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Experimental investigation of laterally loaded double-shear-nail connections used in midply wood shear walls

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HIGHLIGHTS

- Laterally loaded double-shear-nail (DSN) connections with different variables.
- The failure modes are affected by the sheathing thickness and the nail edge-distance.
- Influence of different variables on the load-displacement behavior of DSN connections.
- The analytical model can be used to describe the response of DSN connections.
- The results can be used to develop baseline data for DSN connection model.

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ABSTRACT

Midply wood shear wall is regarded as a preferable lateral resistance system for timber frame structures. One of the most important reasons is attributed to the good lateral performance of double-shear-nail (DSN) connections. In this study, eight groups of specimens were tested under monotonic lateral loads to investigate the influence of different variables on the lateral performance of the DSN connections. Representative variables derived from practical midply wood shear walls were considered, including sheathing thickness, nail edge-distance and loading direction to the grain of framing. Test results indicate that the failure modes of the DSN connections depend on sheathing thickness and nail edge-distance. The increase of nail edge-distance and sheathing thickness can significantly improve the ultimate strength and the ductility, while it had little influence on the initial stiffness. Moreover, loading direction to the grain of spruce–pine–fir (SPF) framing had significant influences on the ultimate strength and initial stiffness of DSN connections. Finally, the testing data was idealized to translate the load–displacement behavior of the DSN connections through a typical exponential function model. This study can be used to develop baseline data for the finite-element DSN connection model to predict the performance of midply wood shear walls.

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1. Introduction

Platform type timber frame structure is a kind of comfortable, economical and environmental friendly constructions, which is commonly used in residential houses and multi-storey buildings in North America and Europe. For this construction, timber shear walls, working as vertical components, play an important role in resisting lateral loads, e.g. earthquake loads and wind loads. A few years ago, FPInnovations [1] proposed an advanced shear wall concept named midply wood shear wall system, which was regarded as a preferable structural system that can provide superior lateral resistance. In this system, the sheathing is placed in the center of the wall and sandwiched by a serious of studs and plates on both sides of the wall sheathing. The studs and plates are placed at a 90° rotated position relative to those in standard shear walls, as shown in Fig. 1. Due to this innovative arrangement of components, midply wood shear wall system is able to provide higher lateral resistance compared to standard shear wall system. Previous studies [2–4] revealed that the load-carrying capacity and stiffness of midply wood shear walls were nearly three times those of standard shear walls. Moreover, the common failure modes of the sheathing connections [5–8], which were directly related to the destruction of standard shear walls, can virtually be eliminated

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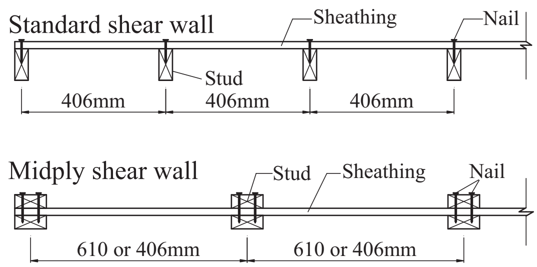


Fig. 1. Top view section of a standard wood shear wall and a midply wood shear wall.

in midply wood shear walls. Therefore, the double-shear-nail (DSN) connections which were distinct from the single-shear nail connections in standard wood shear walls (see Fig. 2) was regarded as one of the most important reasons for the superior performance of midply shear walls.

It is commonly accepted that the performance of a standard timber shear wall is primarily determined by the response of the nail connection rather than the properties of the timber members themselves [9–15]. Hence, many researchers developed various sophisticated finite-element models to predict the lateral performance of shear walls with nail connections in the past decades. Dolan and Foschi [16] employed a finite-element model to simulate standard shear walls. Comparison between the simulated results and the experimental results of full-size standard shear walls indicated that the model was effective to predict the performance of standard shear walls. Judd [17,18] developed a new analytical model for nail connections to predict the performance of standard shear walls. In this model, a nonlinear spring pair oriented along the initial displacement trajectory of nail connections was adopted to simulate the actual behavior of nail connections. The results indicated that this model provided a closer fit to test data compared to previous nail connection model. Likewise in midply wood shear wall system, it can be considered that the properties of the DSN connections among the sheathing and framings have a significant effect on the performance of midply wood shear walls. In the meantime, it is possible to predict the performance of midply wood shear walls by using similar finite-element methods.

