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Temporary beam-to-column connection for precast concrete frame assembly

Daniel de Lima Araújo[a,*], Lisiane Pereira Prado[b], Erlucivânia Bueno da Silva[a], Mounir Khalil El Debs[b]

[a] Escola de Engenharia Civil e Ambiental, Universidade Federal de Goiás, Rua Universitária, n° 1488, Qd 86, Setor Universitário, Goiânia, GO 74605-220, Brazil
[b] Escola de Engenharia de São Carlos, Universidade de São Paulo, Av. Trabalhador São-Carlense, n° 400, Centro, São Carlos, SP 13566-590, Brazil

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ABSTRACT

Several types of connections have been developed for precast structures, many of them with a focus on the beam-to-column connection. An important aspect of the design of these connections is to ensure the safety of the construction building during the assembly of the precast elements, which necessarily takes into account the safety of the temporary beam-to-column connection. Therefore, this paper presents a study of a beam-to-column connection for the assembly stage compound by a U profile steel corbel embedded in the column that support a cantilevered steel tube in the beam extremity, so-called Cazaly-Hanger device. The cantilevered steel tube fits in the U profile steel corbel that restricts the beam tipping. The results of the tests indicate that the proposed connection shows potential to be applied in the assembly phase of precast structures, having adequate torsion strength, against beam tipping, up to a loading equivalent of 60% of the theoretical strength of the steel corbel. The U profile steel corbel showed partial flexural yielding of the cross-section and ultimate load up to 38% higher than the value predicted by the analytical model. In addition, the results show that the steel strap used in the Cazaly Hanger device can be replaced by steel rebars welded to the profile without compromising its strength. The connection tested was computationally modelled using a finite element computational package, and a good agreement with results of the test was showed. Then, two proposals for modifying the connection by used wedding were analysed through the computational modelling. Results show that the connection strength can be increased by up to 17% due to better continuity of the corbel and cantilevered tube in the assembly stage.

1. Introduction

The behaviour of precast concrete structures is considerably influenced by the type of connection used amongst the elements. The choice of connection is one of the critical phases of the design. According to the *PCI Design handbook* [1], the connections have the function of transferring load, restricting movement, and ensuring structural stability. For these purposes, besides the constructive processes, the design of connections must take into account the criteria for strength, ductility, durability, and fire resistance, besides adequate resistance to indirect loads such as shrinkage and creep.

Several types of connections have been developed for precast structures, many focusing on the beam-to-column connection, which is usually the most important in framed structures. In this sense, several researches seek to develop connections with a high degree of stiffness to be used in the stabilization of precast framed structures [2–8]. However, these researchers did not focus the assembly stage, which is still a lack of knowledge.

This paper deal with a research that is an extension of one presented in Oliveira Junior et al. [9] which shows a connection developed to be used in the construction of powerhouses on hydroelectric plants. The authors performed an experimental study on two cruciform models: one of precast concrete and another of cast-in-place, which serve as reference, to study the performance of a rigid beam-to-column connection and analyse the mechanism of transfer of efforts in the connection when subjected to cyclic and dynamic loading. The connection, shown in Fig. 1, had space for a lateral reinforcement splice and longitudinal reinforcement for the positive and negative bending moments. It was completed with steel fibre reinforced concrete to decrease the length of the reinforcement splice and thus shorten the length of the filled region with cast in-situ concrete. To ensure the continuity of the bending reinforcement, the bars were fixed to the column by a threaded sleeve.

The beam-to-column connection developed by Oliveira Junior et al. [9] showed bending strength of the order of 80% of the resistance of the cast-in-place connection, showing potential to be applied in precast framed structures. However, because it does not have an ordinary corbel, temporary propping of the beam is required in the assembly stage, prior to the finishing of the beam-to-column connection with the

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* Corresponding author.
E-mail addresses: dlaraujo@ufg.br (D.d.L. Araújo), lisianeprado@usp.br (L.P. Prado), erlucivania@gmail.com (E.B.d. Silva), mkdebs@sc.usp.br (M.K. El Debs).

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Notation

a	centre of exterior cantilever bearing to centre of Cazaly hanger strap; shear span in a structural-steel corbel
A_s	area of hanger strap; area of additional steel reinforcement in a structural-steel corbel
b	width of cantilevered bar; effective width of compression block on structural-steel corbel
e	eccentricity of load
f_c	specified compressive strength of concrete
f_y	yield strength of strap material; yield strength of reinforcement
h	depth of strap of Cazaly hanger; depth of steel web in a structural-steel corbel
l_e	embedment length of structural-steel corbel
l_p	bearing length at the support of Cazaly hanger
M_u	factored moment in the cantilevered bar
N_u	factored horizontal force in the cantilevered bar
s	centre-to-centre spacing of additional reinforcement in a structural-steel corbel
t	thickness of steel web in a structural-steel corbel
V_c	nominal strength of section controlled by concrete in a structural-steel corbel
V_n	nominal flexural or shear strength
V_r	additional capacity of structural-steel corbel from reinforcing welded to the embedded section
V_u	factored vertical force in a cantilevered bar or a structural-steel corbel
Z_p	plastic section modulus

cast in-situ concrete. To allow the use of this connection in powerhouse structures of hydropower plants, where the propping heights of the beams are high, predictions should be made for a temporary beam-to-column connection during the assembly stage, since a conventional propping system for a beam would be very labour intensive. In this sense, this paper presents a temporary beam-to-column connection formed by a steel corbel with a U profile embedded in the column and cantilevered steel tube embedded in the beam. The steel corbel is formed by welded steel sheets in a "U" shape and serves as a support and lateral locking for a steel profile with a rectangular cross-section made of welded steel sheets and embedded in the end of the beam. Details of the proposed connection are shown in Fig. 2.

