Engineering Structures 65 (2014) 76–88

Contents lists available at ScienceDirect

Engineering Structures

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

Influence of boundary conditions and size effect on the drift capacity of URM walls

Sarah Petry, Katrin Beyer *

[a] Earthquake Engineering and Structural Dynamics Laboratory (EESD), School of Architecture, Civil and Environmental Engineering (ENAC), École Polytechnique Fédérale de Lausanne (EPFL), EPFL ENAC IIC EESD, GC B2 515, Station 18, CH – 1015 Lausanne, Switzerland

ARTICLE INFO

Article history:
Received 21 August 2013
Revised 18 December 2013
Accepted 29 January 2014
Available online 3 March 2014

Keywords:
Unreinforced masonry
Drift capacity
Boundary conditions
Size effects
Quasi-static cyclic tests
Walls

ABSTRACT

In codes the drift capacity of unreinforced masonry (URM) walls is often estimated as a function of the failure mode and the aspect ratio. The empirical relationships are based on results from quasi-static cyclic tests on single URM walls, which were tested simulating either fixed-fixed or cantilever boundary conditions. In real structures, the stiffness and strength of slabs and spandrels define the boundary conditions of the walls and therefore the moment, shear force and axial force imposed on a wall during an earthquake. Depending on the exact configuration of wall, slab and spandrel, the boundary conditions can vary significantly.

In order to investigate the influence of these boundary conditions on the force-deformation behaviour of URM walls, six quasi-static cyclic tests were performed. Different boundary conditions were simulated by varying the axial load ratio and the ratio of top and bottom moment applied to the wall. This article presents the test results and discusses the influence of the boundary conditions on the failure mechanism and the drift capacity of the walls. In addition, the results from 64 quasi-static tests on URM walls of different heights and masonry types are evaluated. These tests confirm the influence of the boundary conditions on the drift capacity. Moreover, they show that a strong size effect is present which leads to smaller drift capacities with increasing wall height. For this reason, an empirical drift capacity equation is proposed which accounts for the moment profile, the axial load ratio and the size effect.

1. Introduction

In unreinforced masonry (URM) buildings, walls are connected by horizontal structural elements such as slabs and masonry spandrels. When walls are subjected to in-plane loading, these horizontal elements act as coupling elements between the walls and the system is often analysed using equivalent frame models [1]. The stiffness and strength of these coupling elements can vary significantly and three levels of coupling are distinguished in the literature, see Fig. 1, e.g. [2,3]: (i) weak coupling, where the horizontal elements impose only equal displacements on the walls of each storey but do not transfer significant shear forces or bending moments, (ii) strong coupling, where vertical and horizontal elements develop together a framing action and where the coupling elements remain largely elastic when the structure is subjected to horizontal loading, (iii) intermediate coupling, where the moments transferred by the coupling elements are limited but not negligible. The coupling elements influence the rotational restraint at the top of the wall and therefore, the moment profile. For outer walls, the coupling elements cause also a variation of axial force in the wall. For inner walls in symmetrical structures, the axial force variation due to the horizontal loading is small and can often be neglected.

In most codes, such as EC8-Part 3 [4], the drift capacity of URM walls is estimated as a function of the failure mode and the aspect ratio. These empirical relationships are based on results from quasi-static cyclic tests on URM walls, which were tested simulating either fixed-fixed or cantilever conditions. Hence, as only two types of boundary conditions were applied, a detailed investigation on the influence of the boundary conditions on displacement capacities of URM walls was not possible. To complement previous tests, this study comprises six wall tests with different boundary conditions typical for internal or external walls in URM buildings with RC slabs. The findings are compared to the results of a dataset comprising 64 wall tests and the relationship between axial stress, degree of coupling and displacement capacity is discussed. The dataset also shows that the displacement capacity of URM walls is affected by a strong size effect: tests on walls with smaller height lead to higher drift capacities than full storey height walls. New equations for drift capacity should therefore account for the

* Corresponding author. Tel.: +41 21 6936234; fax: +41 21 693 57 00.
E-mail addresses: sarah.petry@epfl.ch (S. Petry), katrin.beyer@epfl.ch (K. Beyer).

