Journal of Constructional Steel Research 137 (2017) 286–296

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

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

Exposed column-base plate strong-axis connections for small-size steel construction

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ARTICLE INFO

Keywords:
Small-size steel structures
Exposed column-base plate strong-axis connections
Hysteretic behaviour
Seismic performance
Flexural strength
Stiffness

ABSTRACT

Experimental study on exposed steel column-base plate connections subjected to both axial and lateral loadings is quite limited. Therefore, based on the intensive field investigation, nine specimens were tested to appraise the seismic performance of various column-base plate strong-axis connections of small-size steel structures in this study. The main parameters were the thickness of base plates, the embedment length of anchor bolts, and the presence of hook and rib plates. Flexural strength, deformation capacity, energy dissipation, and stiffness of the test specimens were investigated. Based on the test results, the hysteretic behaviour of exposed column-base plate strong-axis connections was significantly influenced by the base plate thickness as well as the number and embedment length of anchor bolts. However, the effect of rib plates on the flexural performance of column-base plate connections was negligible. The flexural stiffness of the specimens was approximately 15% of the flexural stiffness by the New Zealand Standard with the assumption that the supports were fixed. It was found that although column-base plate strong-axis connections were properly designed in accordance with design guides, the flexural performance of the connections could be unreliable without sufficient bond capacity between concrete and anchor bolts.

1. Introduction

Numerous existing structures have been constructed without appropriate consideration of seismic design in the world. National Emergency Management (NEM) [1] reported that approximately 82% of existing structures in South Korea were built without seismic design. In particular, small-size structures which are defined as buildings with less than three floors and with smaller gross area than 500 m^2 occupy about 85% of the overall building structures in South Korea [2]. According to NEM [1], these structures do not need to be designed to resist earthquake. Thus, the small-size structures may have a possibility of severe damage during earthquake. Currently, the design guidelines for small-size structures provide the minimum requirements to ensure fundamental safety of the buildings [2]. However, these requirements are deemed to be insufficient to resist lateral loads such as earthquake. Therefore, the small-size structures need to have appropriate seismic performance to resist earthquake loading.

This study focuses on the exposed column-base plate strong-axis connections of small-size steel structures. In general, the exposed column-base plate connection is composed of the steel column, steel base plate, anchor bolts, and concrete foundation as illustrated in Fig. 1. For assemblage, mortar grout is used for leveling between the base plate and concrete foundation and also for the efficiency of uniform distribution of applied forces. The connections transmit vertical and lateral loads on the building frame to soil through concrete foundation. When the connection is subjected to vertical and lateral loads, the column base resists the flexural moment by the development of compressive and tensile force. The compressive force meaning bearing force occurs on the concrete foundation and the tensile force occurs in some or all of the anchor bolts. Therefore, the base plate should have wider area then cross-section of the column to resist reactions from the concrete foundation.

However, according to the field investigation, column-base plates of small-size steel structures are generally constructed without proper consideration of structural safety (see Fig. 2). More specifically, some anchor bolts were found to be located between flanges of the steel column. Two or four anchor bolts (two per line) were typically used at column-base plate connection as depicted in Fig. 2(a) and (b). Rib plates were placed for some connections, but not for others [see Fig. 2(a) and (b)]. In some cases, the thickness of the base plate was similar to that of the column flange, which might result in poor flexural capacity as shown in Fig. 2(c) and (d). The embedment length of anchor

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http://dx.doi.org/10.1016/j.jcsr.2017.06.018
Received 27 November 2016; Received in revised form 6 June 2017; Accepted 20 June 2017

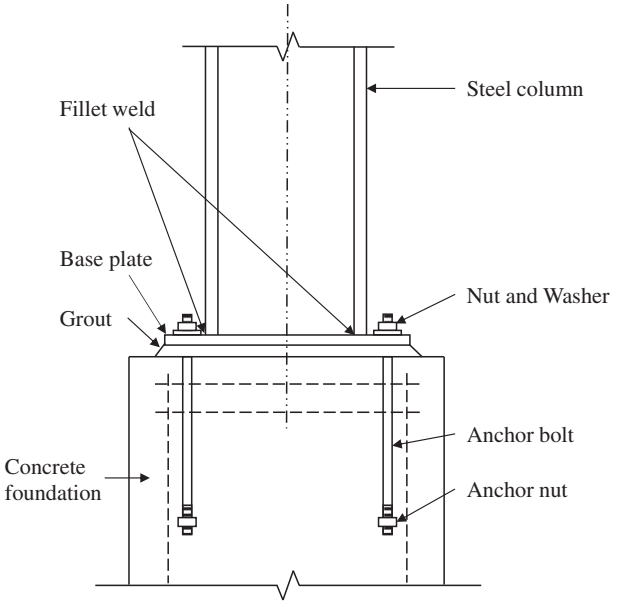

Fig. 1. Exposed steel column-base plate connection components [14].

bolts was approximately 500 mm. With these details observed in the field, it is difficult to secure a fixed end condition at the support. Furthermore, if this type of boundary condition is used with beam-column connections which are assumed to be pinned joint, structures can be unstable.

