Journal of Constructional Steel Research 128 (2017) 362–370

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

Experimental evaluation of bending-moment performance about steel plate-concrete structures with mechanical splice

Moonjeong Kim [a], Hoyoung Park [a], Myounghwan Han [b], Byong J. Choi [a,*]

[a] Department of Plant Architectural Engineering, Kyonggi Universtiy, 154-42 Gwnagkyo-sanro, Youngtong-gu, Suwon, Kyonggido, Republic of Korea
[b] Junglim Architechure, 110-460 187-1 Yeongeon-dong, Jongro-gu, Seoul, Republic of Korea

ARTICLE INFO

Article history:
Received 9 May 2016
Received in revised form 31 August 2016
Accepted 14 September 2016
Available online xxxx

Keywords:
Steel plate concrete structures
SC structures
Mechanical splices
Bending moment
SC module connection

ABSTRACT

The steel-plate composite (SC) structure is recognized as effective for achieving the synergy of reinforced-concrete (RC) and steel structures and shortening the construction period. These advantages attract the attention of engineers, especially with regard to nuclear power plants. The application of the SC structure to nuclear power plants is increasing. Nuclear power plants composed of SC members must have connections between SC and RC members. This paper focuses on the connections between SC and RC walls and presents the results of performance tests on mechanical splices connecting SC walls to RC walls. In the performance tests, two types of splices were used as specimens: the existing type presently applied to nuclear power plants and a type that was improved by considering the modularization and workability using prefab SC members. The specimens were constructed in full scale and were able to simulate the real SC members of existing nuclear power plants. In the tests, the bending-moment capacity of the connections against lateral loads caused by static loading was estimated. The results of the performance tests indicate the real strength of the mechanical splices and the suitability of design assumptions applied to the design members of the mechanical-splice specimens.

1. Introduction

The steel-plate composite (SC) structure was developed for amplifying the synergy of steel and reinforced-concrete (RC) structures and is effective for constructing modular system structures. The modularized SC-structure system is effective for maintaining a constant quality; decreasing the CO_2 and industrial waste; and, especially, reducing construction periods. Because of these advantages, SC structures are actively studied, and numerous theoretical outcomes have been presented in a short period. In particular, SC structures attract attention for nuclear power plant construction, for which the economics are mainly affected by the construction periods. Thus, several studies on modular construction systems for nuclear power plants have been conducted (AIJ [1], BSI [2]). In Korea, national policy-mandated research on plant modularization began in 2010, and SC structure codes for nuclear-plant construction were published (KEPIC [3]). However, despite these constant studies, the data regarding performance tests [4–6], including full-scale specimen tests [7–9], are poor. Few references, such as specifications and design details, are available. The lack of such references causes insecurity regarding SC-structure systems and makes applications of SC structures rare, except for nuclear plants.

We suggest that the accumulation of results of real-scale performance tests will yield the reliability of SC-structure systems and help to extend the structural applications, including nuclear power plants. As a first step, we focused on the connections between the SC wall and RC wall, because these are common in SC nuclear power plants and there are no specifications for these connections. The most important characteristic of these connections is the load-transfer capacity. To check this ability, we conducted bending-moment performance tests on full-scale models with two different mechanical splices connecting the RC and SC walls. After the testing, we estimated the real effective bending ability of the specimens and reviewed the design assumptions regarding the splice members. Through the test results, we provide reference and background information to establish SC building codes and details.

2. Outlines of tests

2.1. Purpose of test

SC members made of two steel plates filled with concrete are typically used as modular wall members. The SC modular system is often recognized as the optimal structure for reducing the construction periods of nuclear power plants. However, even nuclear plants made entirely of a modular system have parts that cannot be established by only SC members, e.g., a foundation. Thus, joints connecting RC and SC members are necessary. Furthermore, almost all SC walls in nuclear power plants have re-bars with diameters over 43 mm (ASTM #14) as main bars, and according to the building codes, these re-bars must

* Corresponding author.
E-mail address: bjchoi@kyonggi.ac.kr (B.J. Choi).

http://dx.doi.org/10.1016/j.jcsr.2016.09.007
0143-974X/© 2016 Published by Elsevier Ltd.

Table 1
Variables of models.

Variables	Model 1	Model 2
wing plate setting on splice setting on	upper base plate inside SC wall	lower base plate between SC an RC wall

connected to others by welding or mechanical splices (ACI [10,11]). Therefore, in nuclear plants, mechanical splices are employed for the connections. However, there are no standard details for mechanical splices; thus, engineers must design each mechanical splice in accordance with the general structural codes of the country.

Because there have been no real-scale performance examinations of existing mechanical splices, it is difficult to ensure the safety of designed splices. Thus, we conducted real-scale performance tests of mechanical splices constructed by Load and Resistance Factor Design (LRFD [12]). In addition to the existing type of splice, considering the construct modularization, which is the main purpose of the SC structure, we present an advanced splice shape. The existing splice is designed to combine mechanical and lap splices but has problems regarding the concrete casting because it is placed in the SC wall. Additional concrete casting is necessary to link the SC wall to the RC wall in existing types, which disturbs the production of all SC walls as precast types. The advanced shape that we present is set at the end of the wall member and thus helps the SC wall to connect to the RC wall as a precast type.

