Engineering Structures 172 (2018) 201–213

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Influence of the vertical grouting in the interface between corbel and beam in beam-to-column connections of precast concrete structures – An experimental analysis

Maiza Moana Silva Lacerda*, Turibio José da Silva, Gerson Moacyr Sisniegas Alva, Maria Cristina Vidigal de Lima

Faculty of Civil Engineering, Federal University of Uberlandia, Brazil

ARTICLE INFO

Keyword:
Precast concrete structures
Beam-column connection
Semi-rigid connection
Rotational flexural stiffness
Reinforced concrete

ABSTRACT

The study of the connection between the elements in precast concrete structures is especially important since the performance of a structural system is directly related to such connections. In this context, an experimental study is presented to investigate structural behavior of a type of semi-rigid interior beam-to-column connection. The type of investigated connection is formed by a precast concrete beam supported on a precast concrete column corbel with the use of grout filling and bending continuity reinforcement bars crossing the column. The main purpose of this paper is to analyze the influence of vertical interface grout filling between the corbel and the beam on the behavior of this type of connection, when it is subjected to negative bending moment. Tests on four specimens were performed: two ones with vertical interface grout filling between the corbel and the beam and two ones without grout filling. The experimental results shown resistance adequate flexural strength capacity of the connections, which exhibited ultimate loads higher than the estimated by usual design of reinforced concrete sections. It was noticed that the vertical interface grout filling contributed to increase in rotational flexural stiffness and flexural strength capacity of the connections, around 5.05 times and 1.4 times, respectively, when compared to the connections without grout filling.

1. Introduction

Precast building system for concrete structures is characterized by its ease of execution, since precast elements are produced outside of its final location in the structure. One of the main advantages of this system is the speed at which the construction can be concluded [1,2]. In addition, the use of precast concrete allows for (i) greater reuse of molds and equipment, (ii) the continuation of the element execution processes, (iii) reduces delays due to bad weather, which consequently allows for a stricter agenda in the construction processes, (iv) greater organization and cleanliness of the worksite, when compared to fabrication of precast concrete elements on site [3]. However, one of the limiting factors in the use of precast concrete structures concerns to the connections [1,2], which corresponds to one of most difficult and expensive activities in the process production.

The study of the beam-column connections assumes great importance for the design of precast concrete structures, as the performance of the structural system is directly related to the performance of its connections. These in fact affect the local behavior of the adjacent elements and the global behavior of the structure [1,4,5]. According to [5] and [6], an ideal connection should transfer forces and restrain relative displacements between elements, providing stability to the structure.

Precast cross-linked systems are formed by the adequate integration between the individual components and their connections, where their conception and execution play a very important role, in both the constructability and the structural performance of the system as a whole [1,4,7,8]. Hence, the details concerning the connections consists of one of the most important parts of the design of precast concrete structures. Therefore, in such details consideration should be given to the tolerance levels permitted for the fabrication and erection of the structure, provide predictions for adjustments between the materials to be used and avoid interference between the reinforcement and other components that constitute the connection [6].

The beam-column connection submitted to bending moment can exhibit a rigid, semi-rigid or pinned behavior, which depends on the moment that can be mobilized and after transferred among its current members [4,9]. Fully-rigid connections are those capable of restricting

* Corresponding author.
E-mail addresses: maiza_mz@hotmail.com (M.M.S. Lacerda), macris@ufu.br (M.C.V. de Lima).

https://doi.org/10.1016/j.engstruct.2018.05.113
Received 28 July 2017; Received in revised form 17 May 2018; Accepted 30 May 2018
0141-0296/

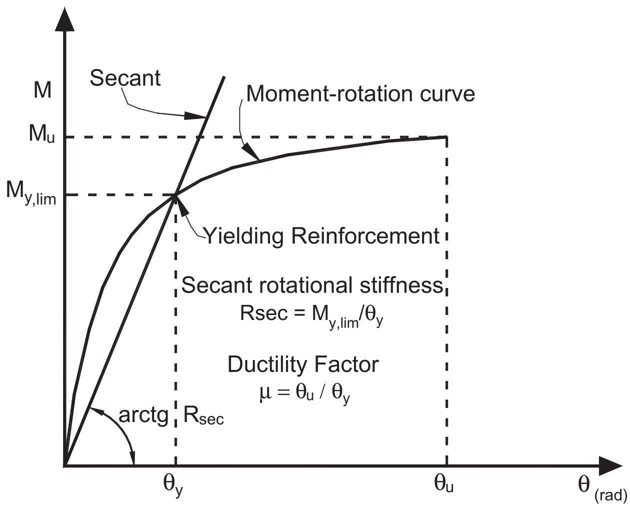

Fig. 1. Secant (rotational) stiffness obtained from moment-rotation relationship of precast concrete beam-column connections – Brazilian Code [12].

all the relative rotation between beam and column (infinite rotation stiffness) and the perfectly pinned connections are those that allow free relative rotation (zero rotation stiffness). However, in a majority of cases, beam-column connections are not fully-rigid or perfectly pinned, but exhibit semi-rigid behavior (an intermediary behavior between fully rigid and perfect pinned connections, which partially transmit the stress [1,4,9]).

