REPAIRING OF SHORT REINFORCED CONCRETE CORBEL BY BONDING COMPOSITE MATERIAL UNDER CONTINUOUS LOAD

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Abstract: This paper presents an experimental study of repairing of short reinforced concrete corbel by bonding composite material under continued load. The short reinforced concrete corbel usually is used in Civil Engineering and in Building Construction as structure element. This structure is very important because it's often supported the load of the metal or the reinforced concrete beams (such as on overhead travelling cranes or bridge pile or in construction). In fact, the damage occurring in corbel is due to: the steel corrosion which is at the source of many disorders in reinforced concrete structures, the excessive load, the cracks caused by high vibration and fatigue of the structure, sometimes, by inadequate ultimate strength. The strengthening by bonding composites materials is a good technique to extending the life of the damaged structures. Sometimes the repair of the structure to can be carried out under continuous load. The aim of this experimental research is to show the impact of continuous load and whether it will affect the repair of the structure. For this study five short reinforced concrete corbels were investigated. Two of them are tested under static test (one is strengthened and other one without strengthened) and three (one without strengthened and two strengthened) are tested under dynamic test by cyclic loading. One of specimen was tested under cyclic loading (500 000 cycles) and after appaired the cracks is repaired under continuous load by bonding fiber reinforced fabric. After strengthened the structure is loaded stepwise up to the failure. The results present ultimate load, strain of steel bar, concrete and fabric of repaired short reinforced concrete corbel under dynamic and static applied load. The results of the repaired specimens are compared to the strengthened and the reference structure. The resistance of reinforced concrete corbel depends strongly on surface conditions. The cracking and fracture mechanic mechanisms are described and presented.

1 INTRODUCTION

The short reinforced concrete corbel is an architectural element used of many architects in different forms. This is very important structural element, used in construction and building. Its position on post or bridge pile or in construction is used to support concentrated load due to beams as well as beams for cranes. The concrete structures no longer meet the current safety standards or have excessive cracks. The causes of this excessive cracks are for example: the steel corrosion which is at the source of many disorders in reinforced concrete structures, the excessive load, the cracks caused by high vibration and fatigue of the structure, sometimes, by inadequate ultimate strength.

There are many methods for strengthening or repairing the reinforced concrete(RC) structures like using steel bars, or steel accessory [1-2], or using different configurations of carbon fiber reinforced polymer (CFRP) by Near Surface Mounted (NSM) technique [3]. Placing additional steel bars or steels elements further increases the weight of the RC structure. In contrast the NSM technique does not increase the weight of the construction but the method is laborious and not easy to apply. Reinforced concrete structures can be carried out by bonding of composite sheets with high tensile strength compared to steel or concrete stresses, on the tensile strength sides of the structures [4-8]. This technique allows to increase remarkably the bending strength and shear strength of the old structures and supported a new stress. Of course, this technique allows to make structures conforming to the criteria of safety and fitness in service when the environment is changing to improve the durability of the structure. The advantages of this technique are that, the good stresses distribution in adhesive layer compared with tightening or brazing technique, the work can be carried out, while the structure is still in use, ease and speed of installation. Composite materials offer the designer an outstanding combination of properties not available from other materials. Fiber materials such as glass, carbon and aramid can be introduced in a certain position, volume and direction in the matrices (e.g. epoxy) to obtain maximum efficiency. Other advantages offered by fiber reinforced fabrics (FRF) are lightness, corrosion resistance, electromagnetic neutrality and greater efficiency in construction compared with the more conventional materials. The FRF were used to confine new concrete beams and columns or to strengthen corbel in seismic areas, subject to repetitive load and strengthening of concrete corbels with unidirectional and bidirectional fiber composite sheets bonded on their tension faces via the use of epoxy adhesives. This technique is [9-17]. The orientation of applied stripes is important for the good performance.

This paper is a continuation of a research performed in previous years. The objective of this experimental study is based to study the contribution of repairing the RC corbel by bonding composite material under continuous load. The repaired specimen is compared with strengthened and damaged specimens.

