Chapter 2

Traditional Timber Frame Walls: Mechanical Behavior Analysis and Retrofitting

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ABSTRACT

Timber frame construction is a characteristic of several historic city centres as well as of vernacular architecture in several countries around the world, either motivated by the availability of materials and construction traditions or by the need of reducing the seismic vulnerability of buildings, namely in south European countries, where this construction technique was adopted for seismic-resistance purposes. From past earthquakes, it has been seen that timber frame construction can be viewed as an interesting technology as it has exhibited a very reasonable behaviour when compared to other traditional construction techniques such as masonry walls. This chapter provides an overview of the main insights on the seismic performance of timber frame buildings from the evidences of past earthquakes and provides the main results of recent research focused on the in-plane cyclic behavior of timber frame walls with distinct geometrical configurations. Additionally, the main seismic performance indexes of timber frame walls, both unreinforced and retrofitted, are presented and discussed in detail.

1. INTRODUCTION

Masonry and timber are materials used since ancient times in construction. Masonry buildings constitute an important percentage of the existing buildings and actions for their preservation should be taken since a large part of historical buildings are actually in masonry. A drawback on the use of unreinforced masonry is the low resistance to tensile stresses, leading often to an inadequate behaviour under seismic actions. A historical construction solution to improve the mechanical behaviour of ancient masonry adopted in different locations at different times, namely in seismic regions, has been the reinforcement
of masonry with timber (Touliatos, 2005; Vintzileou, 2008), namely at the level of the timber floors and at additional levels (e.g. door and window lintels) by adding a ring timber beam aiming at improving the confining effect of masonry walls and thus improving its out-of-plane behaviour, adding also a more global seismic resistance to the masonry building by promoting the known box behaviour. In these cases, timber acted as reinforcement, but the main load bearing system was still constituted by masonry.

An alternative use of timber with masonry is that of timber frame walls, where the timber frame becomes the main load bearing system, creating a two-dimensional plane frame, whereas masonry is only used as infill to add strength and stiffness to the timber skeleton. The particular case of traditional timber frame walls constitute an example of an important structural element of many buildings and are usually composed of vertical posts and horizontal beams with bracing diagonal elements. In Portugal, timber frame walls, known as frontal walls, are usually part of Pombalino buildings, which were introduced by the Marquis of Pombal, who was responsible for the reconstruction of Downtown Lisbon after the great earthquake of 1755, which partially destroyed the city. Timber frame walls create an internal timber skeleton to the building and they are connected to the external masonry walls by means of the timber floor beams, which are connected both to the timber frame walls and to the external masonry walls (Mascarenhas, 2004) and can be beneficial to reduce the out-of-plane vulnerability of the masonry walls. Timber frame walls are also identified in several countries particularly in local vernacular architecture, due to the low cost of such structures composed of timber and several infill materials from brick and stone masonry to mud and cane.

Given the increasing interest of the research community to this structural system, it is important to promote the discussion of the main findings that can contribute to the advance on the knowledge of the mechanical behaviour of timber frame buildings to seismic actions.

Therefore, this chapter intends: (1) to give an overview of the different solutions of timber frame structures in different countries with special focus on the frontal walls characteristic of Pombalino buildings; (2) to describe some examples of the seismic behaviour of timber frame buildings in past earthquakes; (3) to summarize the experimental research carried out in recent years on the analysis of the behaviour to in-plane cyclic loading; (4) to give an overview on the possibilities of retrofitting timber frame walls and summarize some seismic indicator to assess their performance.

2. A BRIEF OVERVIEW

2.1 Traditional Timber Frame Construction

The origin of timber frame structures probably goes back to the Roman Empire, as in archaeological sites half-timbered houses were found and were referred to as Opus Craticium by Vitruvius (Lagenbach, 2009). But timber was used in masonry walls even in previous cultures. According to Tsakanika-Theohari (2008) in Minoan palatial architecture, a sophisticated mixed timber framed and masonry wall system was developed. In historical periods, half-timbered constructions spread not only throughout Europe, such as Portugal (edifícios pombalinos), Italy (casa baraccata), Germany (fachwerk), Greece, France (colombages or pan de bois), Scandinavia, United Kingdom (half-timber), Spain (entramados) etc., but also in India (dhaji-dewari) and Turkey (himis) (Lagenbach, 2009; Tampone, 1996). In each country, different typologies were used, but the common idea is that the timber frame can resist to tension, contrary to masonry, which resists to compression, thus providing a better resistance to horizontal loads.