specimens tested under monotonic loading regime was diagonal splitting failure, and the CFRP did not suffer of de bonding throughout the test as shown in figure 4.
The effect of strengthening corbels with 50 mm of CFRP Strips in horizontal, inclined and mixed orientations on the cracking and failure loads are illustrated in table 2 and figure 5. Test results showed that the first crack appearance was delayed by this strengthening technique. The strengthening technique used helped in enhancing the load carrying capacity with about 11%, 15% and 27% for the horizontal, inclined and mixed orientations respectively, corresponding to an increase in the ultimate deflection of 16%, 18% and 22% respectively.

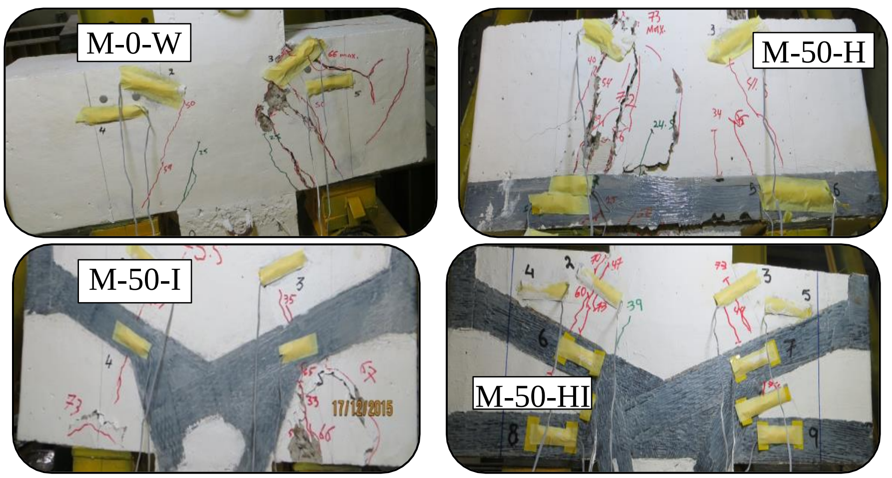


Figure 4 – The Crack pattern and Mode of Failure for Monotonically Loaded Specimen

Table 2 – Effect of Strengthening Technique on the Cracking and Failure Loads for the Monotonically Tested Specimens (M-0-W, M-50-H, M-50-I and M-50-HI)

Specimens	P_{cr} (kN)	$\frac{P_{cr-S}}{P_{cr-W}} \times 100$	Δ_{cr} (mm)	$\frac{\Delta_{cr-S}}{\Delta_{cr-W}} \times 100$	P_u (kN)	$\frac{P_{u-S}}{P_{u-W}} \times 100$	Δ_u (mm)	$\frac{\Delta_{u-S}}{\Delta_{u-W}} \times 100$
M-0-W	250	-	3.37	-	652	-	8.00	-
M-50-H	247	98.8	3.11	92.3	725	111	9.31	116
M-50-I	300	120	3.45	102	750	115	9.41	118
M-50-HI	396	158.4	4.02	119	825	127	9.79	122

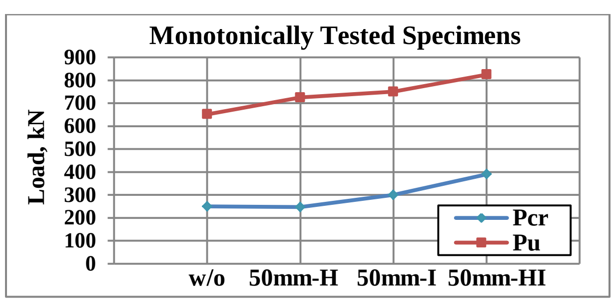


Figure 5 – Effect of Horizontal, Inclined and Mixed Orientation Strengthening

Load-Displacement Response:

The load-displacement responses for the monotonically tested specimens are shown in figure 6. Testing was terminated when failure occurred, the failure of the specimen was recognized either by the damage occurring or when the load could no longer be increased or start to decrease with the continue increase in deflection.

The deflection represents the movements of the loading jack, which correspond to the deflection at the center of the column supporting the double corbels. A data logger connected to the loading frame control system, was used to control and record the displacement and load applied to each specimen.

