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Experimental investigation on stapled and nailed connections in light timber frame walls

Y. Verdret [a,b,*], C. Faye [b], S.M. Elachachi [a], L. Le Magorou [b], P. Garcia [b]

[a] University of Bordeaux, I2M, Department GCE, Bat. B18, Avenue des facultés, 33405 Talence, France
[b] Technological Institute for Forestry, Cellulose, Timber Construction and Furniture (FCBA), Allée Boutaut, BP227, 33028 Bordeaux cedex, France

HIGHLIGHTS

- Experimental results for monotonic and cyclic tests on stapled and threaded nailed connections.
- Stapled connections oriented at 90° and nailed connections behaviors are similar.
- The component strength is impacted by the orientation of the staples.
- The increase of strain rates leads to a decrease of the connections' ductilities in cyclic tests.

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ABSTRACT

Regarding shear wall, the use of staples to connect sheathing panels to wooden studs and horizontal members is increasing because of a faster manufacturing process. In order to enhance the knowledge of the behavior of such connection, this paper presents experimental results for monotonic and cyclic tests (for two levels of strain rate) on stapled and threaded nailed connections. Concerning monotonic tests, stapled connections behavior oriented at 90° and nailed ones is similar; also the component strength is impacted by the orientation of the staples. Concerning cyclic tests, in addition to observations on the monotonic tests, the increase of strain rates leads to an effective decrease of the connections' ductilities.

1. Introduction

For a long time, many kinds of wooden house are existing. Among them, timber light framed construction stay the most common built across the world [1]. In this case, the main lateral load-carrying or bracing members are shear walls. These elements consist of a frame made by assembling timber studs sheathed with different types of panels' material like plywood, particleboard or OSB (Oriented Strand Board). Nowadays, OSB sheathing represent up to 80% of light frame shear walls of the French market [2]. The connection between sheathing panels and frame by means of nails or staples gives a stiff and strong wall assembly allowing the transfer of lateral loads, induced by wind or earthquake, to the foundation, [3]. These timber structures have potentially interesting seismic behavior due to [4]:

- On one hand, the high strength to weight ratio of the wood material;
- on the other hand, the presence of bracing systems with metallic connections involving ductility of the structure.

The majority of testing on wood shear walls has been performed on nailed sheathing-to-framing connections [1]. Over the years, many works concerning nailed shear walls have been presented in the literature in order to study their allowable strength and ultimate capacity ([4–6]), the influence of openings [7] or vertical loads [8]. Concerning nailed shear walls, a comprehensive overview is presented by Källsner and Girhammar [5] and van de Lindt [4].

However, the use of staples to connect sheathing panels of light frame timber wall is increasing because of a faster manufacturing process. Until now and to the knowledge of the authors few works have been undertaken on this type of connection.

Pardoen et al. [9] carried out an extensive experimental program concerning light frame shear walls including one-story and

* Corresponding author at: University of Bordeaux, I2M, Department GCE, Bat. B18, Avenue des facultés, 33405 Talence, France.

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two-story configurations. OSB sheathing connected by nails or staples was used for most shear walls. It was found that for the fully-sheathed one-story configuration, the peak loads obtained for the nailed- and stapled- connections were comparable, whereas the post-peak loads for the nailed shear-walls were 30% higher than those fastened with staples.

Crilly [10] performed dynamic tests on shear walls with OSB sheathing panels fixed using staples. A series of eleven $1220 \times 2440\ mm^2$ shear wall panels were built according to the 1997 UBC Code and tested under static and cyclic loads to determine their load capacity, stiffness, and ductility. The lateral load capacity of stapled panels with hold-down modifications was 40% greater than the allowable load specified in the National Evaluation Report 272.

In Sartori and Tomasi's paper [3] monotonic and cyclic destructive tests on connections between sheathing panel and wood studs are presented for different types of sheathing materials (OSB with various thickness (12 and 15 mm) and gypsum-fiber panels) and connectors (ring and smooth nails/staples). Ten combinations of sheathing materials and connectors were tested. A comparison between different international standards and with the results of the CUREE-Caltech Woodframe Project [11] was carried out. They showed that the ductility and the energy dissipation of the connections done with nails and OSB panels are higher than those realized with staples and gypsum fiber panels. The comparison between test results and Standards (Eurocode 5 [12], Italian national code CNR-DT 206/2007 and German national code DIN 1052:2008) shows a good agreement in terms of strength concerning nails and OSB panel. Less precise is the formula adopted to predict the strength of the connections with staples.

The aim of this paper is to characterize and to compare the experimental behavior of stapled and nailed sheathing-to-framing connections, in terms of strength, stiffness and ductility, seeking to address two issues: staples orientation and strain rates effects. For this purpose, monotonic and cyclic tests, for two levels of strain rates, were carried out at a component level representative of the junction between 12 mm thick Oriented Strand Board (OSB/3 [13]) panel and C24 studs. The influence of the orientation between the staple head and the grain direction of studs, on the performance of the connection, has been analyzed. Two staples orientations are considered: 90° and 0° relative to the grain direction of studs. Finally, experimental results are compared with standard Eurocode 5 design values [12].

