Experimental Investigation on Mechanical Behavior of Y-shaped Steel and Concrete Composite Joints

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1. Introduction

Phase II of the Pudong International Airport has a total floor area of 400,000 square meters and constitutes a terminal building, a boarding hall, and mass transit stations. The terminal building is formed by upper steel roof, lower concrete frame as well as connection members of Y-shaped steel and concrete composite columns. V-shaped steel columns and supporting concrete columns are linked with cast steel bearings to form those composite columns along gridlines A and G, while inclined steel columns are inserted directly inside concrete columns along gridline 0/1A (See Fig. 1). In such cases, the behaviour of connection members turns out to be a key problem under dynamic excitation. Although the mechanical behaviour of hybrid beams and steel column foot inserted into concrete filled steel tube (CFST) piles were investigated in Japan, few studies have been conducted on such composite columns with cast steel bearings which were adopted in terminal building.

2. Test program

This paper describes the mechanical behavior of these composite column joints as investigated by a series of pseudo static tests at Tongji University (See Fig. 2 and Fig. 3). One-quarter scale specimens were tested with different axial compression ratios (μ_c=0.10/0.15) and loading directions (X/Y). The study described represents composite columns including uncertainty in strength and deformation for cast steel bearings. Therefore, the details of the cast steel bearing, such as element proportion and casting procedure, were strictly in correlation with prototype members.

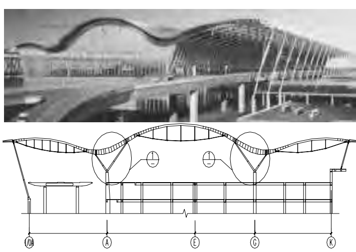

Fig. 1: View of Terminal Building

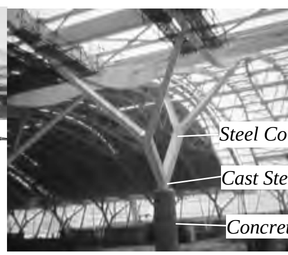

Fig. 2: Prototype Column

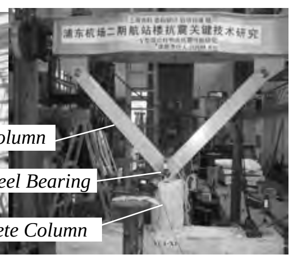

Fig. 3: Test Setup

https://doi.org/10.2749/222137908796292407
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3. Results and discussion

Results showed that damage occurred at the bottom of the steel column because the modulus of elasticity and yield strength were both reduced approximately 10% in the Heat Affected Zone (HAZ). As a result, there exists a weak layer between the steel column and the cast steel, and therefore a stress concentration is elicited. Moreover, reduction of material strength leads to decreased capacity of the steel section. The damage behaviour in the HAZ shows great similarity to that of steel structures in the Kobe earthquake.

Furthermore, as the strength of the cast material is more inconsistent than hot rolled steel; larger variance was used to determine design strength. Therefore, the design capacity of the cast steel bearing is more highly reduced for adoption and the actual performance of the cast steel is more likely to be under-estimated compared to rolled steel. As a result, the weakness as originally designed in the cast steel bearing might be altered. It should be noted that there is a discrepancy between specimen and prototype members in terms of moment-shear ratio. Therefore further investigations into possible weaknesses of the prototype will be needed and such work is still in process.

In detailed measurements of steel and concrete composite beams reported in the literature, three stirrups were arranged side by side at both ends of a steel part that was encased in concrete columns for improved confinement. As serious cracks were also observed at the top of concrete columns due to insufficient confinement, additional stirrups could be introduced and the quantity of stirrups could be determined by concentrated moment on the top of concrete column and stiffness variation for steel and concrete column. Additionally, the longitudinal reinforcement hooks at the top of the concrete section could be lengthened to improve anchorage behavior of the steel reinforcement cages. To mitigate the abrupt transition of stiffness or relatively large moment at the top of concrete columns, steel tubes could be adopted for enhanced confinement.

In addition, no slip was observed between the concrete and the cast steel during any stage of the loading process. Furthermore, pullout damage which was reported in pseudo-static test of steel column foots, was prevented. This verifies that anchorage length of 3 times the depth of the steel section as well as the quantity of shear connectors specified in the Chinese Design Code provided adequate shear transfer.

Hysteresis curves of concrete columns and steel columns are given separately to clarify sources of deformation. The hysteresis curves of the concrete columns still stay in the elastic range until termination while those of the steel columns show clear strain hardening branches. Strength and stiffness reduce significantly in a degradation branch when damage occurs in the HAZ.

In order to investigating mechanical behaviour of cast steel bearing, force transfer mechanism and load-strain hysteretic curves were examined separately. Based on these analyses and findings of Finite Element simulation conducted previously, potential damage section inside cast steel bearing was located thereby. Furthermore, elastic rotation stiffness of cast steel bearing was deduced in accordance with the analysis of measured rotation angle, which can be used determine the component of the displacement at the top of steel columns.