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Monotonic and reverse-cyclic load experiment for plywood and RC slab diaphragms used in timber-concrete hybrid building

Naohito Kawai [a], Hiroshi Isoda [b], Minoru Okabe [c], Solomon Tesfamariam [d,*]

[a] School of Architecture, Kogakuin University, Shinjuku, Tokyo 163-8677, Japan
[b] Laboratory of Structural Function, Research Institute for Sustainable Humanosphere Kyoto University, Gokashou, Uji, Kyoto 611-0011, Japan
[c] Tsukuba Building Research and Testing Laboratory of CBL, 2 Tatehara, Tsukuba 305-0802, Japan
[d] School of Engineering, The University of British Columbia, Okanagan Campus, 3333 University Way, Kelowna, BC V1V 1V7, Canada

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ABSTRACT

In seismically active regions, the use of timber-reinforced concrete (RC) hybrid construction can overcome the structural limitations that occur with timber construction. A series of shake table tests were carried out on RC-timber hybrid systems that used two diaphragms: glulam + plywood system (CN75 @ 50 mm nail spacing) and laminated wood + RC slab system. To develop robust analytical models, however, understanding the different components is crucial. In this paper, a series of in-plane monotonic and reverse-cyclic tests were undertaken on two diaphragm systems and their connections. Salient features of each diaphragm (i.e. stiffness, ductility, and energy dissipation) were computed from the monotonic loading test results. With the test results reported, analytical and numerical models can be developed.

1. Introduction

In seismically active region, use of hybrid system, can overcome the limitation of only using timber structures (e.g. [5,10,18]). In Japan, a five-year national research projects were started in 1999 to explore various timber-based hybrid systems [20]. One such hybrid system proposed was timber frame with reinforced concrete (RC) core [10]. Isoda et al. [10] reported shake table test results for one- and two-story timber-RC system (Fig. 1). The two-story building utilized only glulam + plywood system diaphragm. For the one-story hybrid building, however, two different diaphragm systems were tested: laminated timber beam + RC slab system (Specimen A, Fig. 1a) and glulam + plywood system (CN75 @ 50 mm nail spacing, Specimen B, Fig. 1b). Deformation and energy dissipation of the timber frame is governed by inelastic deformation of connectors [9,13,17]. Isoda and Tesfamariam [9] reported experimental and analytical models for three connections used in the timber-RC hybrid building. In this paper, to study performance of the two diaphragms (Fig. 1), a series of in-plane shear test were carried out. In addition the shear load tests, additional testing were undertaken on the connections used for the two diaphragms. The results from in this paper, coupled with the connection tests results reported in Isoda and Tesfamariam [9], can be used to develop numerical model of the hybrid system.

Various studies are reported on the consideration of flexible and rigid diaphragm (e.g. [3,6,11,15]). Yeoh et al. [19] provided state-of-the-art review on timber-concrete composite structures. Several experimental and analytical studies are provided on the timber-concrete composite system connections (e.g. [2,4,7,16]). The diaphragm stiffness influences the load transferred to the lateral load resisting systems (e.g. [3]). Newcombe et al. [15] tested several alternative diaphragm to lateral loading resisting element connections and showed that inclined fastener connections showed higher stiffness capacity than dowel fasteners (up to four times).

2. Experimental test of diaphragm and connection

2.1. Test specimens

The laminated timber beam + RC slab system (Specimen A) had vertical and horizontal dimensions of 3640 mm (Fig. 2a). A 120 × 240 mm Douglas fir E105-F300 grade (JAS, Japanese Agricultural Standard) laminated timber was used in the outer periphery and internal beams (at a spacing of 910 mm). For E105-F300 grade, the Young's modulus and bending strength are 10.5 MPa and 30.0 MPa, respectively. The laminated timber beams were connected using 12-M20 bolts (Fig. 2b) to the base and top beams.

The RC slab properties were: average concrete compressive strength, $f'_c = 22.9$ MPa, average modulus of elasticity = 24,800 MPa, density = 2.24 g/m^3, and thickness = 80 mm. A 100 × 100 mm-D10 reinforcement mesh was used. Nominal diameter of D10 bars is 10 mm, and

* Corresponding author.
E-mail addresses: kawai-nk@kogakuin.ac.jp (N. Kawai), hisoda@rish.kyoto-u.ac.jp (H. Isoda), okabe@tbtl.org (M. Okabe), solomon.tesfamariam@ubc.ca (S. Tesfamariam).