Despite the studies on the response of DSN connections are few, extensive studies on single nail connections in standard timber shear walls can provide some references. Dolan and Madsen [19] investigated the lateral monotonic and cyclic behavior of single-shear nail connections with the intent of finite-element modeling. The connections fabricated with different sheathing types were loaded parallel and perpendicular to the grain of sheathing and framing. The results indicated that the influence of loading direction on the connection response was small, whereas the sheathing type had an effect on the connections load–displacement curves near the ultimate load capacity of the connection. Girhammar et al. [20] also conducted an experimental study on single-shear nail connections with different sheathing materials, considering the influence of loading direction to grain. The results showed that both loading direction to grain and nail edge-distance had obvious effects on the failure modes and the maximum loading capacity of the connections. Buitelaar [21] and Karacabeyli et al. [2] tested nine types of DSN connections with different nails and sheathing materials under monotonic and cyclic loads. The results indicated that the maximum load of DSN connections is about 80% greater than that of single-shear nail connections, and the initial stiffness of the former is about three times that of the latter. However, these conclusions were drawn just basing on the test results of DSN connections in a specific configuration without regard to other important variables, such as the nail edge-distance and the loading direction to the grain of framing and sheathing. Therefore, their conclusions were not representative and comprehensive.

To evaluate the influences of different variables on the response of DSN connections, eight groups of single fastener DSN connections were tested under lateral loads in this study. The experimental variables consisting of nail edge-distance, sheathing thickness and loading direction to the grain of framing were derived from practical midply wood shear walls. It was also intended to develop baseline data for a finite-element DSN connection model so as to predict the performance of midply wood shear walls as was similarly done by Dolan and Madsen [19]. Up to now, minimal studies have been conducted on DSN connections. Improving the understanding of DSN connections will subsequently aid in improving the understanding of midply wood shear walls and their performance under lateral loads.

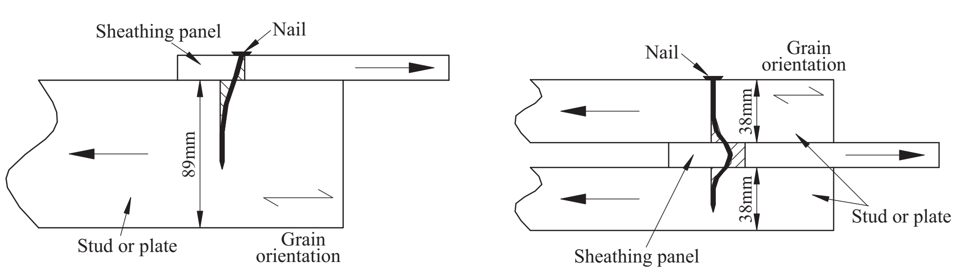
2. Materials and methods

2.1. Connection fabrication

A typical DSN connection was fabricated with a sheathing panel sandwiched between two exterior framing members. In this test, Oriented strand boards (OSB/3) [22] in two different thicknesses (12.5 and 15.5 mm), with an average moisture content of 12%, were used as sandwich sheathing. No. 2 spruce–pine–fir (SPF) 38 × 89 mm lumbers imported from Canada, with an average moisture content of 12%, were used as exterior framing members. Galvanized grooved nails with 3.6 mm diameter and 82 mm length were adopted to connect sandwich sheathing and exterior framings. The nails were manually driven by a hammer. Table 1 shows the design parameters of specimens.

2.2. Description of test specimens and variables

Eight groups of DSN connection specimens were tested under monotonic loads, with ten replicates for each group. Four types of typical specimen configurations derived from practical midply wood shear walls [23] were selected for testing, as shown in Fig. 3. The first three configurations were used to simulate the sheathing displacement condition that was perpendicular to the grain of framing in a midply wood shear wall, consisting of (1) with a nail edge-distance of 10 mm for Specimens DSN12.5-PE-10 and DSN15.5-PE-10 (see Fig. 3(a)), corresponding to the nail connections in the upper and bottom edges of the sheathing panels; and (2) with a nail edge-distance of 22 mm for Specimens DSN12.5-PE-22 and DSN15.5-PE-22 (see



(a) (b)

Fig. 2. Contrast between (a) a single-shear nail connection and (b) a double-shear-nail connection.

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