2 EXPERIMENTAL MODEL

For this study five short reinforced concrete corbels were investigated.

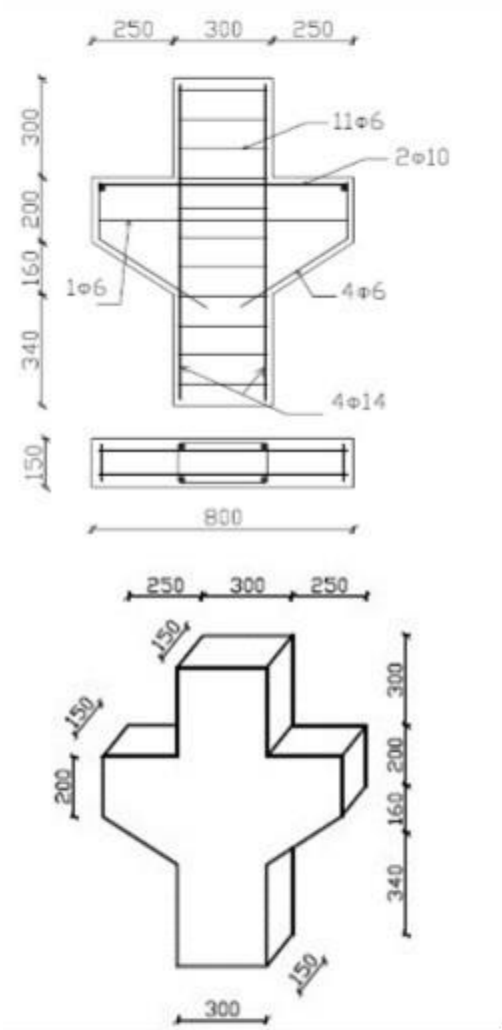

Figure1: Reinforced steel and geometry

Two of them are tested under static test (one is strengthened and other one without strengthened) and three (one without strengthened and two strengthened) are tested under dynamic test by cyclic loading. All reinforced concrete corbel specimens had the same dimensions and are strengthened in the same way detailing, see Figure 1. Steel bars, S500 are used of different diameters: 6, 10, 14mm. The column supporting the two short trapezoidal corbels cantilevering on either side was 150 by 300mm² in cross section and 1000mm long. Reinforced concrete corbels had cantilever projection length of 200mm, with thicknesses of 150mm at both faces of column and the free end.

The specimens are tested using a single load with a shear span to depth ratio; a/d equal to 0,45. From the large amount of data obtained from the tests, only typical data are reported here. Reinforced concrete corbels were strengthened with externally bonded carbon fibre fabrics in horizontal strips, in form of all-around plates – by wrapping. The control specimen without strengthening is denoted with "**C0**", the letter "**C**" for **C**orbel, zero **0** indication without strengthening. The names of strengthened corbels specimen "**CB3u**" are made up as follows: The first letter "**C**" is as Corbel, and the second letter represents the type of strengthening (e.g: **B** for Bandage). Carbon fabric thickness is taken constant equal to 3mm. Finally, the small letter indicates the type of the composite material (e.g.: **u** for **u**nidirectional). The widths are extended 150mm to the reinforced concrete corbel faces.

3 MATERIALS PROPERTIES

Normal strength concrete was used for all corbel. The cement:sand:gravel proportions in the concrete mix were 1:1.7:2.9 by weight. The water/cement ratio was 0.5 and cement type II Portland was used. The maximum size of the aggregate was 12.5 mm. The glue used for the CFC sheet technical bonding are generally two-part systems, a resin and a hardener, and they are mixed. The glue had (measured value) an elastic modulus of 4.1±0.1GPa and yield stress of 19±1MPa, see Table 1.

Steel specimens were characterized by tensile testing, Figure 2. The stress f_u and the modulus of elasticity E values are in Table 1. The high deformation of steel at the failure is 11.04%.