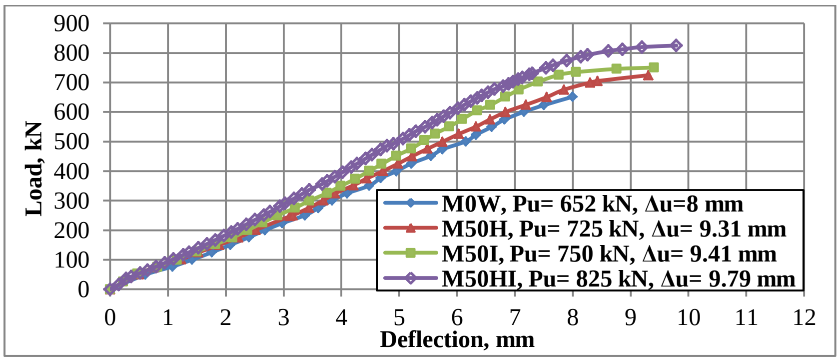


Figure 6 - The Load-Deflection Curves of the Monotonically Tested Specimens

Results for Non-Reversed Repeated Loaded Specimens

Fourteen specimens were tested under non-reversed repeated loading regime; the specimens were divided into five groups. R_W, included three non-strengthened specimens, subjected to three different non-reversed repeated loading regimes, LH1, LH2 and LH3. R_{LH} included three horizontally strengthened specimens, subjected to the three schemes of loading. R_H, included three (50, 100 and 150) mm horizontally strengthened specimens. R_I, included three (50, 100 and 150) mm inclined strengthened specimens. Finally, R_{HI}, included three (50, 100 and 150) mm mixed strengthened specimens. The latter three groups were subjected to the third non-reversed repeated loading regime, LH3.

The repeated loading history schemes were applied depending on the results of the monotonically tested specimens.

The sequence of the cycles followed a percentage of the failure load equal to 20%, 40%, 60%, 80%, 90% and 95%.

The loading history schemes are shown in figure 7. The details of the cycles, (C_i), of the three load histories are shown in table 3, where (i) refers to the cycle's number.

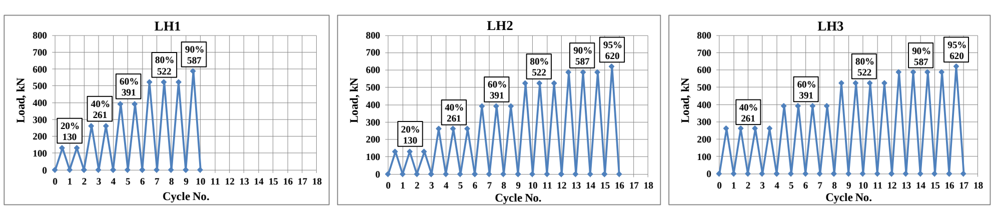


Figure. 7 – Non-Reversed Repeated Load History Schemes, LH1, LH2 and LH3

Table 3 – The Details of the Cycles of the Repeated Loading Histories

Loading History	% of Failure Load						No. of Cycles
	20%	40%	60%	80%	90%	95%	
LH1	C_1-C_2	C_3-C_4	C_5-C_6	C_7-C_9	C_{10}-	-	10-
LH2	C_1-C_3	C_4-C_6	C_7-C_9	C_{10}-C_{12}	C_{13}-C_{15}	C_{16}-	16-
LH3		C_1-C_4	C_5-C_8	C_9-C_{12}	C_{13}-C_{16}	C_{17}-	17-

Test results showed a reduction in the failure loads for non-strengthened specimens tested under non-reversed repeated loading regimes, LH1, LH2 and LH3 by 11.5%, 12.6% and 16.1% respectively.

Crack Pattern and Modes of Failure:

The results of all the specimens tested under non-reversed repeated loading regime including the first cracking load, the first cracking deflection, the ultimate load, the ultimate deflection and the modes of failure, are illustrated in Table 4.

Test results showed that specimens, with or without strengthening, tested under LH1 and LH2, were free from cracks through the first two or three cycles. In contrast, the first crack was observed in the first cycles of most specimens tested under LH3. With the increasing of the width of strengthening strips from 50 mm to 150 mm, the appearance of the first crack was delayed to the second, third, fifth and ninth cycles respectively.

After the appearance of the first cracks, more new cracks were observed in the following consecutive cycles with the same altitude. No further cracks were observed during the unloading part of the cycles throughout all the tests. In the final cycles the cracks became wider and failure occurred in the ascending part of the cycle before reaching its peak. The cracks and the modes of failure for the non-strengthened and the 50-mm- strengthened specimens tested under non-reversed repeated loading regime are shown in figure 8.

