

Research & Development Summary



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Connection Systems for Prefabricated Wall Panels

Panelized housing is a construction system which has grown in popularity in the last few years, and a constant growth is predicted in North America for at least the next twenty years. It is estimated that there are approximately 320 prefabricated building manufacturers in Canada (Industry Canada, 2009). More and more prefabricated components and subsystems (i.e., walls, floors and roofs) are being produced due to recent improvements in the manufacturing process, lack of site-built skilled labour and the need for optimum solutions for the wood building industry.

As for any other type of construction, there is a need to understand the performance of such assemblies when subjected to extreme environmental loads such as high winds or earthquakes, which are common natural disasters in North America. As part of the lateral load resisting system, shear wall panels transfer external loads from the diaphragms (roof systems or upper floors) to the foundation. The shear wall performance under load is ultimately related to different parameters such as framing-to-framing and sheathing-to-framing connections' configurations, type and thickness of sheathing, and type of wall-to-foundation anchorage (Dolan and Heine 1997; Salenikovich and Dolan 2000).

Wall panels are fabricated in lengths ranging from 2 feet to 16 feet and are connected linearly or to form a corner. Joining wall segments and attaching them to the upper and lower structures may require justifiable extra effort and cost. Connection practices differ from one manufacturer to another and depend on the geographic location of the construction site. While the design and manufacture of such components and subsystems are carried out in controlled environments, assembly and connection on-site is proving to be quite challenging. There is a need



to learn more about the performance of such prefabricated systems to ensure they can meet local code requirements.

Work reported in this document was carried out with the key objectives of:

- evaluating entire wall systems, with several wall-to-wall connection configurations, subjected to racking and out-of-plane loadings;
- providing recommendations on potential improvements to connection systems typically used in prefabricated wood wall panels.

Methodology

Several visits were made to major manufacturers of prefabricated wall panels and modular houses in Quebec to provide a better understanding of the prefabricated components and housing industries, the type of prefabricated wall panels that these companies produce and the different types of connection systems commonly used in the prefabricated wall assemblies. These visits also provided an opportunity to discuss with the plant staff the various issues associated with the production and assembly of prefabricated wall panels.

Results of eighteen racking tests and nine bending tests on full-size 2.44 by 2.44 m walls composed of two segments (1.22 by 2.44 m) attached with three different types of connection configurations are presented in this document (Figures 1 and 2). Studs were spaced 406 mm on centre (o.c.) and the chords were made of double studs fastened using two \varnothing 4.1 x 89 mm common nails (16d), every 610 mm o.c. The studs were fastened to the top and bottom plates with two 16d common nails at each end. The frame was sheathed on one side with 11 mm thick oriented strandboard (OSB) panels. The panels were attached to the frame with power-driven nails \varnothing 2.9 x 63.5 mm (8d) every 152 mm o.c. on the perimeter, and 305 mm o.c. in the field. Several wall-to-foundation attachments were also investigated using bolts, nails and a combination of bolts and hold-down anchors. Monotonic and cyclic racking tests were performed in accordance with relevant ASTM standards. Out-of-plane wall bending tests were carried out following a proposed protocol based on the calculation of the wind pressure corresponding to five hurricane categories from 112 to 257 km/h. These bending tests were carried out using an airbag system to simulate the inward wind-pressure with three types of foundation attachments.



Figure 1: Typical shear wall test set-up with instrumentations for measuring deformation.

Results

Results from the various racking tests on wall assemblies evaluated with different types of inter-segment and bottom anchorage configurations revealed the following:

- The racking load-carrying capacity of wall assemblies subjected to either monotonic or cyclic loading was not strongly affected by the type of central connection configuration commonly used to join the two wall segments.
- For all types of inter-segment connections tested under monotonic or cyclic loading, wall assemblies with hold-down anchors were nearly three times stronger than those nailed to the base. They were 80% stiffer and dissipated five to seven times more energy before failure.
- The type of loading seems to have some influence on the maximum load-carrying capacity and to a lesser extent on stiffness of prefabricated wall assemblies, regardless of the type of inter-segment and wall-to-foundation attachments.

