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Corbels strengthened with CFRP under deferent loading

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ABSTRACT

Short cantilevers under loads are known as corbels, and they generally have a detrimental impact on the strength of concrete structural components by reducing their resistance to external loads. Strengthening with CFRP strips as an externally bounded approach is employed to raise that. The behavior and durability of strengthened corbels under (constant and incremental) loads are examined in this research. Twelve double corbels were cast and tested as part of the experimental program, with the dimensions of the corbels on all specimens remaining constant. While the other nine are left un-fortified as control corbels, nine of them are strengthened using CFRP strips in various patterns. The results indicate that the maximum load capacity of corbels is affected by both constant and incremental loads. In addition, the ultimate load and ultimate deflection of the legs subjected to five load cycles were less than those subjected to constant stress. The bull legs reinforced with externally bonded CFRP strips demonstrated a significant increase in ultimate load under any applied load but a reduction in ultimate deflection relative to the unreinforced bull legs under the same applied load. All failures of the bull limb were ascribed to the unbounded CFRP strips.

Keywords: CFRP strips, Corbels, externally bounded strengthening, deferent loads.

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1. Introduction

While previous research on cantilevers has looked at enhancing their strength through external restraint methods and exposing them to consistent loads, none have examined the reinforcement of cantilevers using externally restrained CFRP strips that are simultaneously subjected to both constant and incremental loads. This study aims to investigate these aspects. The subsequent section provides an overview of the materials utilized in the research and their properties.

Table 1. Mix proportions (by weight) [1,2]

Material	W/C	W	C	F.A	C.A
Proportion, kg/m^3	0.505	172	379	797	910

Strips made of carbon fiber-reinforced polymers (Sika Wrap®-300 C) It is a woven black unidirectional carbon fiber fabric that has been employed in this work to reinforce the corbels' outward structural integrity. Compound A (white color) and Compound B (light grey color) are the two parts of the epoxy (Sikadur®-330) that the CFRP standard recommends for bonding CFRP strips with a thickness of 0.167 mm to the concrete surface. Deformed bars with a diameter of six millimeters are employed as column ties and secondary (shear) bars of the bull leg. In contrast, deformed bars with a diameter of twelve millimeters are employed as column bars, main (tensile) bars, and crossbars of the bull leg [1,2]. Figure 1 depicts the measurements of the column, the reinforcement of the corbel specimen, the welding details of the cross bar, the loading method, and the test equipment.

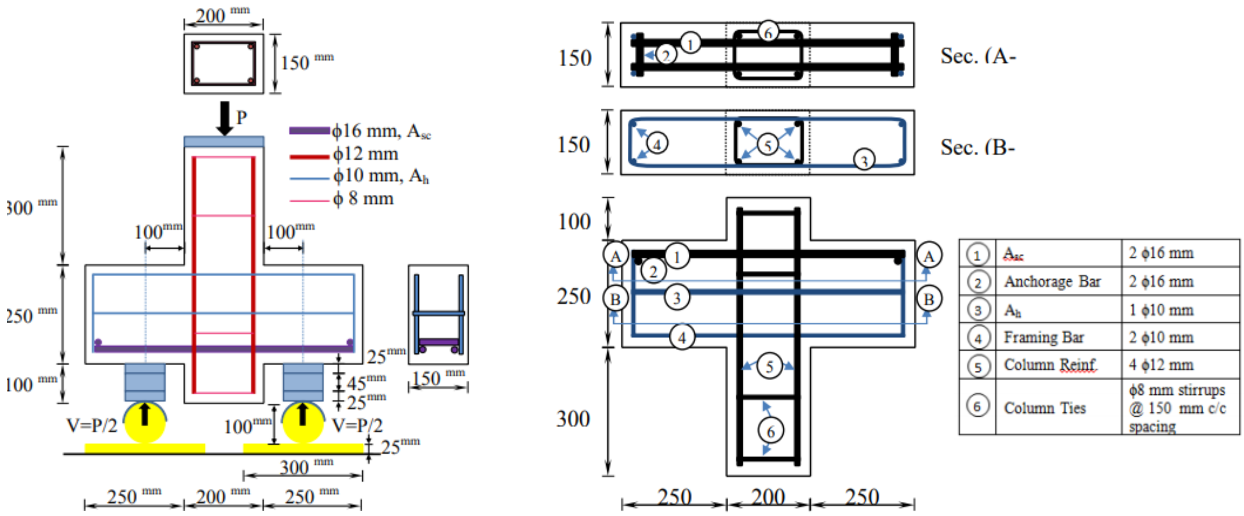


Figure 1. Geometry of analytical model [3]