This proposed connection considers the splice of the continuity reinforcements showed in Fig. 1. The steel elements have width less than width of the beam to avoid the interference of the lateral reinforcement of the connection with steel elements. The continuity reinforcements of connection are fixed to the column by a threaded sleeve after the assembly stage. Attention is draw of the cutting on the upper face of the beam to allow the greater lap splice of the negative reinforcement due to its greater diameter when compared to positive reinforcements. The continuity reinforcements were not showed in Fig. 2 to simplify the view of components of temporary beam-to-column connection. Also, the continuity reinforcement was not considered in tests carried out in this paper because its focus on the assembly stage of the connection.

The great advantage of this solution is the rapid assembly of the precast beam, which is only supported by the U profile steel corbel. Positive and negative continuity reinforcements are installed after the beam is assembled on the steel corbel. Thus, the connection shown is jointed since there are no additional bars between the column and the beam in the assembly stage. The elements of the temporary connection can be designed according to the *PCI Design handbook* [1] for a steel corbel embedded in the column or for a Cazaly Hanger device. This device is a type of cantilevered steel beam, usually embedded in beams and slabs (Fig. 3). In this device, beyond the cantilevered top bar, there are a strap, top dowel bars welded to the cantilevered bar, and a bottom dowel anchor welded to the strap.

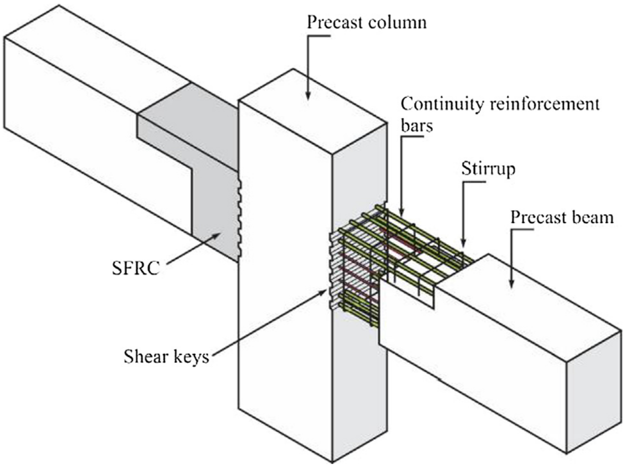

Fig. 1. An overview of the connection proposed by Oliveira Junior et al. [9].

The objective of this research is to evaluate, by means of experimental tests and computational modelling, the strength of the beam-to-column connection shown in Fig. 2 in the assembly stage. Furthermore, it is proposed to change the usual Cazaly Hanger device by replacing the steel strap with steel rebar that is more appropriate for reinforced concrete due its superficial shape. Thus, the research is justified by the fact that the design models available in the literature for embedded steel corbels do not apply to structural steel corbels with U profile. In addition, there are no design models available to evaluate the strength of the Cazaly Hanger type device when it is associated with flexible supports, which is the case of the U profile steel corbel.

2. Experimental program

To determine the strength of the U profile steel corbel and cantilevered steel tube, a structural frame with the proposed temporary connection was assembled, following the same dimensions as the Oliveira Junior et al. [9] models, which represented a powerhouse hydroelectric plant structure reduced to 1:3 scale to suit laboratory conditions. The connecting elements (steel corbel and cantilevered steel tube) were made with different sheet thicknesses to ensure that failure would occurs in only one of the elements that form the connection.

At one end of the frame, to ensure the failure of the steel corbel, the cantilevered steel tube was made of 12.5 mm thick steel sheet (cantilevered steel tube type B) and the steel corbel had a sheet with a thickness of 7.5 mm (steel corbel type A). At the other end of the frame, to ensure the failure of the cantilevered steel tube, the steel corbel was made with steel sheet with a thickness of 12.5 mm (steel corbel type B) and the cantilevered steel tube had a 7.5 mm thick sheet (cantilevered steel tube type A). Figs. 4 and 5 shows, respectively, the geometry of the components of the structural frame and the assembly details of the connection. The precast columns had axial load capacity of 7450 kN and the precast beam had factored flexural strength at section was 794 kN m.

The U profile steel corbel has a height of 150 mm, a width of 120 mm, and a total length of 750 mm, with 300 mm of the total length being salient to the column for the fitting of the cantilevered steel tube (Fig. 6). Two steel rebars with a diameter of 12.50 mm and a length of 1000 mm each were welded on each side of the steel corbel, as recommended in the *PCI Design handbook* [1]. Fig. 7 shows the prepared steel corbel and the steel corbel inserted in the column reinforcement.