Engineering Structures 33 (2011) 2525–2534

Contents lists available at ScienceDirect

Engineering Structures

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

Cyclic behavior of prefabricated circular composite columns with low steel ratio

Chang-Su Shim *, Young-Soo Chung, Jae-Young Yoon

Department of Civil & Environmental Engineering, Chung-Ang University, Seoul, Republic of Korea

ARTICLE INFO

Article history:
Received 7 September 2009
Received in revised form
13 April 2011
Accepted 26 April 2011
Available online 1 June 2011

Keywords:
Precast composite column
Bolt connection
Prestress
Ultimate strength
Displacement ductility
Energy absorption

ABSTRACT

Improved economy and speed of construction can be achieved through the use of prefabricated structural members. As a step toward the advancement of prefabricated substructures, a precast composite column for seismic regions is proposed in this paper. Concrete-encased composite columns with core structural steel can be utilized for a fast construction method using steel connections. Six concrete-encased composite specimens with low steel ratio were fabricated. Quasi-static tests were conducted to investigate the cyclic response of the prefabricated composite columns. For composite columns with bolt connections, the cyclic behavior in terms of ultimate load and post-cracking behavior was enhanced significantly as the transverse reinforcement ratio increases. Higher prestressing gave greater flexural strength to the composite columns with prestressing and better energy absorption capacity, while displacement ductility of the prestressed composite column was decreased as the prestressing increased.

1. Introduction

Encased composite steel–concrete columns, which are made up of a combination of steel members and concrete, have been widely used in buildings. The advantages of using composite columns are: smaller cross-section and higher strength-to-weight ratio than a conventional reinforced concrete member, significant savings in material and construction time, inherent ductility and toughness for use in repeated and reversal loads, enhanced fire resistance characteristics when compared to plain steel, higher load carrying capacity due to the composite action of steel and concrete and confinement of concrete in the case of in-filled columns, and higher rigidity for use in lateral-load resisting systems. Recently, these composite columns have been increasingly used for bridge piers in seismic regions. For building columns, the percentage of steel commonly exceeds 4% of the total cross-sectional area of the composite column. However, the steel ratio for the bridge piers needs to be reduced for cost-effective construction because bridge piers have relatively larger dimensions [1]. Experimental and analytical studies on rectangular concrete-encased composite columns were performed and showed that the concrete confinement provided by lateral ties play an important role in enhancing the ultimate strength capacity and ductility of short and slender composite column members [2,3].

In the civil engineering community, prefabricated structures and systems have received increasing attention as a way to increase construction speed, to enhance work zone safety and to minimize the environmental impact. In particular, bridge structures for light railway lines in urban areas need fast construction. The impact and costs associated with traffic control and disrupted traffic flow have increased significantly in recent years. Additionally, direct and indirect costs related to traffic control, disruption, and environmental impact have become major concerns. Newly developed precast columns have been suggested by several researchers [4–13]. Precast concrete segmental columns with internal tendons were investigated by Shim et al. [4], Hewes [6] and Billington and Yoon [7]. As introduced by Hieber et al. [9], various structural systems were utilized for fast construction of bridges. Among several design issues of the precast pier, the connection detail is the most important concern. A composite column with embedded steel members can be used effectively for the connection.

A prefabricated substructure system has been suggested based on the previous experiments on cast-in-place composite columns [1]. Fig. 1 shows two prefabricated bridge piers without prestressing for small columns and with prestressing for large columns. Considering site conditions and available lifting equipment, a single pier module without prestressing can be designed to have bolt connection with a foundation. High piers with large dimensions normally need segmented structures with prestressing to prevent gap opening between segments.

In this paper, we propose a concrete-encased composite column with a steel ratio of less than 4.0% to reduce the initial cost. The embedded steel member can increase the ultimate strength and

* Corresponding author. Tel.: +82 31 670 4707; fax: +82 31 675 1387.
E-mail addresses: csshim@cau.ac.kr (C.-S. Shim), chung47@cau.ac.kr (Y.-S. Chung), skynurija@paran.com (J.-Y. Yoon).

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doi:10.1016/j.engstruct.2011.04.024