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Testing of flexure-dominated interlocking compressed earth block walls

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HIGHLIGHTS

- Flexure-dominated ICEB walls can exhibit desirable seismic performance.
- Larger height-to-width aspect ratios tend to increase ductility of ICEB walls.
- Flange under tension can increase lateral strength of an ICEB wall.
- Opening in an ICEB wall significantly reduces the wall lateral resistance.
- Stress concentration occurs at the corner of an ICEB wall opening.

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ABSTRACT

Interlocking Compressed Earth Blocks (ICEBs) are a form of dry stack masonry units made with indigenous soil and typically stabilized with cement. This paper presents testing results for seismic behavior of flexure-dominated ICEB walls. A total of four 1.8-m high ICEB wall specimens were constructed and tested. The specimen dimensions were varied to identify the effects of the following factors on performance of ICEB walls: height-to-width aspect ratio, presence of a flange at one end of the wall, and presence of an opening in the wall. Testing results show that flexure-dominated ICEB walls can exhibit stable hysteretic behavior until a ductile failure occurs. Additionally, wall ductility increases with increasing height-to-width aspect ratio when other design parameters remain the same. Furthermore, strength of an ICEB wall can be enhanced due to the presence of the flange at one end but reduced due to the presence of an opening.

1. Introduction

Recent rapid population growth has created significant demands for housing globally, particularly, in developing countries. The high cost of materials and the need for experienced labor have prevented many people from buildings with appropriate and safe construction methods. Developing affordable, safe, and sustainable building systems has become an urgent task for civil engineers and researchers around the globe. As one of the oldest building materials, with documented use as far back as 2500 BC [1], earth construction has been used extensively around the world due to the sustainable and economical use of indigenous soils as well as the relatively sparse need of manufactured materials (such as cement). Interlocking Compressed Earth Blocks (ICEBs) discussed in this paper are a special form of dry stack earth construction units made with indigenous soil typically stabilized with cement. ICEB construction combines the benefits of compressed earth technology and dry stack interlocking masonry. A typical stabilized ICEB consists of less than 10% Portland cement by weight [2], which significantly reduces the amount of cement necessary to build a structure. Therefore, from an environmental perspective, ICEB constructions allow for a large reduction in embodied energy as compared to buildings with concrete or kiln fired clay masonry. Moreover, ICEBs can be manufactured by inexperienced laborers and construction of ICEB buildings requires no special skills, making ICEB construction a viable building option throughout the globe.

To date, extensive research and testing have been conducted for ICEBs aiming at understanding specific compressed earth material

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properties such as compressive strength, flexural strength, and bond characteristics based on soil and stabilization properties, optimum earth block mix with consideration of different soil types, cement content, water content, and durability and compaction of ICEBs [3–10]. While these efforts have improved the performance of ICEBs at the material level, there are remaining issues regarding the structural performance of ICEB structures, particularly performance of ICEB walls in the regions with moderate and high seismicity, limiting the wide spread acceptance of this system. This paper presents results from a testing program investigating the seismic performance of flexure-dominated ICEB walls. A total of four large-scale specimens (designated as W1, W2, W3, and W4, respectively) were constructed and tested. The specimen dimensions were varied to identify the effects of the following factors on the performance of ICEB walls: height-to-width aspect ratio, presence of a flange at one end of the wall, and presence of an opening in the wall. The following sections describe ICEB material properties, specimen design and construction, test setup, loading program, observations and results from testing. Concurrently, seismic performance of the shear-dominated ICEB walls and out-of-plane performance of ICEB walls were also investigated by the authors and the corresponding results are presented elsewhere [11–13].

2. Description of ICEBs and material properties

The ICEBs used in construction of the wall specimens in this investigation were manufactured using the Soeng Thai Model BP6 press developed by the Center for Vocational Building Technology (CVBT), a non-governmental organization in Thailand [14]. The Soeng Thai Model BP6 press is capable of producing different types of block by adding or removing various inserts. The standard masonry unit is a 100 × 150 × 300 mm (4″ × 6″ × 12″) block commonly called the "Rhino Block" as shown Fig. 1(a). The "Rhino Block" is composed of two reinforcement holes used for vertical grouted reinforcement, three "grout key channels" commonly filled with a fluid grout to provide wall stability and load transfer, and two interlocking dowels aligning adjacent blocks. Five variations of the standard full block shown in Fig. 1(b)–(f) were used in this investigation. A mixture identified to provide the best durability, desired constructability, and most stable compressive strength from past testing work [15] was used. It consisted of soil, sand, cement, and water in the following proportions by weight 74.3%, 10.0%, 6.2% and 9.5%, respectively.

