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EXPERIMENTAL ANALYSIS OF GYPSUM PANEL-TO-CFS PROFILE SCREW CONNECTIONS

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Abstract

This study presents an experimental investigation on the shear behaviour of screw connections between cold-formed steel (CFS) profiles and gypsum panels, which includes both monotonic and cyclic shear tests. The attention is focused on the most common scenario, where screws are inserted perpendicular to the steel-gypsum interface. Initially, tests on materials were conducted, including tensile tests on the steel from CFS profiles, tensile tests on screws, and bending tests on screws, together with interaction tests, i.e. gypsum panel embedment tests and screw head pull-through tests. These kinds of tests were carried out in order to properly characterize the behaviour of the individual components which affect the overall behaviour of the screw connections between CFS profiles and gypsum panels.

Keywords: Cyclic Tests, Drywall Partitions, Cold-Formed Steel, Gypsum Panels, Screw Connections, Shear behaviour.

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1 INTRODUCTION

The literature contains many studies that highlight the effectiveness of steel structures under cyclic loading conditions [1-13]. However, non-structural architectural steel components often suffer significant seismic damage. As a result, there is a growing demand for non-structural architectural components that are specifically qualified against seismic actions.

The main objective is to reduce the risk of loss of life related to the collapse of non-structural elements or part of them. In addition, the economic implications can be very important, as non-structural components account for a high percentage of the total cost invested in the construction of a building. The study by Whittaker and Soong (2003) [14] shows that the costs associated with finishes and fixtures on non-structural components after an earthquake, are significantly higher than those associated with the structural part. In this context, the evaluation of the seismic performance of drywall partitions, one of the most important non-structural elements in a building, can play a key role.

This study presents an experimental investigation on the shear behaviour of screw connections between gypsum panels and cold-formed steel (CFS) profiles, which significantly affect the in-plane behaviour of the drywall partition. Both monotonic and cyclic tests will be carried out.

Component-level tests will be also carried out in order to derive all the fundamental variables that affect the shear response of the connection. The importance of carrying out these tests lies in the possibility of either formulating an analytical method to derive the shear response of CFS-to-gypsum connections or validating existing analytical methods derived to evaluate the shear response of connections, such as the one developed by Vella et al (2021) [15] for CFS-to-timber connections.

2 SHEAR BEHAVIOUR OF THE CONNECTION BETWEEN GYPSUM PANEL AND STEEL PROFILE

Drywall partitions are made of CFS stud and track profiles (CFS frame) usually sheathed with a gypsum panel on both sides. Studs generally have a C-section, with a spacing ranging from 300 mm to 600 mm, connected at the ends to the tracks, which generally have a U-section. Gypsum panels generally used for drywall partitions are 12.5 mm thick and are attached to the steel skeleton through self-piercing screws with diameters up to 3.5 mm. Figure 1 shows a typical drywall partition configuration.

This type of non-structural element must be ductile enough to accommodate lateral displacements of the surrounding structure. The current version of the second-generation Eurocode 8 [16] provides the following limitations regarding storey drifts: 0.35% for buildings having ancillary elements of brittle materials attached to the structure; 1.00% for buildings having ductile ancillary elements attached to the structure or fixed in a way so as not to interfere with structural deformations, or without non-structural elements. In this context, drywall partitions can be assumed as ductile elements [17].

In this perspective, seismic behaviour of drywall partitions must depend mainly on the shear behaviour of the connections between gypsum panels and CFS profiles, which ensure the most ductile mechanism in a drywall partition subjected to an in-plane lateral action. To make this happen, the other components that are part of the drywall partition must be oversized.