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Fig. 1. Timber-RC hybrid building; a) laminated timber beam + RC slab diaphragm, and b) glulam + plywood diaphragm (CN75 @ 50 mm nail spacing).

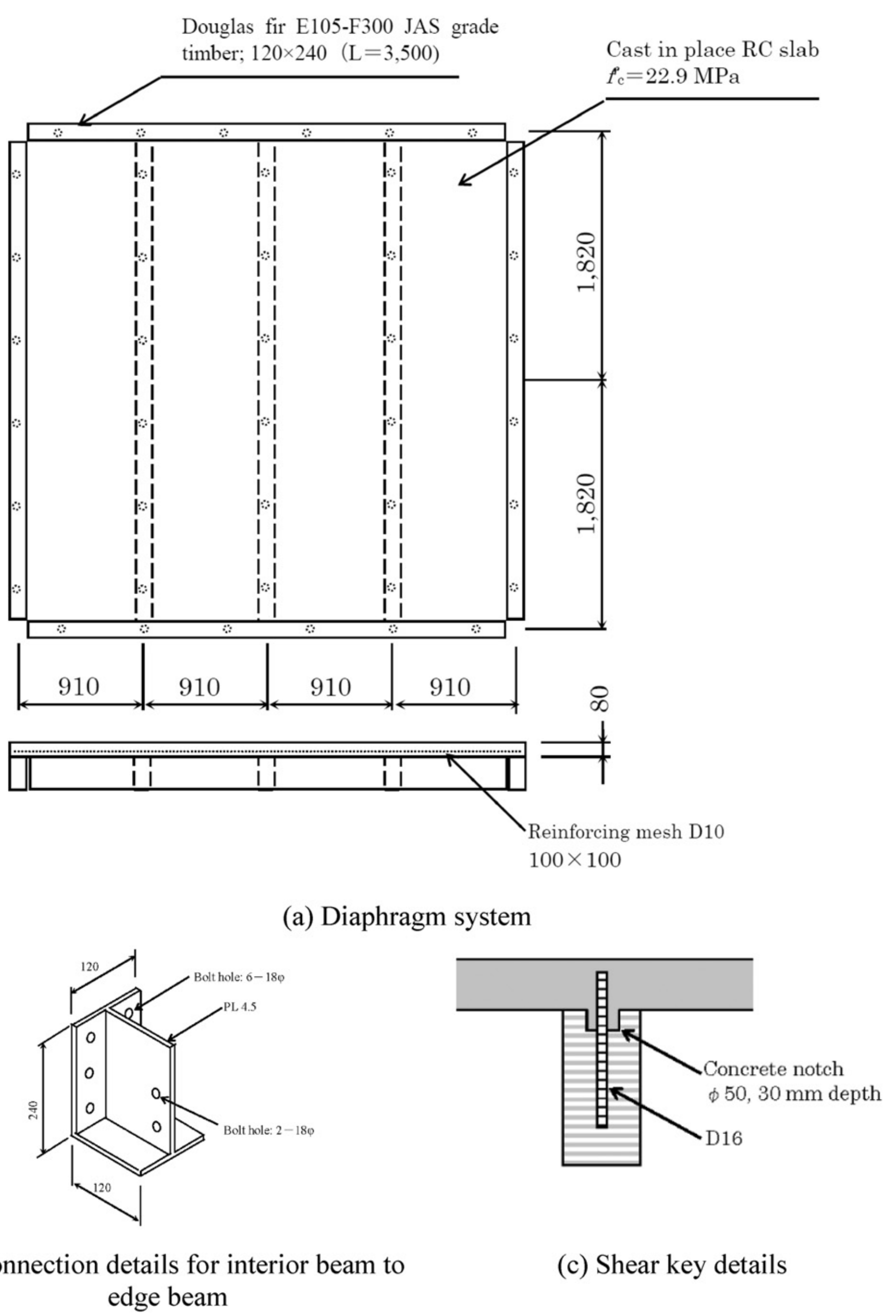

Fig. 2. Laminated wood + RC slab diaphragm (units are in mm).