10th International Congress on Civil Engineering, 5-7 May 2015
University of Tabriz, Tabriz, Iran

Experimental Analysis of Exterior Beam-Column Joints with Headed Bars under Cyclic Loading

Alireza Pourhassan[1], M. Reza Esfahani[2]

1- MSc of civil engineering, Ferdowsi University of Mashhad
2- Professor of civil engineering, Ferdowsi University of Mashhad

ar.pourhassan@gmail.com

Abstract

The use of headed bars often provides an adequate solution to steel congestion, particularly at beam-column joints. An experimental research was performed to evaluate the applicability of closely spaced headed bars in exterior beam-column joints. Two large scale cyclic beam-column joint tests were carried out to examine seismic anchorage behavior of headed bars. The variables selected for seismic tests were the small clear spacing and two layers of headed bars in the beam which are both prohibited by ACI 318-11. The behavior of the tested connections showed satisfactory seismic performance for both specimens. It was concluded that the clear bar spacing of approximately $2.3d_b$ or the use of two bar layers may be permitted for headed bars anchored in exterior beam-column joints.

Keywords: anchorage, beam-column joint, cyclic test, headed bar.

1. INTRODUCTION

Hooked bar anchorages are commonly used for longitudinal beam flexural reinforcing bars terminating within a building beam-column joint. To promote the development of a diagonal compression strut within a beam-column joint under earthquake-type loading, it is well accepted that hooked bars should be bent into the joint with the hook embedded as far as possible from the critical section. This requirement and the specified dimension of standard hooks in ACI 318-11 [1], however, often cause steel congestion in an exterior or corner beam-column joint, thereby making fabrication and construction difficult. To ease the congestion problem within the beam-column joint, the use of headed bars in place of hooked bars is a viable option [2-6].

Relevant provisions and limitations have been provided in the 2011 edition of ACI 318 [1]. The limitations or restrictions (Section 12.6.1) include bar strength, bar and head size, clear cover, bar spacing, and concrete weight which specified based on the lower bound of the used data in Code development phase. However, previous data from beam-column joint tests were not considered. Prior to this, design guidelines for headed bars in beam-column connections were incorporated into the 2002 edition of the ACI-ASCE 352 report based on both monotonic and cyclic tests [7].

In the last two decades, significant amounts of experimental investigation have been carried out to determine the suitability of each parameter restriction and limitation as imposed by the ACI Codes. Three-quarters of the data were available only in Japanese. There is still a need for additional data for various design parameters such as headed bar clear spacing and number of layers of beam reinforcement.

According to Section 12.6.1 of ACI 318-11, the clear headed bar spacing (c_s) should not be less than $4d_b$, where d_b is the bar diameter. This is a significant problem, because beam-column joint regions often involve the use of headed bars in order to reduce steel congestion, in which typical bar clear spacing (c_s) in a beam or column range from only 1 to $3d_b$ [3,5]. No special provisions regarding headed bars used in seismic applications exist in ACI 318-11, so that the overly strict requirements of Section 12.6 must be followed both in cases of seismic and non seismic designs.

Given the aforementioned restriction, the current study investigates the applicability of closely spaced headed bars in exterior beam-column joints that are part of earthquake-resistant structures. An experimental program was performed at the Dynamics of Structures Laboratory of the Ferdowsi University of Mashhad. The following sections discuss details of test procedures and results from large-scale exterior beam-column connections with closely spaced headed bars subjected to earthquake-type loading.