2. Experimental program

The practical application protected the casting and checking out of 12 double cantilevers to learn about the conduct and energy of the cantilevers beneath the load. Nine have been strengthened with CFRP strips of exclusive patterns, and the relaxation has been stored as consoles. As well as the column and reinforcement dimensions, the principal and secondary ridges have been saved steady for all models. Tables two and three provide the small print of the pillow beams and variables and help users in this work, respectively [2,3,4].

Table 2. Details of corbels and their variables [1,2]

Variable Considered	Width of CRF strips	Configuratio ns f CRF stips	Number of strips	Type of Loading	Load variables
R1	un-strengthened			monotonic	ultimate load
R2				Load -constant	60 % of ultimate load at 5 cycles
R3				Load incremental	20, 40, 60, 80 % of ultimate load at 5 cycles
R4	50	horizontal	one	monotonic	ultimate load
R5	50	horizon	one	Load -Militant	60 % of ultimate load at 5 cycles
R6	50	horizontal	one	Load - incremental	21), 40, 60, 80 % of ultimate load at 5 cycles
R7	50	horizontal	two	monotonic	ultimate load
R7	50	horizontal	two	Load -constant	60 % of ultimate load at 5 cycles

Variable Considered	Width of CRF strips	Configuratio ns f CRF stips	Number of strips	Type of Loading	Load variables
R9	50	horizontal	two	Load - incremental	20, 40, 60, 80 % of ultimate load at 5 cycles
R10	50	inclined	one	monotonic	ultimate load
R11	50	inclined	One	Load -constant	60 % of ultimate load at 5 cycles
R12	50	inclined	One	Load-incremental	2A, 40, 60, 80 % of ultimate load at 5 cycles

Loading Regimes [5,6,7]**:** Two different loading regimes—monotonic and non-reversed repeated—were applied to the specimens.

Monotonic: The Monotonic Group, the initial group of specimens, was loaded monotonically until failure. The price of pressure utility on the trying-out equipment used to be extended with the aid of 2.2 kN/sec. The loading section started when the hydraulic elevate used to practice a burden to the summit of the column, which was once steadily multiplied till failure. The load and displacement readings are reset to zero when the cylinder (hydraulic lift) contacts the specimen. The strain gauge values were recorded throughout the test at a 5 kN increment while the load and deflection were recorded every second.

Non-inverted repeated loading mechanism: In this investigation, the predicted repeated loading values are established on the failure masses of the manipulated samples, which had been examined using a monotonic loading mechanism. This study's non-inverting repetitive loading mechanism is established on the load manipulation investigation technique. For every loading cycle, the utilized load is expanded regularly till the anticipated load, which is a small fraction of the failure load of the monotonic take a look at the manipulated sample, is attained and then reduced progressively till it reaches zero. Before failure occurs, these cycles will be repeated primarily based on the chosen load history. The inquiry uses three loading histories primarily based on the results of the monotonic specimen; the order of the cycles corresponds to a fraction of the monotonic specimen's failure load—the different percentage. Three cycles with a failure load of 20% contain a minimum of 15 cycles in the second load records LH2. Three cycles at 40% failure load. Three cycles at 60% failure load. Three cycles at 80% load to failure. Three unsuccessful load cycles at 90% total capacity. Suppose the pattern does not fail; greater cycles at 95% failure load until it fails. Four cycles with 40% failure load contain a minimum of sixteen cycles in the 0.33 load records LH3. An extra sixty percent of the failure pressure for 4 cycles. For 4 cycles, eighty percent of the failure burden. Four cycles at ninety percent of the failure load. If the pattern is successful, extra cycles are performed.

3. Load-deflection relationship

In Figures 5-8, the load versus deflection relationships for all corbels that have been put to the test with constant loads are shown for all loading stages up to failure. The type of strengthening and loading seemed to have an impact on where such correlations occurred. The initial shape of any load-deflection curve is typically linear (elastic behavior) and has a constant slope. The slope of the curve then starts to alter, and this variation signals the emergence of the corbel's first fracture. Following the onset of the first fracture, the load-deflection curve adopts a nonlinear shape and begins to pursue a curvature route, indicating an increase in ductility. Figure 5 depicts the load-deflection relationships for the R1, R2, and R3 specimens of the control corbels that were not reinforced and were loaded [2,6].