Through the tests, we examined the following: 1) the failure mode of the existing and proposed mechanical splices, 2) the capabilities of the splices regarding the bending moment and load transfer, and 3) the effectiveness of the suggested design method.

2.2. Details of specimens

We used two full-scale models for the performance tests. One model had the mechanical splice that is currently used for connections at in nuclear power plants (Model 1) and the other had the advanced mechanical splice shape considering the modularization and the workability of the concrete casting (Model 2). The models were designed at the same scale as members of existing plants. The experimental variables of the models are shown in Table 1. Fig. 1 presents the details of the connections. The main bars from RC wall were connected to base plate of the mechanical splice by a coupler.

2.3. Design of specimens

2.3.1. Cross section of specimen

Fig. 2 presents a shop drawing and the sections of the SC and RC walls. The depth and width of the wall in the models were 900 mm, which is equal to the depth of the walls in actual nuclear power plants. The height of each wall was 4600 mm, which is close to the height of the walls in nuclear plants. The concrete stress of the models was 42 MPa (high-strength concrete), and the nominal stress of the re-bars was 1) 350 MPa (diameter ≤ 25 mm) and 2) 420 MPa (diameter > 25 mm). The steel stress of the SC wall plates was 490 MPa (tensile stress) and

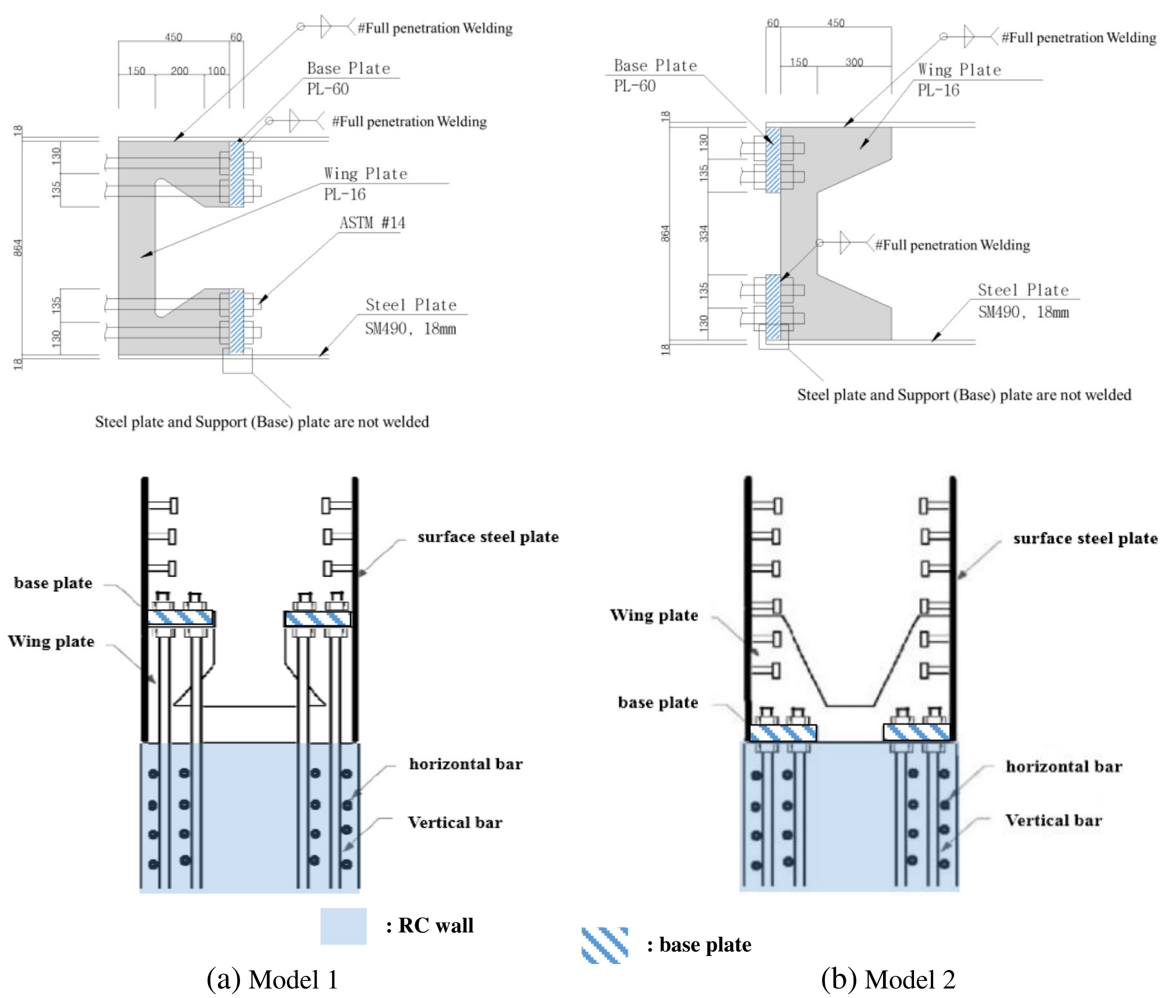

Fig. 1. Details of connection between RC and SC parts.