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The effect of fatigue test on short reinforced-concrete corbel strengthened by externally bonded composite fibre fabrics

I. Ivanova *, J. Assih

University of Reims Champagne-Ardenne, Reims, France

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ABSTRACT

This paper investigates the strengthening of a short reinforced-concrete corbel under fatigue test. The objective is to examine the behaviour of a short console under the influence of a fatigue test through a specified number of loading cycles. For the experimental program, four short reinforced-concrete corbels were tested and two of them were strengthened. Two of the four strengthened and reinforced-concrete corbels were submitted to static loading and the other two strengthened and reinforced-concrete corbels submitted to fatigue loading. In fact, the corbels are reinforced by wrapping them with carbon fibre fabrics. The number of cycles for the fatigue test is limited to one million. This study describes and compares the failure modes of different specimens. Indeed, the results showed that fatigue tests changed the cracking of corbels and also that using externally bonded carbon fibre fabrics significantly increased loads up to 82% with static loading.

1. Introduction

During the lifespan of concrete structures, their original quality and sustainability degrades. In order to protect them from environmental conditions, a good knowledge of mechanical properties and concrete structure behaviour is required. Their durability can be improved using the bonding composite material technique [1–5]. The short reinforced-concrete corbel is an important structural element often used in industrial buildings and structures. For example, on a bridge structure, the reinforced-concrete corbel is a structural element onto which are disposed beams and plates. In this case, the corbel is subjected to stresses caused by varying loads of traffic. These stresses on a large scale can lead to the ultimate limit state of fatigue.

The carbon fibre composite materials are very attractive due to their low weight and high strength. The ease of installation significantly reduces repair time and expenses making them a major advantage. These composite materials can be used for the maintenance of civil engineering structures, protecting them by ensuring better sealing or by limiting steel corrosion. The carbon composite materials resist especially well to fatigue tests [6]. Fatigue investigation is an important parameter because it is similar to the actual real state of structure degradation.

Extensive research has been conducted on mechanical behaviour of strengthened reinforced-concrete corbels under the static loading [7–11]. But, very limited research is noted on the mechanical behaviour of strengthened reinforced-concrete corbels under the effect of fatigue loading. The fatigue process is defined by variable stresses or deformations. The material local properties modify over time and can begin cracking and eventually cause structure failure [12]. Two possibilities

* Corresponding author.
E-mail addresses: ivelina_ivanova82@hotmail.com (I. Ivanova), jules.assih@yahoo.com (J. Assih).

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Nomenclature

F	applied load
F_u	ultimate load
F_{min}	minimal load in fatigue test
F_{max}	maximal load in fatigue test
E	Young's modulus
σ_b	concrete strength
σ_s	steel strength
ε	strain of material
C0	unstrengthened reinforced-concrete corbel under static test
C0 fatigue	unstrengthened reinforced-concrete corbel under fatigue test
CB3u	strengthened reinforced-concrete corbel under static test
CB3u fatigue	strengthened reinforced-concrete corbel under fatigue test

remain: either submit the specimen to a certain number of cycles below the yield strength or create a small crack above the elastic zone and follow the cracking phenomenon under cyclic loading. The main steps leading to fatigue crack initiation are the propagation of cracks ongoing until the final failure.

External bonding of carbon fibre fabrics on reinforced-concrete corbels is a particularly attractive solution for reinforcing civil engineering structures in order to increase their mechanical resistance. Mainly, in tensile zones the corbel retains most of the tensile stress and allows the structure bearing capacity to extend. However, two series of two reinforced-concrete corbels are tested under static and fatigue loads. The first series of two corbels are not strengthened but the second series of corbels are reinforced by wrapping them with carbon fibre fabrics. The number of fatigue cycles was defined to one million. After one million cycles, the specimens were submitted to static loading until collapse. In fact, a three-point bending test is used. The local behaviour is investigated upon by using electrical gauges [13] to measure strains in the steel, concrete and carbon fibre fabrics were used in this study. The failure modes of the corbels were compared with control specimens.

2. Experimental program

2.1. Test specimens geometry

The detail of sizes of reinforced-concrete corbels is shown in Fig. 1a and b. All corbels had the same dimensions and are strengthened alike. Indeed, the horizontal reinforced steel is localized to resist to tensile strength induced by bending top and transversal strength-absorbing contribution. The corbels are tested using a single load with a shear span to depth ratio a/d equal to 0.45.

The control specimen without strengthening is denoted “C0” where the letter “C” means Corbel and “0” zero indicates without strengthening. The name of the strengthened reinforced-concrete corbel denoted “CB3u” means that the first letter

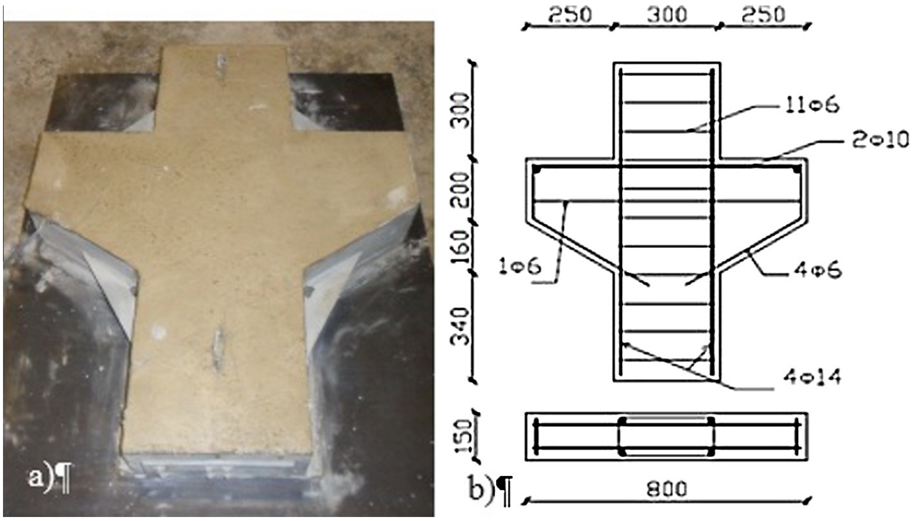

Fig. 1. Details of corbel - (a) geometry and (b) reinforced steels.