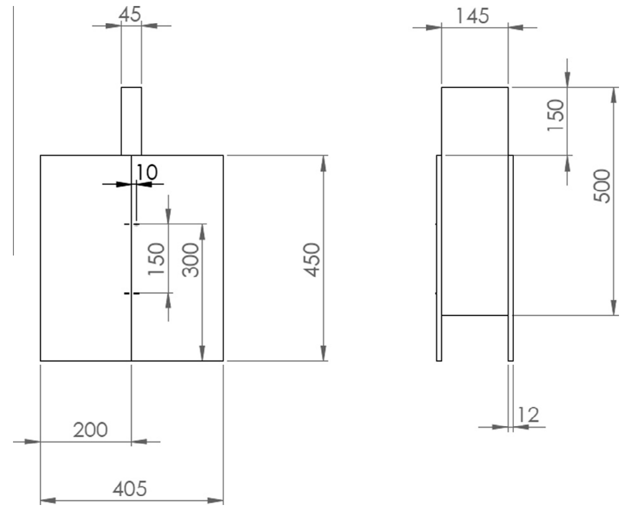

Fig. 1. Specimens' geometry.

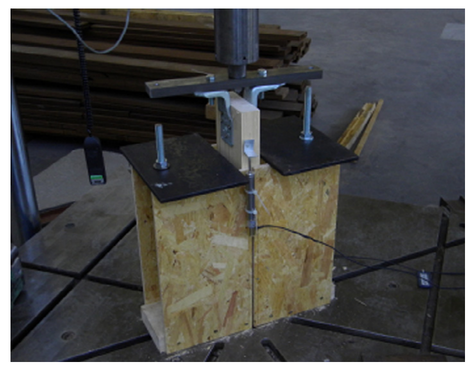

Fig. 2. Test setup.

2. Experimental system and configurations tested

In order to compare stapled and nailed connections behaviors, staple's dimensions were determined so that its performance is similar to 2.5×50 mm annularly threaded nailed connections in terms of static strength according to Eurocode 5 design (§8.3.1.3). Moreover staples dimensions should also be in accordance with standard EN 14592 [14]:

- staple head should have a minimum length of $6 \times d$ where d is the equivalent diameter calculated according to Eurocode 5 [12], §8.4-(2);
- each staple should have a cross sectional area of between $1.7\ mm^2$ and $3.2\ mm^2$;
- length of the staple should be less or equal $65 \times d$.

On the basis of these criteria, the characteristics of the rectangular staples used were: 50 mm long, 11.2 mm crown and has a cross sectional area of $(1.34 \times 1.6)\ mm^2$.

Specimens' geometry and tests setup are shown in Figs. 1 and 2, the loading direction being vertical. Fig. 3 shows detail of implementation of the staples in an actual configuration of a light frame wall, staples' orientations are given relatively to the grain direction of studs. Specimens reproduce the junction between four sheathing panels and a stud (C24) with a cross section of $45 \times 145\ mm^2$. The distance between the edges of OSB/3 sheathing panels and fasteners (nails and center to the staple) is 10 mm in accordance with French standard for execution of light frame timber buildings, DTU 31.2 [15]. This distance does not respect the rules of the Eurocode 5 [12] (§8.4) which is considered too severe. The vertical distance between two fasteners on one sheathing panels is 150 mm and 5 mm is left between the two OSB/3 sheathing panels.

Before tests, each sample was kept in a controlled atmosphere with moisture content about 65%. At equilibrium, specimens contain about 12% of moisture. The average measured densities of 12 mm thick OSB/3 and C24 stud were respectively $690\ kg\ m^{-3}$ and $461\ kg\ m^{-3}$ associated respectively to a coefficient of variation of 4.33% and 11%. In Section 4.2, to compare experimental and standard values of strength, an adjustment factor will be used to consider a reduced density of the experimental strength data.

During the tests, the vertical load (tension/compression) was applied to the central stud fixed to the hydraulic actuator by means of eight screws $3.2 \times 50\ mm^2$. In order to keep constant the spacing between board of sheathing panels, their bottom were screwed to a sill beam rigidly connected to the steel reaction frame. On the upper part, sheathing panels were restrained to the steel reaction frame by metal plates and tie rods. The tests setup is illustrated in Fig. 2. The applied force was measured by a load cell placed between the actuator and the specimen. The actuator was controlled by the stud to panels displacement which was measured using two L.V.D.T. (Linear Variable Differential Transformer) transducers placed on both sides of the specimens.

Monotonic tests were performed according to EN 26891 [16] which is devoted to connections made with mechanical fasteners. The load is applied according to the loading path shown in Fig. 4. The procedure is based on an estimated maximum load, F_{est}. For each configuration, a preliminary monotonic test was performed to evaluate F_{est}. It was equal to 10 kN for each configuration. During monotonic tests, a constant load rate corresponding to $0.2F_{est} \pm 25\%$ has to be applied below $0.7F_{est}$. Above $0.7F_{est}$ the slip rate has to be adjusted in such manner as the ultimate load is reached with an additional test time from 3 to 5 min. The total test time is about 10–15 min.

Cyclic tests were performed according to the standard ISO 21581 [17] which proposes the same experimental protocol as ASTM 2126 B [18] or ISO 16670 method tests [19]. ISO 21581 standard has been chosen rather than EN 12512 [20] because: