Engineering Structures 123 (2016) 451–472

Contents lists available at ScienceDirect

Engineering Structures

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

Full-field measurement with a digital image correlation analysis of a shake table test on a timber-framed structure filled with stones and earth

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ARTICLE INFO

Article history:
Received 10 July 2015
Revised 19 February 2016
Accepted 7 June 2016
Available online 14 June 2016

Keywords:
Shake table
Digital image correlation
Seismic tests
Earthquake
Haiti
Traditional houses
Rural houses
Wood-frame structure
Stonework masonry
Earth mortar

ABSTRACT

This paper aims at presenting a digital correlation technique to capture the full-field displacement thanks to a high-speed camera of a full scale structure tested on a shaking table. The challenges are both the measurements at a full scale to visualize damages versus the resolution of pictures and the dynamical loading that requires a large number of pictures. The final goal is a better understanding of the seismic behavior of timber-framed structures with infill to help at modeling such structures and predicting their seismic vulnerability. For this purpose, results of shake table tests carried out on a full-scale one-story timber-framed house filled with stones bonded by an earth based mortar are presented and discussed. DIC full-field measurements allow deriving displacements and accelerations on shear walls as well as lateral forces applied on them. The experimental results presented herein allow analyzing the influence of bracing and might be used to propose optimized aseismic constructions based on cheap technological solutions. These results demonstrate the seismic-resistant behavior of timber-framed structures with infill and constitute a key issue for the promotion of such constructions in developing countries.

1. Introduction

From a worldwide perspective, the construction industry is arguably one of the most resource-intensive and environmentally damaging. This sector accounts for 40% of the total flow of raw materials into the global economy each year [11]. Given the coming shortage of raw materials (sand, cement, metals, [24,8]) coupled with the need to promote sustainable and virtuous development for the planet particularly within the building sector, bio-based and completely reversible materials must be developed. Timber-framed structures filled with earth and other locally available materials might constitute one response to the challenges associated with human settlement and construction sector challenges. Moreover, this type of structure is found throughout the world and heavily present in seismic prone areas [28] by offering the double advantage of meeting the population's local capacity constraints (economic and available materials) and featuring an intrinsically seismic-resistant behavior. These kinds of structures unfortunately have been overlooked by locals and decision-makers due to a lack of knowledge of their potential behavior and a lack of building codes and standards for their proper design.

In many countries across the world, reinforced concrete structures have nearly unanimously replaced the vernacular architectural style within a single generation. This rapid transition may be explained by the fact that reinforced concrete buildings are typically associated with modernity, whereas more traditional construction is perceived as suboptimal and old-fashioned [13]. However, following the latest earthquakes in many developing nations, a large number of poorly reinforced concrete buildings collapsed, leading to widespread destruction and loss of life, while well-maintained traditional vernacular neighboring structures survived in sustaining just slight damage [14]. Poor design,

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http://dx.doi.org/10.1016/j.engstruct.2016.06.009
0141-0296/

(a) Urban project in Port-au-Prince (Entrepreneurs du Monde)

(b) Rural project in Terre rouge, 10^{th} section of Petit-Goâve (Concert-Action and Misereor project, photo by Elsa Cauderay)

(c) School two-storey project in Grand Boulage, (Entrepreneurs du Monde)

Fig. 1. Buildings completed for reconstruction projects.

Fig. 2. The house on the shake table.

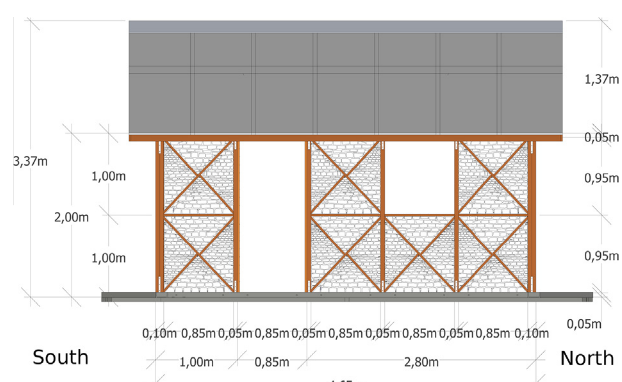

Fig. 3. Dimensions of the wall recorded by camera (East shear wall).

inadequate construction techniques and cost savings would be reasonable explanations behind many reinforced concrete failures [5].

For a safer and greener planet, infilling timber-framed structures with local materials, wherever relevant, should be promoted to move towards more sustainable development and to cease wasting the precious resources that led to the domination of reinforced concrete structures, even when conditions are not absolutely dire. Recently, a number of research projects have been conducted to further the state of knowledge on seismic-resistant behavior, in drawing comparisons with traditional timber-framed structures using infill (e.g. at the wall scale: [17,20,2,3,1,7,28]).

Table 1
Shake table characteristics.

Dimensions	6×6	m^2
Weight	6	tons
Payload	10	tons
Max. dis.	± 0.125	m
Max. vel.	0.75	m/s
Max. acc.	4	g
Frequency range	0–30	Hz
Overturning moment capacity	250	kN m