According to the current version of the second-generation Eurocode 8 [16], also shear walls with gypsum panels (i.e., structural elements) must be designed ensuring that the collapse mechanism is governed by the shear resistance of the connections between gypsum panel and CFS profiles (i.e., dissipative component). To allow this mechanism to be activated, the other components of the wall (i.e., non-dissipative components) must be oversized, following the capacity design criteria. In the case of shear walls with gypsum panels, the standard specifies that this resistance should be evaluated experimentally. While for connections between wood panels and steel plates the current version of the second generation of Eurocode 5 [18] provides formulas for calculating shear resistance, for connections between gypsum panels and steel plates the European standards do not provide any analytical method for calculating shear resistance. However, the formulas provided by the current version of the second generation of Eurocode 5 [18] for connections between wood panels and steel plates, specifically connections used in shear walls with wood panels (i.e., connection between OSB or plywood panels and thin steel plates), have been found to excessively underestimate the shear resistance of the connection [19].

When a connection between CFS profiles and gypsum panels is subjected to a shear action, the collapse can usually involve the screw, the panel and the steel plate with different types of phenomena, such as: tilting of the screw; bending of the screw; screw head pull-through; screw pull-out; edge rupture of the panel; and embedment of the steel plate. In order to take into account, within a possible analytical method, all the possible phenomena that can occur when a connection is subjected to shear, it is necessary to carry out tests at the component level, as well as shear tests on the connection.

Recently, a theoretical model has been proposed by Vella et al (2021) [15] to predict the load-slip behaviour of CFS-to-timber connections, which assumes three components: timber embedment, screw bending, and axial pull-through. The model is very general and allows development of load-slip response curves also for CFS-gypsum connections with winged and/or inclined screws. Figure 2 from Vella et al (2021) [15] illustrates the load-slip response curve for a not-inclined winged screw specimen. Figure 2 also shows the corresponding experimental load-slip response curve. This experimental response curve is taken from Vella et al (2020) [20]. This work presents an experimental campaign, which also includes component-level tests in order to derive the basic parameters needed to calibrate the analytical model presented in Vella et al (2021) [15].

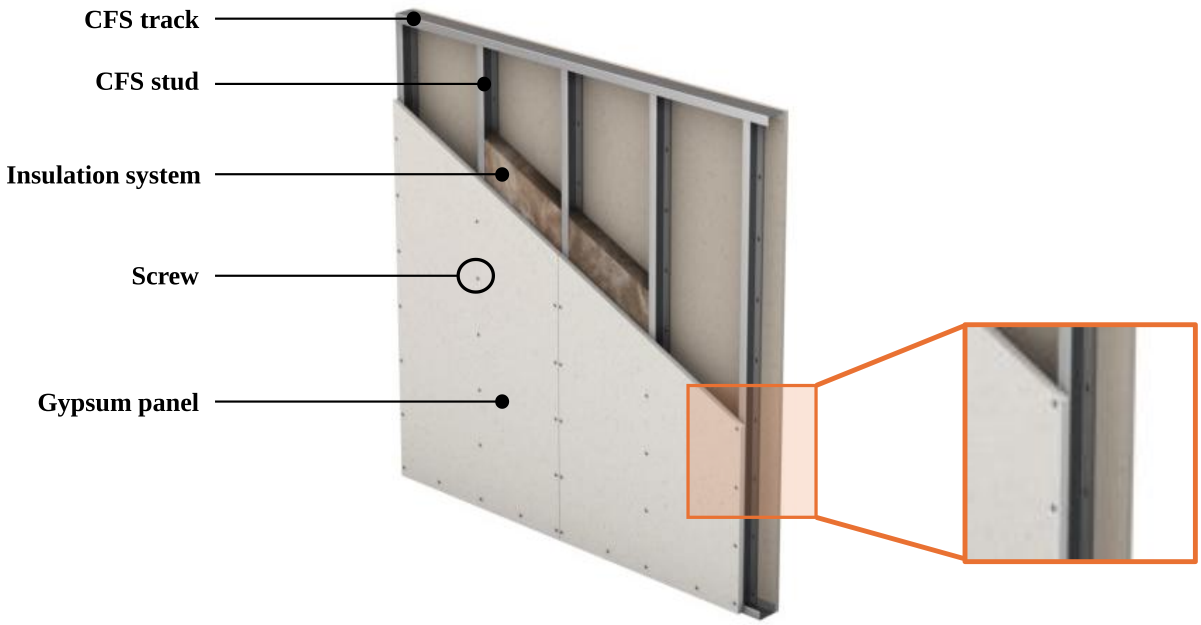

Figure 1: Typical drywall partition configuration.

