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Numerical analysis of sheathing boards influence on racking resistance of timber-frame walls

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ABSTRACT

This paper provides a numerical analysis of sheathing boards influence on racking resistance of timber-frame walls coated with single sheathing boards fastened to a timber frame. Worldwide, the walls are usually broadly used as main bearing capacity vertical elements in prefabricated residential timber buildings. Designers or producers usually face the important dilemma of using the best sheathing board with regard to the height and location of a building. The presented research thus aims at comparing the results obtained through calculations made on test samples covered with either fibre-plaster or wood-based sheathing boards. Therefore, the presented conclusions, supported by the measured results, propose some important indications in behaviour of the timber-framed wall elements under a horizontal load covered with different sheathing boards and present some useful recommendations in designing of tall timber-framed buildings located on heavy windy or seismic area.

1. Introduction

Timber is commonly associated with lightweight construction although it is ubiquitous as a building material. Timber construction is an important part of the infrastructure in a number of areas around the world. Well-built timber structures usually maintain good performance under the influence of wind and especially earthquake forces. Nowadays, there are the strongest arguments for building timber frame buildings. Brand new and improved features, being introduced in the early 80s in the last century, brought about the expansion of timber frame buildings all over the world. Nevertheless, competitive fields of construction are aware of the fact that a modern timber-frame house is extremely highly valued and capable of satisfying the requirements of our society and the environment. There are many arguments for timber-frame residential buildings, the most important are: very good building physical properties, built-in materials showing environmental excellence, lower energy consumption while preparing built-in materials, the speed of construction and good seismic security.

Very good building physical properties are the most important. Not only because in the well isolated object energy for heating is saved, which is environmentally friendly, but also homeowners have extremely positive feeling about the living in such houses. Actually, the wood or gypsum treatment as the most used materials in such homes uses less energy than bricks or concrete or some other prefabricated products. Another advantage of timber-frame houses is the speed of their construction which results from a significant proportion of prefabricated elements. This means that in the building stage just minimum of time is spent on inconvenient weather conditions. Given these facts, it is clear, that a strong expansion of timber frame construction appears worldwide, Premrov and Kuhta [1].

There are three main construction systems of prefabricated residential timber buildings: (a) massive panel system with cross-laminated panel walls, (b) balloon system and (c) timber-framed system. In our paper attention will be limited to the timber-frame system, where the basic vertical load bearing elements are panel walls consisted of load bearing timber frames and sheathing boards. As shown in the photograph in Fig. 1a, an insulation material is usually inserted between timber studs and girders to assure energy efficiency of a wall element. The wall elements, containing openings for doors and windows, as shown in Fig. 1b, are completely produced in a factory and then transported to the building site. The construction performs systematic floor-by-floor building; after the walls are constructed the floor platform for the next level is built. Consequently, this system is very useful for multi-storey buildings; therefore the interest in the world is growing, Deplazes [2], Deplazes and Fischer [3].

2. Timber-frame walls

2.1. Composition of the wall elements

Prefabricated timber walls as main vertical bearing capacity elements of usually typical dimensions with a width of $b = 1250$ mm

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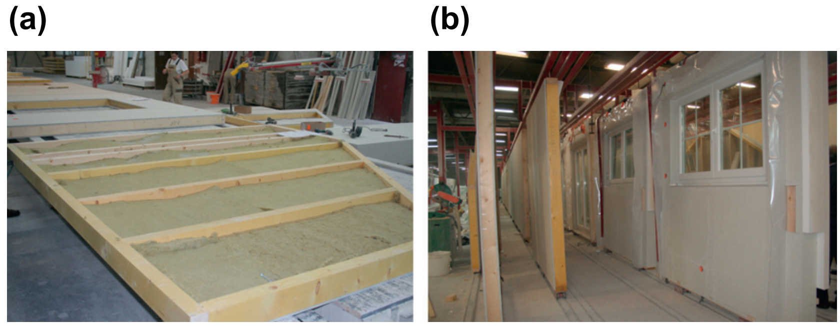

Fig. 1. (a) An insulation material is placed between timber frame elements. (b) Wall elements with openings are completely produced in a factory.

and a height of h = 2500–2600 mm are composed of a timber frame and sheets of board-material fixed by mechanical fasteners to the both sides of the timber frame, schematically presented in Fig. 2a. This is actually an old building system (sc. single-panel system) while in current production wall element units are usually connected together in a maximal length up to 12 m (sc. macro-panel system), as shown in Fig. 2b.