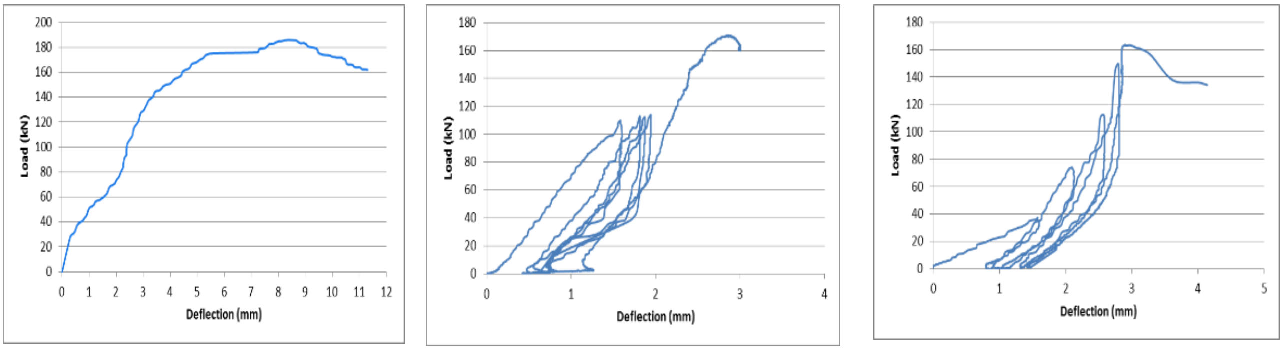


Figure 5. Load-Deflection relationship for specimens (a) R1, (b) R2, and (c) R3

Figures 6–8 depict the load–deflection correlations for corbels reinforced with CFRP strips while being loaded (R4, R5, R6, R7, R8, R9, R10, R11, and R12 specimens) [1,2].

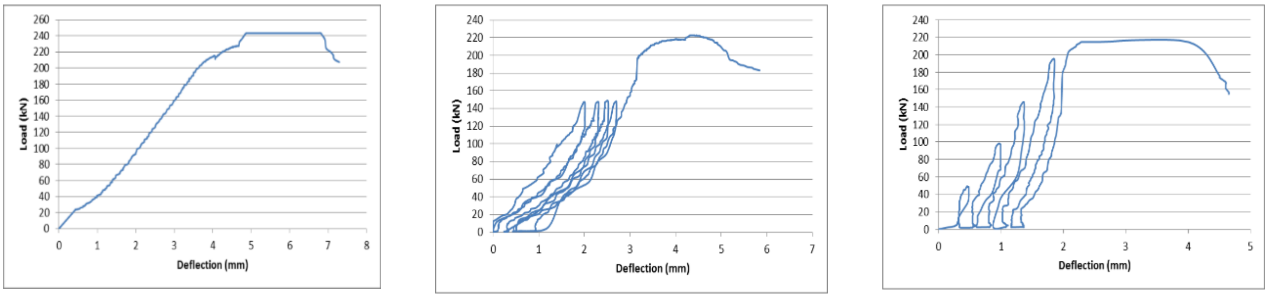


Figure 6. Specimens (a) R4, (b) R5, (c) R6's load-deflection relationship.

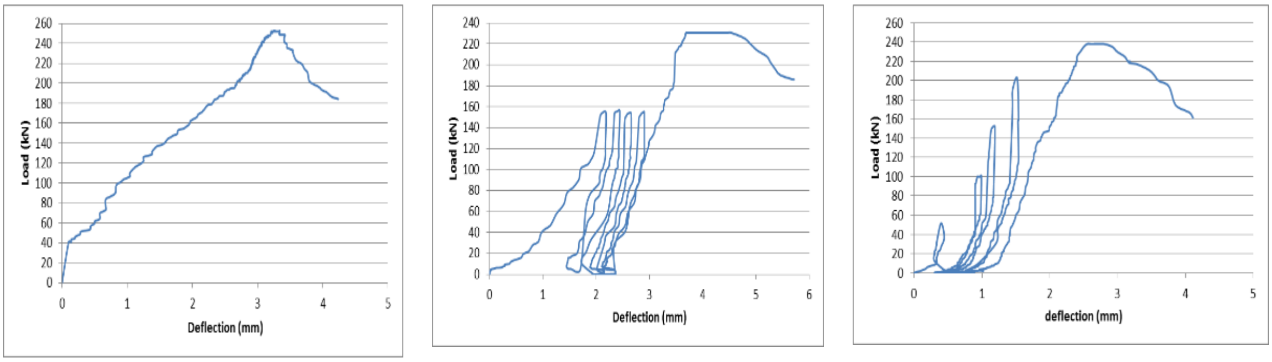


Figure 7. Connection between load and deflection for the specimens R7, R8, and R9.