Figure 8 - The Crack pattern and Mode of Failure for the Non-Reversed Repeated Loaded Specimens

Table 4 – Results of Non-Reversed Repeated Loaded Specimens

Groups	Name of Specimen	P_{cr} (kN)	Δ_{cr} (mm)	P_u (kN)	Δ_u (mm)	Max. Repeated Load (kN)	Modes of Failure
R_W	R-0-W-1	196-C_3	2.83	577	7.85	C_{10} - 587	SS
	R-0-W-2	230-C_4	3.20	570	7.19	C_{13} - 587	DS
	R-0-W-3	121-C_1	1.86	547	7.80	C_{14} - 587	DS
R_{LH}	R-50-H-1	200-C_3	2.63	636	7.80	C_{11} - 650	DS
	R-50-H-2	242-C_4	3.36	616	7.69	C_{13} - 590	SS+LBF
	R-50-H-3	240-C_1	3.14	605	7.87	C_{14} - 650	SS
R_H	R-100-H-3	322-C_5	3.92	659	7.60	C_{17} - 680	SS
	R-150-H-3	435-C_5	4.68	676	7.55	C_{17} - 680	DS+STF
R_I	R-50-I-3	250-C_1	2.91	646	7.65	C_{14} - 680	DS
	R-100-I-3	280-C_2	2.82	683	7.29	C_{17} - 710	DS
	R-150-I-3	245-C_2	2.84	679	7.76	C_{15} - 680	DS
R_{HI}	R-50-HI-3	310-C_3	3.55	659	7.03	C_{13} - 710	DS
	R-100-HI-3	440-C_5	4.93	703	7.80	C_{17} - 750	DS
	R-150-HI-3	400-C_9	4.48	687	7.24	C_{14} - 710	DS+CCF

Where:
P_{cr} : Load at the appearance of first crack
Δ_{cr} : Deflection at P_{cr}
P_u : Ultimate Load, at Failure
Δ_u : Deflection at P_u
DS : Diagonal Splitting Failure.
SS : Sliding Shear Failure.
STF : Shear Tension Failure, at Extreme Fiber in Tension.
LBF : Local Bearing Failure.
CCF : Column Crushing Failure.

Effect of Non-Reversed Repeated Loading Regime

A reduction in the cracking loads was observed for the three strengthened specimens tested under LH1, LH2 and LH3 of about 19.03%, 39.27% and 2.83% respectively. The same reduction was observed with the failure load of about 12.28%, 15.03% and 16.55% respectively. This reduction in the load capacity, between the three loading history schemes used, can be related to the excessive cracks in the concrete specimens through the consecutive cycles of loading and is affected by the number and amplitudes of the cycles.

It can be noted that strengthening the corbels with 50 mm CFRP strips wrapped horizontally around the specimens helped in delaying the appearance of the first crack and in increasing the failure loads. The percentage of increase of the ultimate load was about 10.2%, 8.1 and 10.6% for the three schemes of non-reversed repeated loading used in this research, LH1, LH2 and LH3 respectively.

Effect of the Width of CFRP Strips:

An increase in the amount of cracking load was observed with the increase in the width of the CFRP strengthening strips from 50 mm to 150. This increase was about 34% and 81%, for the horizontal orientation, 64% and 52%, for the inclined orientation and 42% and 29%, for the mixed orientation respectively. The same was observed in the failure load but with less percentage of increase which was about 9% and 12% for the horizontal orientation, 6% and 5%, for the inclined orientation and 7% and 4%, for the mixed orientation respectively. Moreover, this increase made the specimen stronger and was able to bear the repeated loading for more cycles before failure occurred.

Effect of the Orientation of CFRP Strips:

Test results showed that the inclined strengthening gave the best result regarding the cracking and failure loads. And as for the successive cycles of non-reversed repeated loading schemes, this kind of strengthening technique, made the specimen stronger and was able to bear more cycles from the other two techniques, before failure occurred.

Although, the horizontal strengthening gave, in some cases, higher enhancement in the load carrying capacity, but the application of this kind of strengthening technique is rather difficult in reality because of the inability to wrap the CFRP around the corbel and the supporting column.

Moreover, using the mixed strengthening technique gave reasonable results, but it was approximate to the results of the inclined orientation; therefore, in the researchers' point of view, it is economically recommended, to use the inclined strengthening technique on reinforced concrete corbels.