Table 1: Properties of materials

Material	Young's modulus E (GPa)	Ultimate stress fu (MPa)	Poisson 'ratio
Concrete	30±2	33,2±2 (fc)	0,25
Steel bar	200±1	610±10 (fu)	0,29
Adhesive	4,1±0,1	36±1 (fu)	0,41
UCFC sheet*	86±2	1035±63 (fu)	0,45

The experimental results obtained for carbon composite unidirectional and bidirectional are also showed in Table1. The failure tensile stress is 960MPa for unidirectional carbon fiber sheet. The behavior of carbon composite sheets is a linear elastic up to failure. The high elongation at failure is 0,8% for the unidirectional carbon fibre sheet.

Figure2: Tensile test of reinforced steel

4 SURFACE PREPARATION

The surface preparation, before bonding composite material was of primary importance and calls for care. The concrete surfaces must be carried out to remove any loose or weak material, oil, grease etc... The grit blasting was being the good method in this case. It is also of particular importance that the four corners of the corbel are rounded to prevent tearing of the composite material. To avoid any contamination the surface preparation was carried out just prior to the bonding operation.

5 BENDING TESTS

All the corbels are tested under 3-point bending control see Figure 3. At each test, ultimate loads are noted. Strains of concrete, composite carbon fibers sheet and steel strain are measured at embedding section (where strains are highest) with strain gauges. Corbels are submitted to a vertical load equivalent to the response of the bearing which is half of load. The average loading rate for all experimental tests was 0,2kN/s. Every 0,1 seconds the system data was recorded. The test bending machine have load maximum capacity of 1000kN.

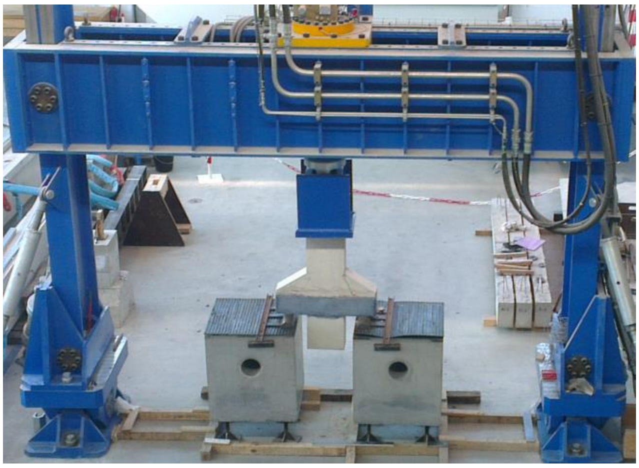

Figure3: Bending test

Firstly, two RC corbels are tested under static loading to collapse. One of them is referent specimen C0 without strengthening is submitted to a vertical load under static loading to collapse. The second specimen is strengthened by wrapping and after this submitted to a vertical load under static loading to collapse [10].
Two other specimens are tested under repetitive load. The load range selected from 20% to 40% of the maximum load in the static tests respectively for C0 and CB3u [11-12]. The magnitude and number of the repeated loads are fixed to one million cycles. The fifth RC corbel without strengthening is loaded under cyclic load with load range selected from 15% to 35% of the maximum load in the static test for C0, see Table 2. The magnitude and number of the repeated loads are fixed to 500 000 cycles. After 500,000 cycles the specimen is repaired by bonding composite materials under continuous load.

Table 2: Conditions of fatigue load

Speci mens	F_u (kN)	F_{min}(kN) 20%	F_{max}(kN) 40%	Nombre of cycles
C0	357	54	125	500 000
C0	357	71	143	1 000 000
CB3u	651	130	260	1 000 000

Waiting for the required time of 48 hours, the repaired RC corbel by wrapping is tested under static loading and unloading up to collapse. The value of the incrementing step is 15%, see Figure 4.