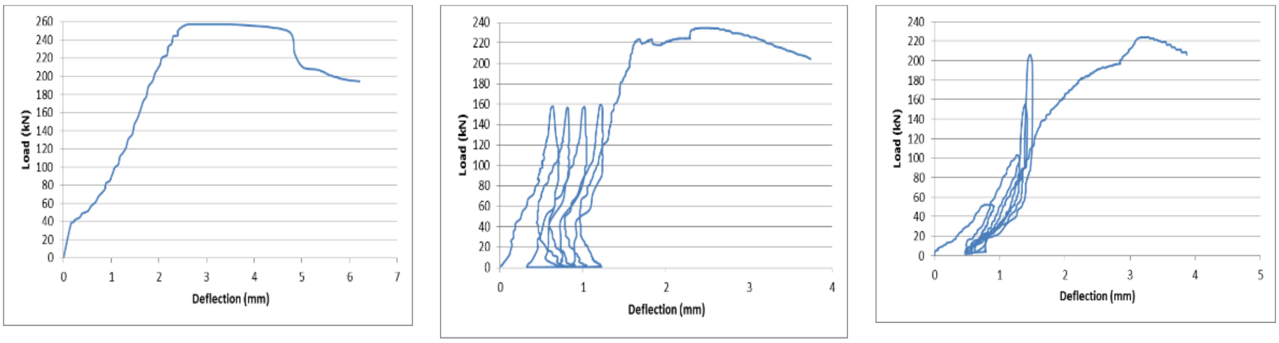
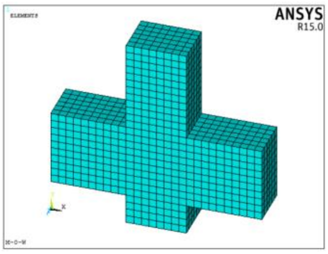


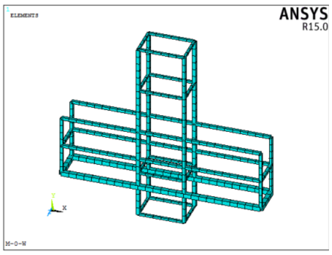
Figure 8. Load-Deflection relationship for specimens (a) R10, (b) R11, (c) R12

4. Finite element modeling

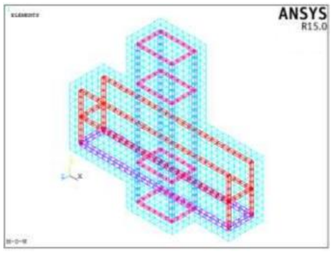
In the current study, nonlinear FE analysis is performed to model and simulate the behavior of reinforced and unreinforced concrete cams. This chapter describes three-dimensional nonlinear finite element simulations performed using ANSYS-15 software. It includes all the steps needed to create an FE model, such as element types, different material parameters, model geometry, loads and boundary conditions. It serves as a convergence criterion used to generate analytical load-strain responses of models under static and nonlinear analysis procedures and dynamic loads [7,8].



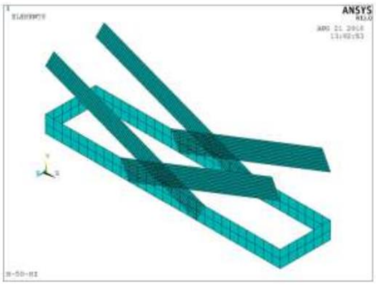
The Concrete FE Mesh



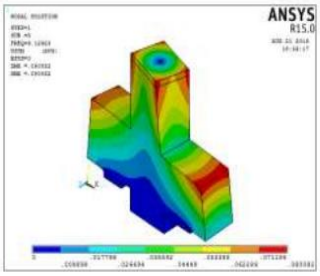
The Mesh of the Steel Reinforcement



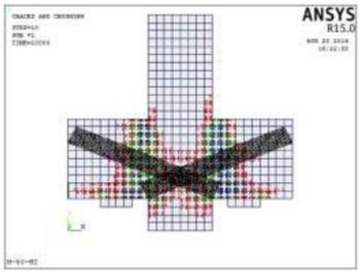
The FE Mesh of the Concrete and Steel Reinforcement