Load-Displacement Response:

The load-deflection curves showed that at early stages of loading the curves were initiated in a linear form with a constant slope. Soon after cracking the behavior changes and the load deflection response takes a nonlinear form with varying slopes, gradually, the slope decreases with consecutive cycles.

The load-displacement hysteresis loops for the fourteen specimens, tested under the three non-reversed repeated loading regimes selected in this study, show degradation in the load carrying capacity during the repeated cycles, due to the accumulation of cracks in the concrete.

Reinforced concrete corbels subjected to this type of loading always show a deflection increase through successive cycles. However, the consecutive increments of deflection decrease gradually with repeated loading.

The load applied at the first cycle produced a residual deflection; accumulation of this residual deflection increases through consecutive cycles. Cracking in concrete may be one of the causes for this residual deflection.

Generally, it was found that applying the non-reversed repeated loading regimes led to a decrease in the total deflection at failure when compared with specimens subjected to monotonic loading regime as shown in figures 9 through 16.

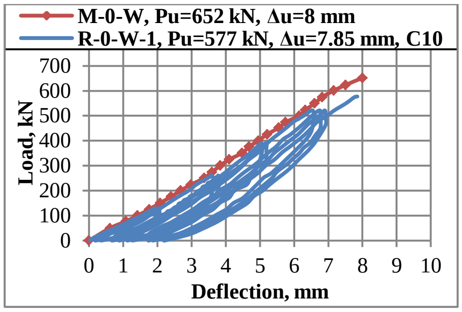


Figure 9 - L-D Curves of R-0-W-1

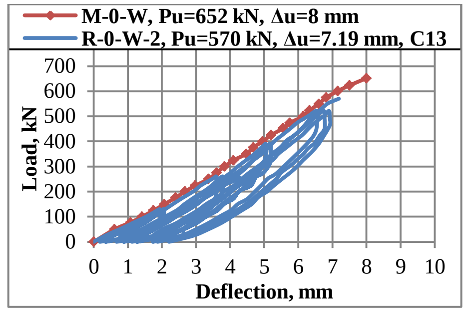


Figure 10 - L-D Curves of R-0-W-2

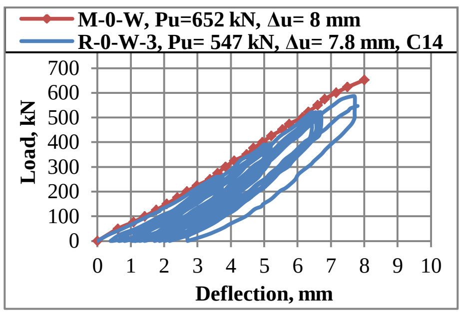


Figure 11 - L-D Curves of R-0-W-3

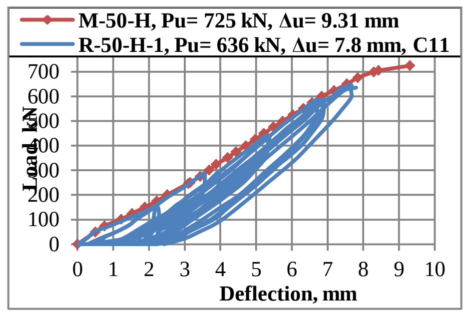


Figure 12 - L-D Curves of R-50-H-1

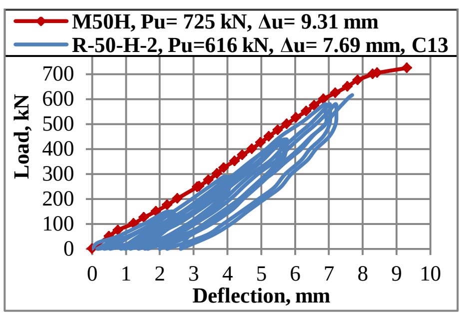


Figure 13 - L-D Curves of R-50-H-2

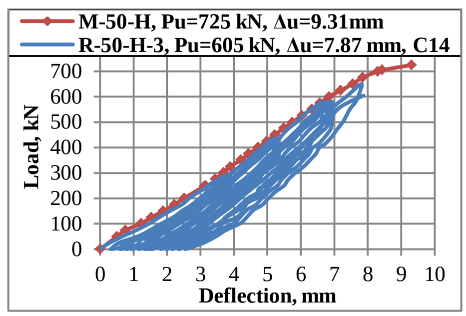


Figure 14 - L-D Curves of R-50-H-3

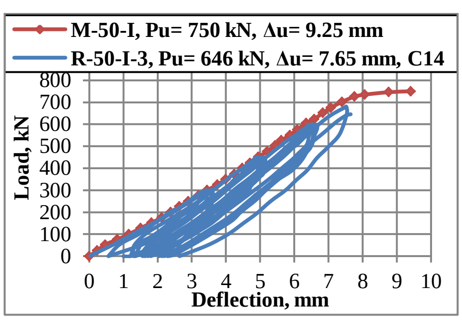


Figure 15 - L-D Curves of R-50-I-3

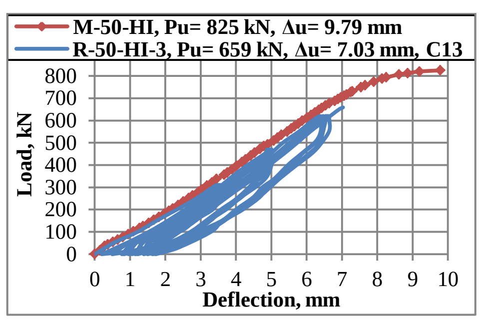


Figure 16 - L-D Curves of R-50-HI-3

Strain Records in Steel Reinforcement, Concrete and CFRP Strips:

Strain gauges were installed on steel bars, at the location of maximum moment, one strain gauge on each bar in opposite directions, before the casting of the specimens, figure 17; and on the concrete surface, figure 18 and CFRP strips, figure 19, after casting and before testing, to record the strains in these materials during testing. The strain records were represented as Load-Strain curves between the load on the corbel, V, (which is equal to half the load applied on the column, P/2), and the strains recorded from strain gauges.

Figure 17 - Locations of Steel Strain Gauges

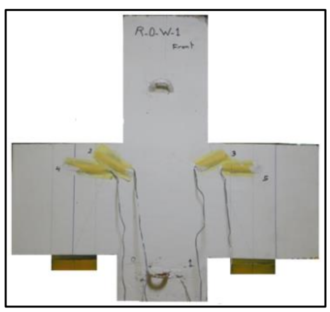


Figure. 18 - Locations of Strain Gauges Fixed on Concrete

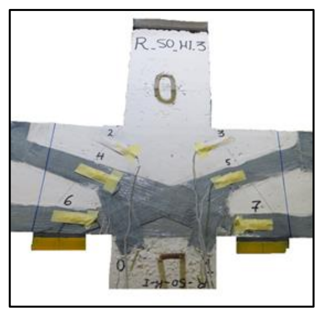


Figure. 19 - Locations of Strain Gauges Fixed on CFRP Strips

During the first stages of loading, the main steel reinforcement recorded small strains until the initiation of the micro cracks in concrete. After that, the steel strains started to increase with a constant rate until the yielding of the main steel reinforcement. The results showed that the external CFRP improved the corbels' stiffness, and the specimens with inclined CFRP strips exhibited the highest stiffness.

The surface compressive strain in concrete was recorded by fixing the gauges on both sides of the front face of the corbels, within the compression side. The locations of these strain gauges were selected to be perpendicular to the expected line of failure, as shown in figure 18.

For the non-reversed repeated loaded specimens, and during the first cycles, while the specimens within the elastic stage, the surface strains in concrete were rather small, and the cycles were close to each other; the residual strains were rather small. Then as micro cracks were created within the concrete, a large increase was observed in the records of the strains. In the latest cycles, there was an enormous increase in the residual strain readings, which may lead to a conclusion that the cracks created in concrete, during the ascending part of loading, were unable to be closed completely with the release of the applied load, in the descending part of loading. Comparisons between monotonic and repeated load-strain curves in steel reinforcement and concrete for Specimen without strengthening are shown in figures 20 and 21.

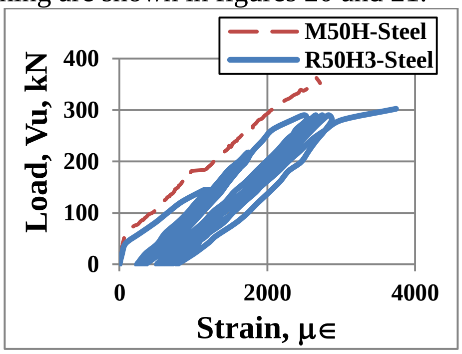


Fig. 20- Comparison of Load-Strain Curves in Steel Reinf. for Specimen M-50-H and R-50-H-3

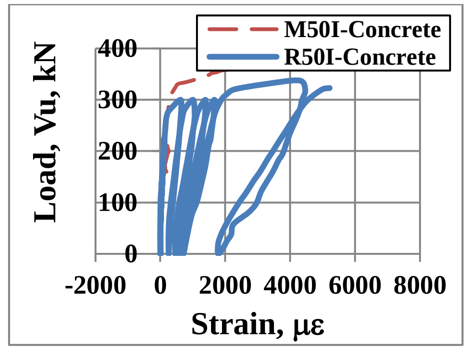
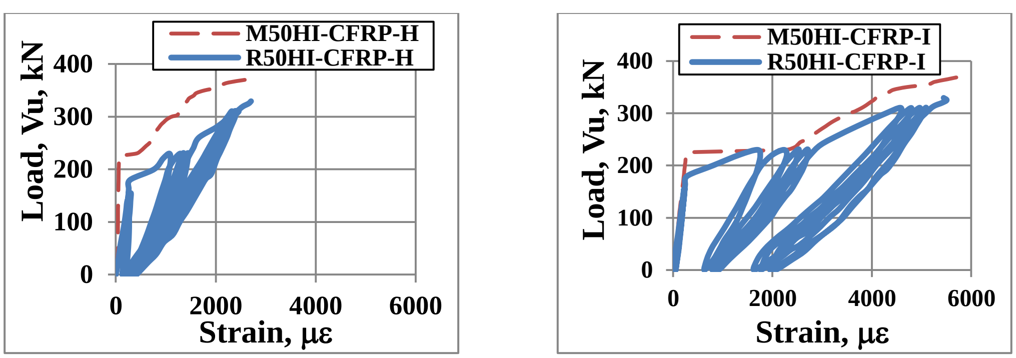


Fig. 21 - Comparison of Load-Strain Curves in Concrete for Specimen M-50-I and R-50-I-3

For the CFRP strips, strain gauges were mounted on both sides of the front face of the corbels, located at the center of the strip and in the direction of the fibers' orientation, to record the tensile strains in the CFRP during the test. The locations of the strain gauges are shown in figure 19.

For the strengthened specimens and at first stages of loading the tensile strain recorded were almost zero or of low values, which imply that there are no cracks in the specimen and the strips did not suffer from any elongations. After the initiation of cracks, the CFRP strips started to work and, the strains started to increase which means that the strips started to suffer from high elongation caused from resisting the widening and propagation of cracks. The horizontal CFRP strips in all specimens remained full bonded to the concrete until failure.

The CFRP strips experienced small strains until the initiation of the cracks. Then the strains started to increase until failure occurred. The inclined strips exhibited a settled strain response up to failure. This shows the effectiveness of the inclined strengthening in limiting the width of inclined shear cracks, allowing the corbels with inclined strengthening technique to experience higher strains before failure, as shown in figure 22.



(a) Horizontal Strip **(b) Inclined Strip**

Figure. 22 - Load-Tensile Strain Curves in CFRP for Specimen R-50-HI-3

CONCLUSIONS:

From experimental results the following conclusions can be drawn:

1) The external CFRP strengthening improved the load carrying capacity of the corbels. For the monotonically loaded corbels, strengthening corbels with 50 mm of CFRP strips helped in enhancing the load carrying capacity with about 11%, 15% and 27% for the horizontal, inclined and mixed orientations respectively. While for the non-reversed repeated loaded corbels, the enhancement was about 11%, 18% and 21% for the horizontal, inclined and mixed orientations respectively.

2) A strength gain was recorded with increasing the width of strengthening strips from 50 mm to 150 mm, this gain, ranged between of 11% to 24% for horizontal orientation, 18% to 25% for inclined orientation and 21% to 29% for mixed orientation.

3) The three strengthening orientations of the CFRP used in this research reduced the main steel reinforcement strains at the section of maximum moment, and hence, increased their yield load leading to an increase in the failure loads of the corbels.

For the monotonically loaded specimens, the yielding load was increased with about 8%, 13% and 30% for the horizontal, inclined and mixed orientations.

For the non-reversed repeated loaded specimens, this increase was about 27%, 25% and 30% for the horizontal, Inclined and mixed orientations respectively.

Moreover, the diagonal CFRP strengthening controlled the widening and growth of shear cracks, leading to an obvious increase in the load capacity.

4) The shape of the load-deflection curves at post cracking stages and stages closed to failure, depend on the type of loading history applied, which included the number of cycles and the altitude of each cycle.

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