Journal of Constructional Steel Research 88 (2013) 206–219

Contents lists available at SciVerse ScienceDirect

Journal of Constructional Steel Research

Experimental study on seismic behavior of high-strength concrete filled double-steel-plate composite walls

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ARTICLE INFO

Article history:
Received 17 August 2012
Accepted 3 May 2013
Available online 15 June 2013

Keywords:
Concrete filled double-steel-plate composite walls
High-strength concrete
Experimental study
Seismic behavior
Super high-rise buildings

ABSTRACT

In order to improve the ductility of the core wall in super high-rise buildings subjected to high axial compressive force and seismic effect, a new detailed concrete filled double-steel-plate (CFDSP) composite wall using high-strength concrete is proposed. This CFDSP composite wall is composed of concrete filled steel tubular columns at the two boundaries and concrete filled double-steel-plate wall body which is divided into several compartments by vertical stiffeners transversely connected by distributed batten plates. In order to intensively investigate the structural mechanism of this new type of CFDSP composite walls, twelve specimens are tested under large axial compressive force and reversed cyclic lateral load. No evident buckling of surface steel plates can be observed due to reasonable width-to-thickness ratios of steel plates and properly arranged batten plates, so that the surface steel plates and infill high-strength concrete can work compatibly in the whole loading process. All the specimens exhibited good energy dissipation ability and deformation capacity with full hysteretic curves and large ultimate drift ratios, thereby indicating that high-strength concrete can be used in seismic-resistant structures when the proposed new detailed walls are adopted. Based on the test results, the stiffness and strength degradations are analyzed, and the deformation characteristics of all the specimens are discussed in detail. Finally, a strength prediction approach based on the section analysis method is presented, and some detailing requirements for routine design practice are recommended.

1. Introduction

In recent years, several super high-rise buildings have been built in China. The two tallest buildings in China—PINGAN IFC and Shanghai Tower both exceed 600 m. In a modern super high-rise building, a frame (or mega frame)-core tube hybrid structural system is usually used for its superior seismic behavior, large lateral stiffness, low cost and rapid construction, etc. Since the core tube sustains the majority of the seismic action and plays a significant role in the energy dissipation, the structural wall of the core tube is one of the most critical elements for the seismic design of the whole structural system.

To ensure adequate deformability of the core walls under lateral loads, the axial load ratio should not exceed an upper limit value. With the increase of building height, the axial compressive force at the base of core wall grows quickly. As a result, for the traditional RC structural walls, the only effective way to limit the axial load ratio is to increase the core wall thickness when the maximum available concrete strength is restricted for the consideration of ductility. The excessively thick wall would increase the difficulty of construction and greatly reduce the usable floor areas. In addition, the cross sections of the frame beams and columns should also be designed very large to ensure that the frames can resist a certain part of lateral forces so that a dual system can be realized. The increase of wall thickness may also result in the increase of the structure self-weight, and correspondingly the increase of seismic effect. Therefore, it is hard to obtain an economical and rational design, or even impossible to accomplish the design, when the building reaches a certain height and the traditional RC structural wall is adopted.

One effective way to solve this problem is to employ new forms of structural walls that have high bearing and deformation capacities under large axial compressive force and cyclic lateral load with acceptable wall thickness. Steel plate–concrete composite walls are recently developed structural walls and have been used in the actual practice [1–3]. These steel plate–concrete composite walls can be classified as steel-plate reinforced concrete (SPRC) composite walls and concrete filled double-steel-plate (CFDSP) composite walls according to different relative positions of steel plates and concrete as shown in Fig. 1.

Several experimental programs have been conducted on the seismic behavior of SPRC walls. Lv et al. [4] tested 16 SPRC walls with different parameters and 3 RC walls for comparison. The measured ultimate top displacements of the SPRC walls were much larger than those of the control RC walls. In the tests by Chen et al. [5], SPRC walls also exhibited much greater deformation and energy dissipation capacities than RC walls. The compressive strengths of

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0143-974X/$ – see front matter
http://dx.doi.org/10.1016/j.jcsr.2013.05.001

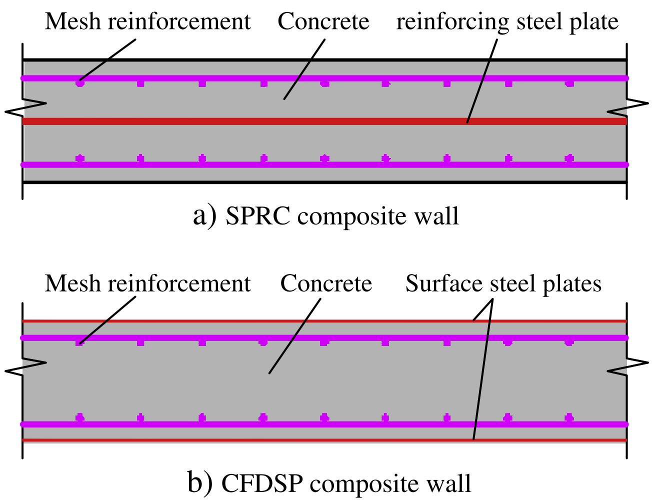

Fig. 1. General details for SPRC and CFDSP composite walls.

concrete used in these two experimental programs ranged from 16 N/mm^2 to 36 N/mm^2, and tests on steel-plate reinforced high-strength concrete walls are still not available in the literature.