The beam-column connections design to resistant to bending moments can lead to a significant economy, depending on the configuration adopted. According to [9], the connections that are resistant to bending are mainly used to:

(a) provide more stability and increase stiffness in precast frames;
(b) reduce the dimensions of the flexural members;
(c) reduce bending moments in columns, with the distribution of second order moments to beams and slabs;
(d) increase structural strength to progressive collapse.

The rotational stiffness of a beam-column connection is normally obtained by experimental results, by analytical models or by numerical models via Finite Element Method. For a reliable evaluation of the precast concrete beam-column connections behavior, it is recommended that experimental tests are performed, due to the complexity of the details involved [7,10], and to assure that nonlinear response can be noticed [11]. According to [9], mechanical tests should not be discarded as methods for connection design, mainly in those cases where there exist actions that are combined between the elements, and which produce a complex stress field, such as stress redistribution.

In general, experimental results provide the moment-relative rotation curve and the rotational stiffness of precast beam-column connections [12]. However, the nonlinear behavior of the connections

Table 1
Typology of the specimens.

Specimen	Continuity Reinforcement	Variable Filling with Grout	Quantity
PWO	Crossing the column	Without	2
PW	Crossing the column	With	2

PWO – Specimen Without grout filling.
PW – Specimen With grout filling.

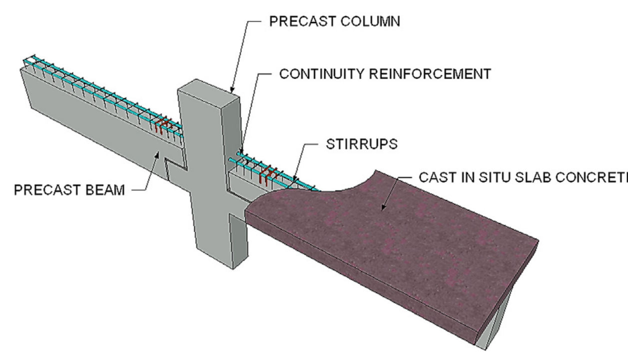

Fig. 3. Reinforcement layout of tested specimens.

represents an obstacle for structural designers when it comes to a simple and practical analysis. In this manner, simplified moment-rotation relationship were developed that provides reliable results and are suitable for practical applications. Fig. 1 shows a typical moment-rotation curve of precast concrete beam-column connections, where the nonlinear response can be noticed. In Fig. 1, $M_{y,lim}$ is the yielding moment and M_u is the flexural strength moment of the connection. According to Brazilian Code [12], secant rotational stiffness R_{sec} (Fig. 1) may be used for linear analysis to take into account the nonlinearity response of the connection, noticed in moment-rotation curve.

According to [13], the use of secant rotational stiffness is a safe approximation for representing the behavior of the connection, in global analysis of structural stability. The initial (tangent) rotational stiffness should not be used for the analysis of lateral displacements, as it is conditioned to the smallest displacements, thus underestimating the P-Delta effects.

This paper presents experimental results of precast reinforced concrete beam-column connections subjected to negative bending moments. These connections were classified as semi-rigid and had reinforcement steel bars crossing the column. Slab concrete casting in place was employed in order to emulate the continuity between precast units (beam and column). This connection can be used in the erection of structures with more than one floor, as in the construction of industrial complexes, as well as commercial and residential buildings.

The main aim of this paper is to present the evaluation of the influence of vertical grouting in the interface between corbel and beam on rotational stiffness and on flexural strength moment of the connections.

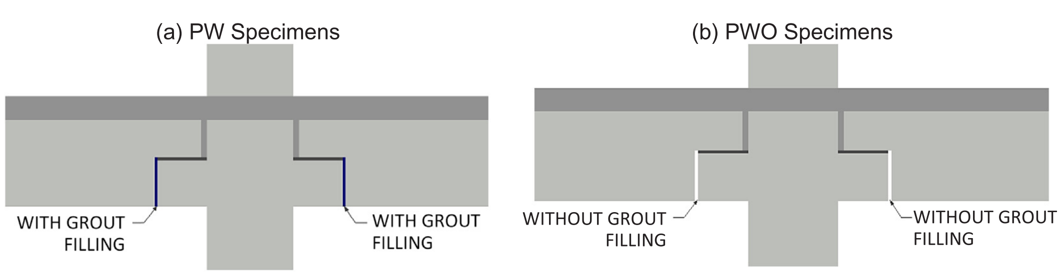

Fig. 2. Filling with grout in the space between the corbels and the beams.