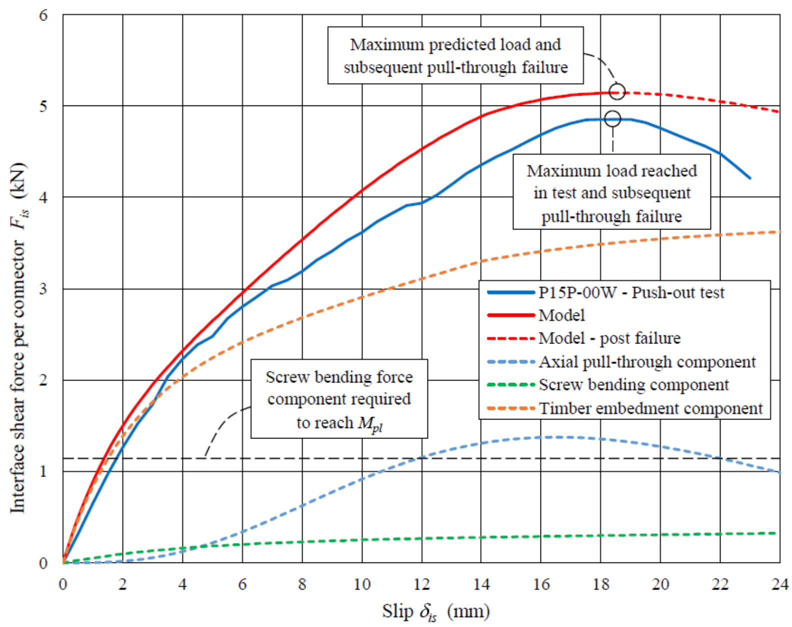

Figure 2: Load-slip curve for a not inclined winged screw specimen showing typical screw rotation failure [15].

3 EXPERIMENTAL PROGRAM

The experimental program involves performing shear tests on connections between gypsum panels and CFS profiles, in order to experimentally characterize the connections within typical drywall partitions. Component-level tests are also scheduled, with the aim of deriving the basic parameters on which the shear behaviour of the connections between gypsum panels and CFS profiles should depend.

3.1 Shear tests and specimens description

The connection between sheathing panels and the steel studs plays a paramount role in the overall response of a drywall partition. In particular, the shear response of gypsum-to-CFS connection influences the in-plane behaviour of the drywall partition. Monotonic and cyclic shear tests will be carried out to investigate the behaviour of the connections.

A series of 12 shear tests in total (6 monotonic tests and 6 cyclic tests) will be performed on 12 nominally identical specimens. The tests will be carried out in accordance with EN 520:2009 [21] standard (which refers to connections between wooden elements and gypsum panels), adapting it to the case covered by this work.

Figure 3 shows the assembly of the connection specimens. In particular, the specimen representative of the gypsum-to-CFS connections consists of one 12.5 mm thick gypsum-based sheathing panels screwed to the opposite flanges of two CFS profiles. The adopted fasteners are self-tapping screws with a diameter equal to 3.5 mm. The profiles, representative of the partition stud sections, are 75x50x6x0.6 mm (web depth x flange size x lip size x thickness) lipped channel stud sections. The profiles are placed at a distance of 160 mm from each other. The length of the profile installed on the top of the specimen is 340 mm, while the length of the profile installed on the bottom of the specimen is 280 mm. The upper side of the panels is fixed to the flange of the profile with three screws (connections to test) at a distance of 50 mm from the edge parallel to the direction of loading, while the lower side is fixed to the flange of the profile with six screws (overstrength connections) distributed on two rows at a distance of 30 mm from the edge parallel to the direction of loading, 40 mm in the direction parallel to the direction of loading, and 15 mm in the direction perpendicular to the direction of loading. The length of the specimen is 980 mm.