The CFRP Modeling



The Mode Shape



Under Load

Figure 9. Finite element modeling

Table 3. Specification

Type of Element [7,8]	
Concrete (Solid65)	
Steel Reinforcement (Link180)	
Steel Plates (Solid 45)	
CFRP (Shell181)	Horizontal Orientation, H
	Inclined Orientation, I
	Mixed Orientation, HI

5. Conclusion

The experimental findings of the corbels that were put to the test lead to the following conclusions:

- A cantilever of corbels under a load will break more flexibly than a cantilever of corbels under constant load.
- Two types of loading (constant and incremental) affect the bearing capacity, with reductions in ultimate load and ultimate deformation of beams subjected to 5 loading cycles compared to beams subjected to constant loading.

- 3. When compared to corbels that are exposed to constant loading, incremental loading has a greater impact on the reduction of ultimate load and ultimate deflection.
- Few or no strain gauge readings connected to CFRP the stress measured before cracking. Therefore, CFRP it began bearing the load immediately after the cracks appeared.
- For consoles reinforced under any kind of load by externally constrained CFRP strips, while the ultimate deflection is reduced compared to the unreinforced one under the same load, the ultimate load increased sharply.
- To increase stiffness, cracking and ultimate stresses, and their related deflections, CFRP strips' position, orientation, and quantity are crucial factors. As a result, it has been discovered that the inclined wrapping method of strengthening produces stronger specimens than either the horizontal complete wrapping method of strengthening or no strengthening at all.
- In terms of the strengthening impact, the ultimate loads increased by (36.7 - 47.18) % when the number of horizontally oriented strips increased from one to two strips in comparison to those that weren't reinforced. The ultimate loads rose by (40.20-43.11) % in comparison to the un-strengthened strips when the orientation of the strips was changed from horizontal to inclined strips.
- The CFRP strips quickly and brittlely debond from one another. Thus, the few noises that indicate strong stresses in the CFRP strips are the only indication of the de-bonding. Due to this situation, the corbels' ductility is decreased using CFRP strips, and the loading has a negative impact on the corbels' stiffness, whereas the stiffness of tested corbels was increased by CFRP strengthening.

References

[1] L. A. Yassin, "Behavior of R C Corbels Strengthened with CFRP under Monotonic and Repeated Loading," Ph.D. Thesis, University of Technology, Iraq, 2016, p. 10.

[2] F. J. Al-Talqany and A. M. Alhussainy, "Structural Behavior of Reinforced Concrete Corbel Using High-Strength Materials under Monotonic and Repeated Loads," International Journal of Applied Science, vol. 2, no. 2, 2019.

[3] R. S. Farhan, "Behavior of Reinforced Concrete Corbels under repeated lodging," Ph.D. Thesis, AL-Nahreen University, Iraq, 2014, p. 10.

[4] L. B. Kriz and C. H. Raths, "Connections in Precast Concrete Structures: Strength of Corbels," PCI Journal, vol. 10, no. 1, Feb., 1965, doi: https://doi.org/10.15554/pcij.02011965.16.61.

[5] L.A.G Yassin, "Behavior of RC Corbels Strengthened With CFRP Under Monotonic And Repeated Loading," Ph.D.Thesis , University of Technology ,Iraq ,2016 .

[6] Z. Zielinski and M. Riogotti, "Test on Shear Capacity of Reinforced Concrete," Journal of Structural Engineering, vol. 121, no. 11, Nov. 1995.

[7] Z. Zielinski and M. Riogotti, "Test on Shear Capacity of Reinforced Concrete," Journal of Structural Engineering, vol. 121, no. 11, pp. 1660-1668, Nov. 1995, doi: 10.1061/(ASCE)0733-9445(1995)121:11(1660).

[8] J.K. Wight, "Use of Strut and Tie Modeling within the ACI Building Code," in Structures 2001: A Structural Engineering Odyssey, vol. 140, pp.1-2, Jan. 2001, doi: 10.1061/40558(2001)140.