As an important design parameter, the compressive strength of ICEBs, f'_{mo}, was determined from testing of masonry prisms. Each prism was constructed from three fully grouted, vertically stacked ICEBs which were built at the same time and cured under the similar conditions as the wall specimens. The grout consisted of sand, cement, and lime with volume percentages of 75%, 18% and 7%, respectively. Each prism was capped with a hydrostone capping compound to form a flat surface for uniform load distribution on the top of the prism. Passive confinement was applied on two opposite sides of each prism by two plywood boards tightened against each other. The prisms were loaded at a strain rate of 20 microstrains per second. The strain was measured in two ways: (1) with extensometers fastened to the outside of the prism to directly measure the strain in the masonry, and (2) with Linear Variable Differential Transformers (LVDTs) placed on both ends of the prism. Extensometers were used to measure the strain in the masonry until the prism began to crack and spall outwardly; the extensometers were then removed to prevent the instruments from damage. Following the removal of the extensometers the strain for the remainder of the test was measured by the two LVDTs. The test set-up of ICEB prism specimens is shown in Fig. 2.

Six ICEB prisms (two for each of Specimens W1 and W4, and one for each of Specimens W2 and W3) were tested. The prism compressive capacities of ICEBs from Specimens W1, W2, W3, and W4 were determined to be 3.04 MPa, 2.77 MPa, 3.16 MPa, and 2.25 MPa, respectively. A representative strain–stress curve from prism testing is provided in Fig. 3. When the strain reaches the level of about 0.012 mm/mm, the maximum compressive stress can be observed. Beyond the strain of 0.012, the stress begins to drop until the crushing failure. All prisms failed due to diagonal compression cracking followed by conical spalling on the unconfined sides and vertical crushing of the prism.

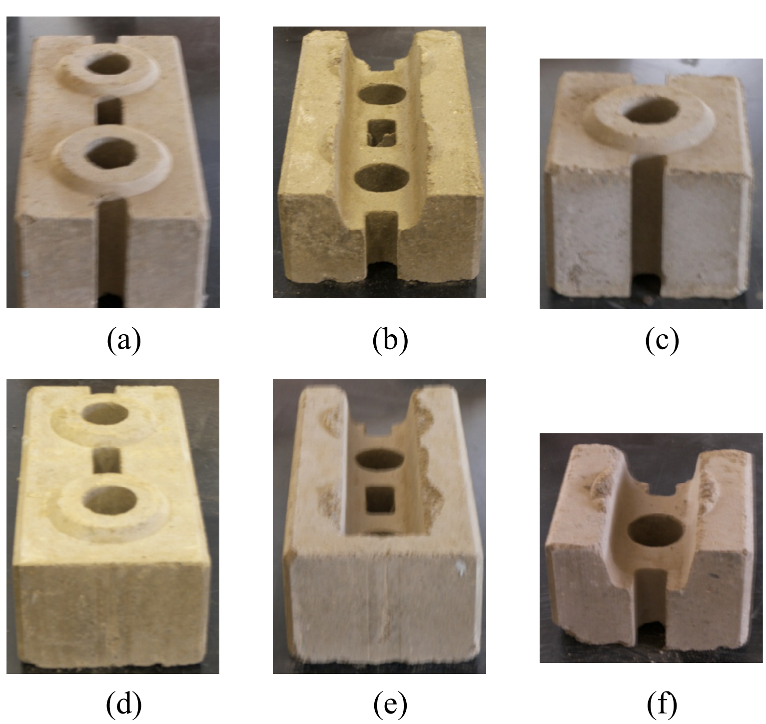

Fig. 1. Types of blocks used in wall construction (a) full block; (b) full channel block; (c) half block; (d) end block; (e) end channel block; and (f) half channel block.