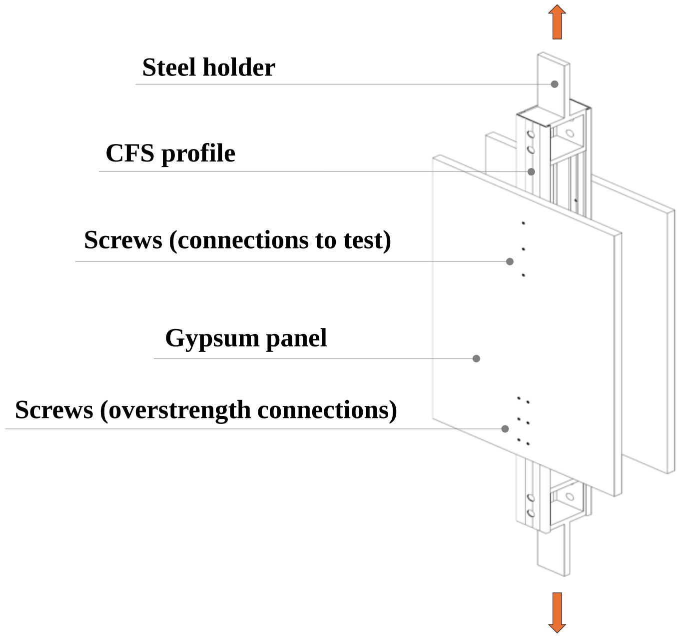

Figure 3: Assembly of the connection specimen.

3.2 Component-level tests and parameters under investigation

To derive an analytical method for evaluating the shear behaviour between gypsum panels and CFS profiles, component-level tests will be carried out in order to derive the parameters that should affect the shear behaviour of these connections. Such tests include tests on material (tensile tests on CFS material, screw tensile tests, and screw bending tests) and interaction tests (gypsum embedment tests and screw head pull-through tests). Table 1 shows the number of nominally identical tests for each type of test and the respective reference standards that will be applied. Instead, Table 2 shows the basic parameters for evaluating the connection shear behaviour according to the methodology provided by Vella et al (2021) [15] for connections between wood panels and CFS profiles.

Test typology	**Number of nominally identical tests**	**Reference standard**
Tensile test on CFS material	3	ISO 6892-1:2019 [22]
Screw tensile test	4	ISO 898-1:2013 [23]
Screw bending test	6	ASTM F1575/F1575M-21 [24]
Gypsum embedment test	3	EN 383:2007 [25] (1)
Screw head pull-through test	3	EN 1383:2016 [26] (1)

(1) Standard for wood panels.

Table 1: Component-level tests.

Test typology	**Corresponding experimental curve**	**Parameters**
Tensile test on CFS material	Strain-Stress	Yielding strength
Screw tensile test	Strain-Stress	Yielding strength Yielding strain Hardening modulus Extreme fiber strain
Screw bending test	Load-Displacement (1)	Ultimate moment
Gypsum embedment test	Stress-Embedment	Embedment strength Embedment stiffness
Screw head pull-through test	Load-Displacement	Pull-through strength Pull-through stiffness

(1) Load and displacement at the screw midpoint.

Table 2: Basic parameters under investigation.

4 CONCLUSIONS

The study carried out showed that:

- The seismic behaviour of drywall partitions depends on the shear behaviour of the connections between panels and CFS profiles, which can be evaluated experimentally;
- There is a need to derive an analytical method for calculating the shear resistance of gypsum-steel connections, which is not provided by European standards;
- In addition to shear tests on connections, it is also necessary to carry out component-level tests in order to derive the required parameters for the validation of an analytical method.

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