There are many types of panel sheet products available which may have some structural capacity such as wood-based materials (plywood, oriented strand board, hardboard, particleboard, etc.) or plaster and fibre-plaster boards (FPB), originally started in Germany and recently the most frequently used in Central Europe. Between the timber studs and girders a thermal insulation material is inserted.

In the following analysis we will focus our attention on comparison in behaviour of the treated wall elements covered with wood-based (WBB) or fibre-plaster (FPB) sheathing boards. The compared numerical results, supported by values measured on a set of test samples from our previous research, see Premrov and Kuhta [1], could be beneficial to designers. Indications showing behaviour of the wall elements covered with different types of sheathing boards, according to the known horizontal load acting on the building, might serve as useful assets in designing and planning.

2.2. Oriented strand boards (OSB)

Oriented strand boards (OSB) have been in the market for over 30 years. The European standard EN 300:2006 [4] classifies them within the group consisting of particle boards. Oriented strand boards have been originally developed with intention to replace the lower grades of plywood on the market. Their main characteristics are a large size of the particles they are composed of, along with the intentional orientation of the fibres that give the boards high mechanical performance in their longitudinal axis, which surpasses that in the traverse direction to a considerable extent, see Rebollar et al. [5]. From a structural point of view it is important to underline that the tensile strength of OSB is essentially higher than that of FPB. Therefore, according to the given statements for FPB in Section 2.3, we can predict that the OSB are, in a contrast with FPB, usually not a weaker part of the presented composite timber-framed walls.

2.3. Fibre-plaster sheathing boards (FPB)

One of the most important reasons for an increased application of types of gypsum products, like FPB, is their relatively good fire protection. For example, single gypsum sheathing board of 15 mm thickness assures 30 min of fire protection. Additionally, gypsum is a healthy natural material and is consequently particularly desired for residential buildings. On the other hand, from a

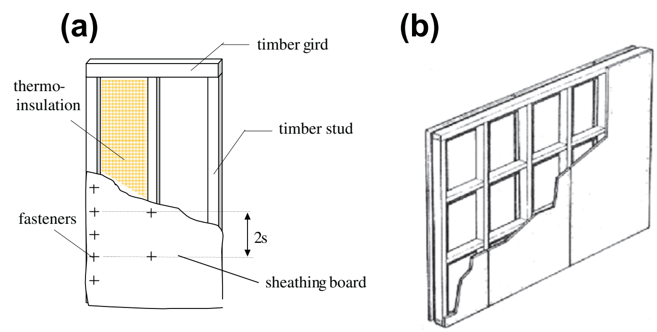

Fig. 2. Composition of the wall element. (a) Single-panel system. (b) Macro-panel system.

structural point of view, the tensile strength of fibre-plaster boards (FPB) is very low, approximately 10-times lower than the compressive one, and can not be compared with the overall strength of the timber frame at all. Consequently, the FPB are usually a weaker part of the presented composite system. Thus, especially in multi-level buildings located in seismic or windy areas, cracks in FPB usually appear, which is already experimentally investigated in Dobrila and Premrov [6], Premrov et al. [7,1]. In these cases the FPB lose their stiffness and therefore their contribution to the total horizontal stiffness of the whole wall assembly should not be considered at all. Stresses in the timber frame under horizontal loads are usually not critical. In such cases it is necessary to strength the wall elements to assure the horizontal stability of the structure. There are several possibilities of reinforcing arrangements:

- by using additional boards; the boards are usually doubled symmetrically (on both sides of a timber frame) or non-symmetrically (on one side of a timber frame),
- by reinforcing boards with steel diagonals,
- by reinforcing boards with carbon or high-strength synthetic fibres like Fibre Reinforced Polymers (FRP) or Carbon Fibre Reinforced Polymers (CFRP).

In [6] experimental results using *additional FPB* are presented. The test samples demonstrated higher elasticity, whilst bearing capacity and especially ductility were not improved in the desired range.

With the intention to improve the resistance and especially the ductility of the walls it is therefore more convenient to insert *classical diagonal steel strips*, which have to be fixed to the timber frame. In this case only, a part of the horizontal force is shifted from boards over the tensile steel diagonal to the timber frame after the appearance of the first crack in the tensile zone of FPB.

The strengthening concept using *CFRP diagonal strips* is such that the composites would contribute to tensile capacity when