http://dx.doi.org/10.1016/j.engstruct.2014.01.048
0141-0296/

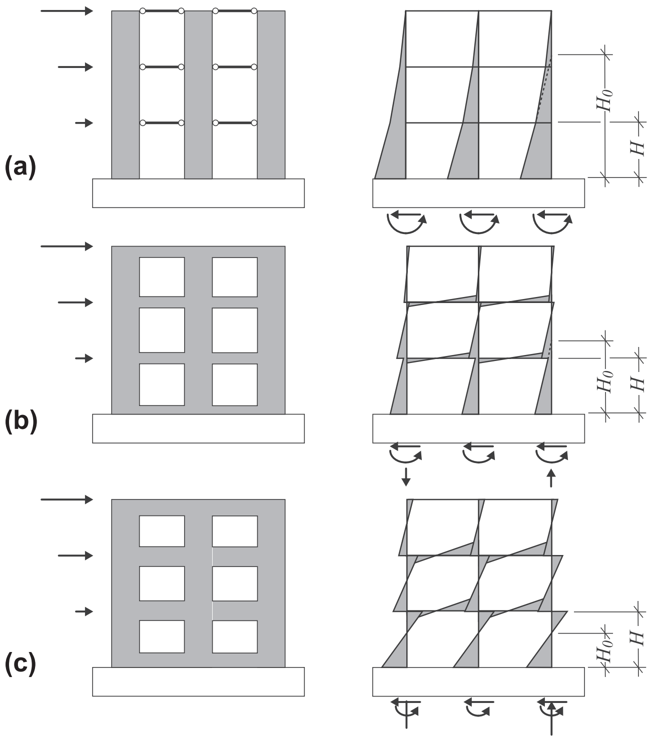

Fig. 1. Moment profiles of masonry wall structures with (a) weak coupling, (b) intermediate coupling and (c) strong coupling, taken from [3].

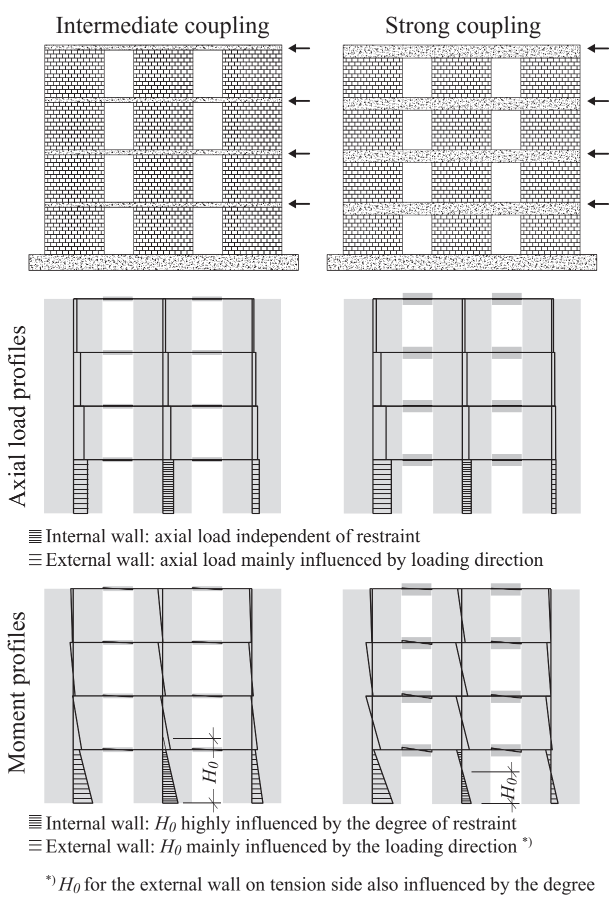

Fig. 2. Results from a pushover analyses on URM-wall structures with intermediate coupling (left) and strong coupling (right).

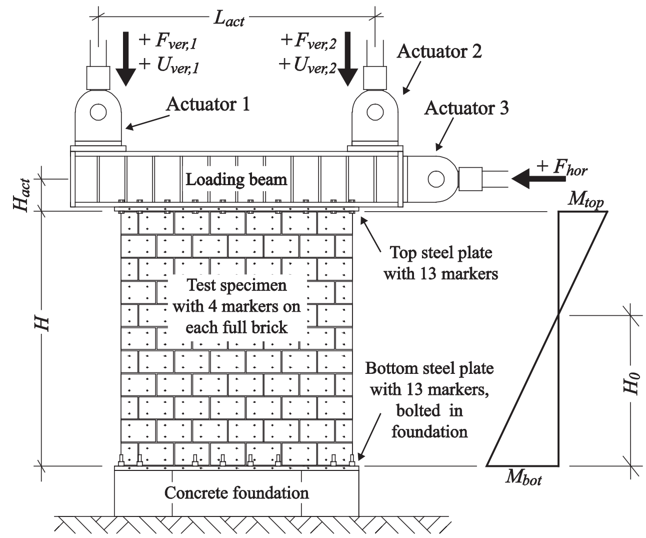

Fig. 3. Drawing of EPFL test stand.

Fig. 4. Photo of EPFL test stand.

boundary conditions (moment profile, axial load ratio) and the size effect.

2. Quasi-static cyclic tests on masonry walls

To investigate the effect of the boundary conditions (axial load ratio and moment profile) on the deformation capacity of URM walls, a series of six wall tests was designed. The boundary conditions to be applied in the tests were derived from pushover analyses of a 4-storey masonry wall with RC slabs using the macro-element program Tremuri [1,5]. The wall was analysed for