Studies on CFDSP walls have been carried out by several researchers in the past years, and several different configurations have been proposed. Wright et al. [6] first conceived a composite wall formed from two skins of profiled steel sheeting filled with concrete as shown in Fig. 2a, which was to be applied in common commercial

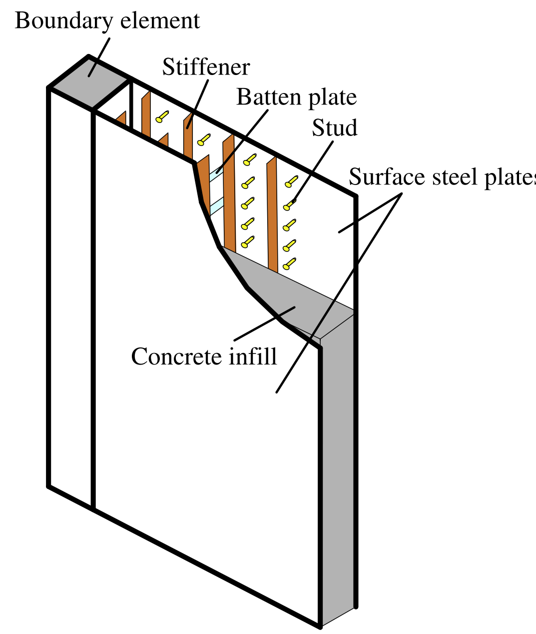

Fig. 3. A new detailed CFDSP wall.

buildings. An integrated research program was carried out to investigate the performance of this kind of composite walls under different loading conditions and finally to establish design formulas for actual

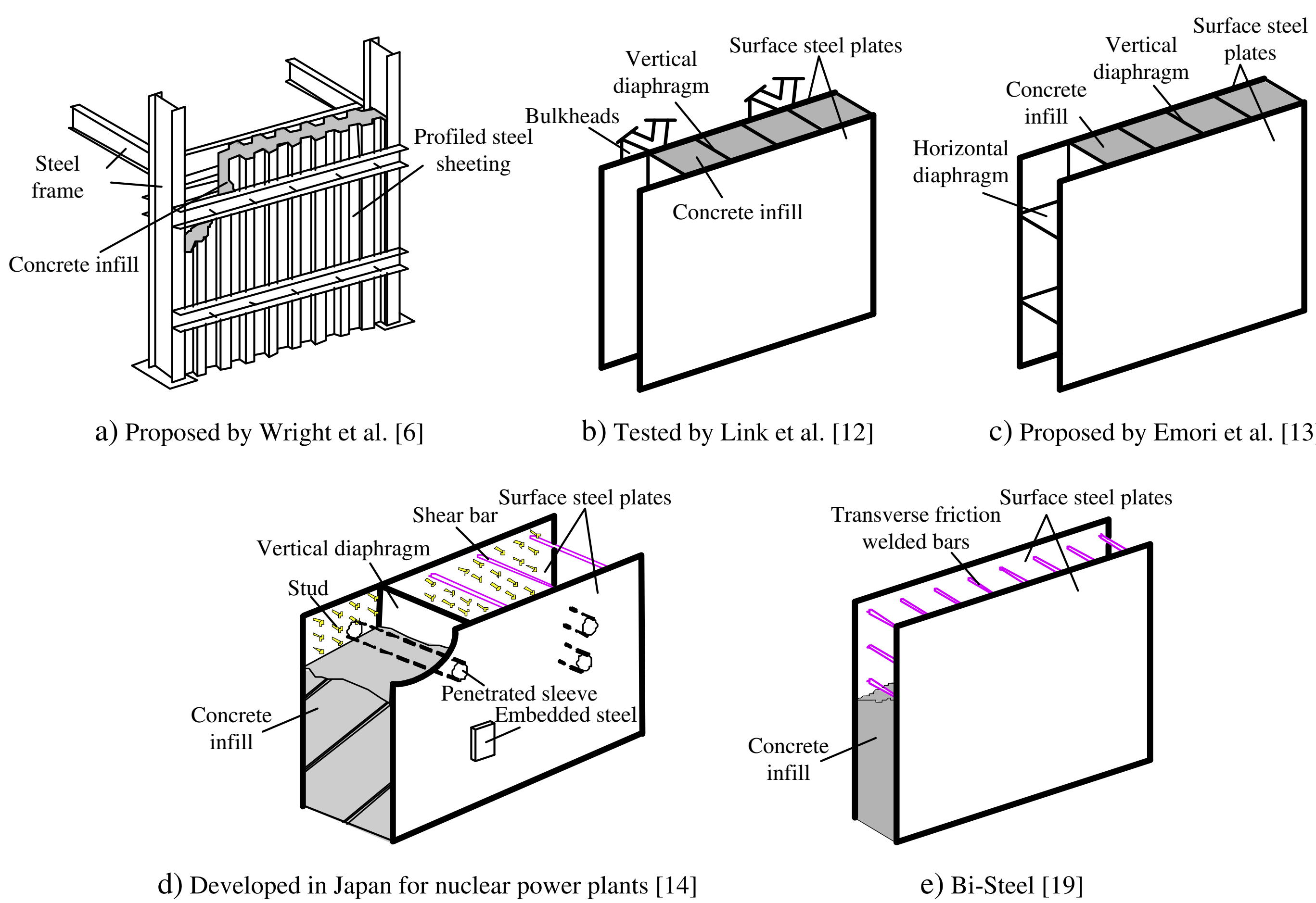

Fig. 2. Previous developed CFDSP walls.