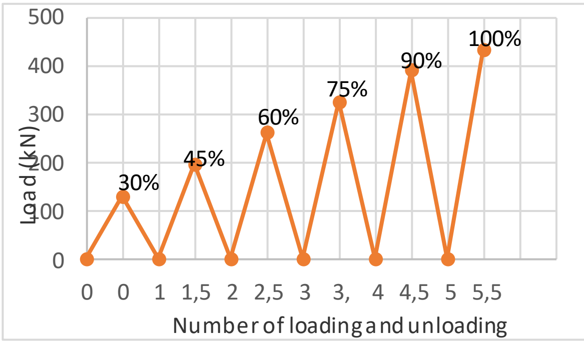

Figure4: Bending test of reinforced concrete corbels

6 EXTENSOMETER TECHNIQUE USED

The electrical strain gauges with different length were used to study the local behavior of the structures. This technique allows to measure the strain of steel, carbon fabrics and concrete. In fact, the load versus strain in cross section between column and corbel are plotted. Figure 11 shows the positions of strain gauges on corbel. The strain gauges G1, G2 and G3 are placed on steel tie rod and they have a length of 5mm, see Figure 11 (a). The strain gauges (GC1 and GC2) are placed on composite fibre fabrics in shear span between corbel and column, their length is 10mm. (GB1) with length of 30mmis placed on concrete surface, see Figure 5.

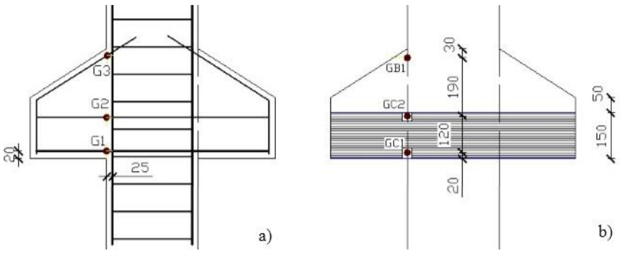

Figure 5: Local instrumentations with strain gauges. (a) steel investigation, (b) composite fabrics and concrete investigations

7 EXPERIMENTAL RESULTS AND DISCUSSIONS

From the large amount of data obtained from the tests, only typical data are reported here. The results are presented in Table 3. The ultimate loads after statics and dynamics tests are compared. The results showed that the strengthened and repaired techniques by bonding composite materials by wrapping as a good solution in the field of RC structures. The stresses in specimens C0 and CB3u under static loading are compared with the stresses in strengthened and repaired specimens. The effect of strengthening and repairing increase the maximum load.

Table 3: Comparison of ultimate loads.

Specimens	F_{max} Static test	Notes
C0	357 kN	-
CB3u - Strengthened	651 kN	-
C0	381 kN	After 1 000 000 cycle
CB3u - Strengthened	584 kN	After 1 000 000 cycle
CB3u - Repaired	408 kN	After 500 000cycle

Figure 6 shows the local steel deformations in cross section of repaired RC corbel after 500 000 cycles. In fact, the dynamic loading is modified the behaviour of specimen. The elastic area in steel bar was lost. Still the composite material responds to the stresses that emerge from loading and unloading steps.

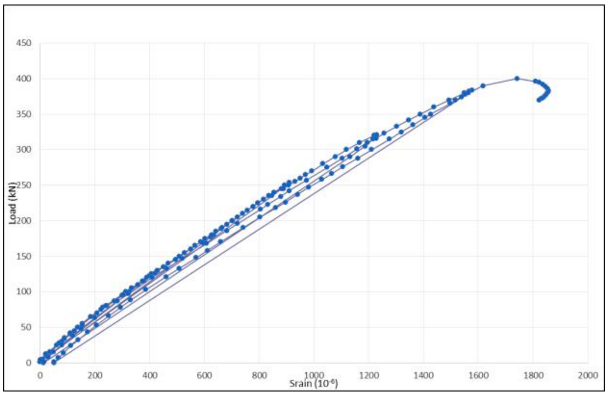

Figure 6: Strain of steel tie in G1 for repaired corbel

8 CONCLUSIONS

This experimental study focused on the repaired the RC corbel bonded by composite material under continuous load.

The results showed that the strengthened and repaired techniques by bonding composite materials by wrapping as a good solution in the field of RC structures.

The cyclic loading modified the stresses in the specimens.

The repairing of short RC corbel by bonding composite materials under continuous load is increased the ultimate load with 14% compared with the control specimen.

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