Although research was extensively conducted for the design of column-base plate connections, limited study on the behaviour of the connections subject to axial and lateral loads can be found in the literature [3–13]. Di Sarno et al. [3] performed experimental study on such connections under monotonic (pushover) loading. They reported that the traditional connection was considerably affected by the behaviour of anchor bolts. Some studies on rotational flexibility were conducted [7–11]. For instance, Kanvinde et al. [7] proposed a new approach to characterize the rotational flexibility of exposed column-base plate connections. In particular, it is quite difficult to find experimental study on the hysteretic behaviour of exposed column-base plate connections used for existing steel structures in the field. Therefore, further research and more data on column-base plate connections with various connection details are vital for better understanding of connections for existing small-size steel structures in the field.

In this study, the seismic performance of exposed column-base plate strong-axis connections with various details was evaluated using both existing and developed connections under both axial and cyclic loads on the basis of the field investigation. Through the tests, vital factors such as stiffness and energy dissipation capacity were investigated.

2. Design guidelines for exposed steel column-base plate connections

According to the design criteria [2], column-base plate connections of steel structures should be designed to have a fixed condition for transmitting moment to foundation effectively. The length of a base plate should be 150 mm longer in each direction than that of a column for proper anchor bolt locations. The thickness of a base plate should be equal to or larger than 20 or 30 mm for one- or two-story buildings, respectively. Furthermore, the diameter of an anchor bolt should be equal to or lager than 20 or 22 mm for one- or two-story buildings, respectively. In the small-size steel structures, the connections should have more than six anchor bolts, and the embedment length of an anchor bolt should not be less than 30 times the diameter of the anchor bolt. In addition, the anchor bolts should be hooked to have sufficient bond strength.

In accordance with the AISC Design Guide 1 [14], the nominal bearing strength on concrete can be calculated as follows:

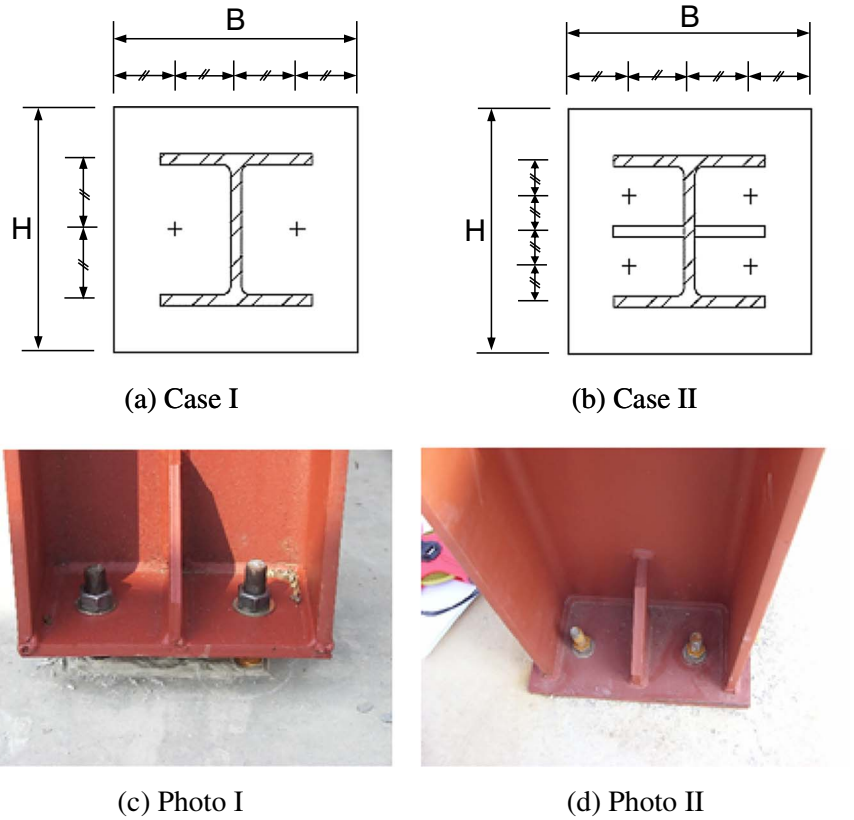

Fig. 2. Investigation of exposed steel column-base plate connection of existing small-size steel structures.