As for out-of-plane loads, it was found that the tested wall assemblies were able to resist wind-pressure above 4.3 kPa (corresponding to 232 km/h sustained wind speed) which is equivalent to a Category 4 hurricane. Their strength was controlled by the strength of the studs rather than the type of the connections used.

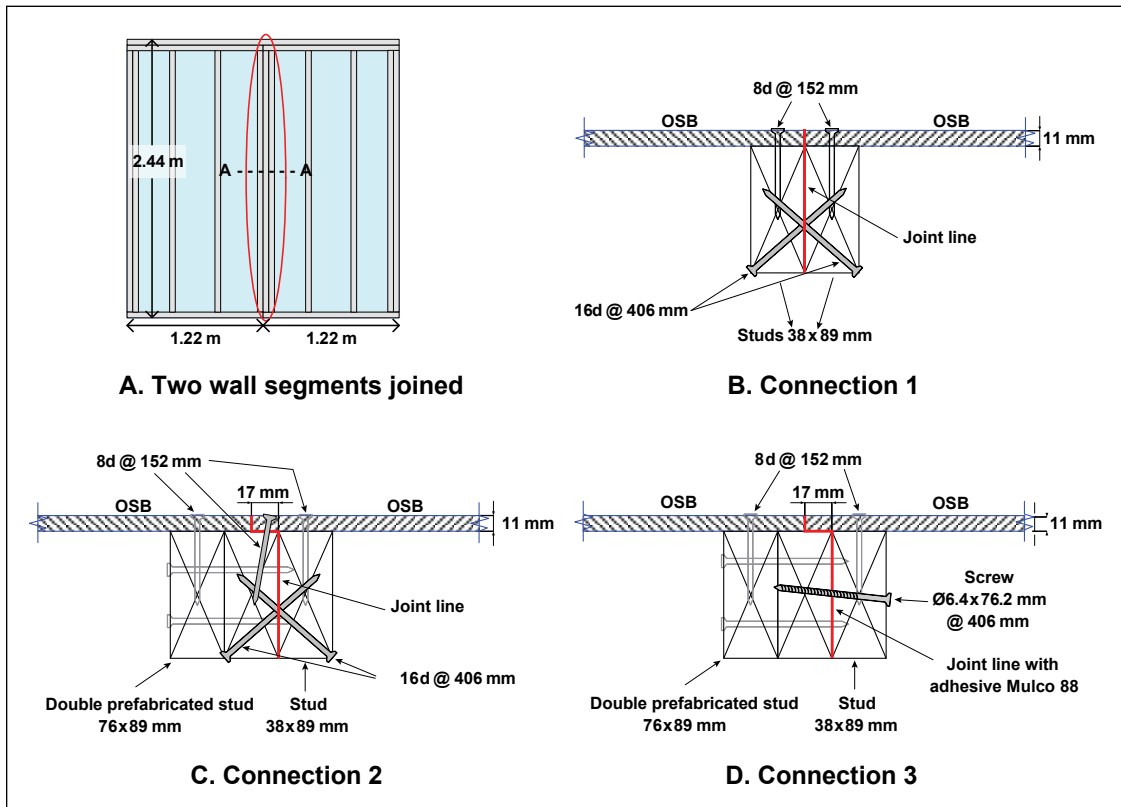


Figure 2: Schematic for a typical two-segment test wall with the three types of inter-segment connections.

Application of Results and Benefits

In 2007, Canadian exports of prefabricated buildings were valued at \$554M which is a 12.5% increase over the previous year. Duties imposed by the US on Canadian softwood lumber were a major factor in this industry's growth. To continue the growth of this industry, it is necessary to provide quality assurance and increase client confidence in the prefabricated assemblies through research and development.

Results from this study indicate that current connection systems commonly used by the industry in the assembly of prefabricated wall panels can resist to a certain extent the typical in-service loads to which they could be subjected. However, certain parameters such as the erection speed and ease of assembly remain

major concerns for the prefabricated building component industry. Some recommendations for future work which could lead to improvement of the connection systems typically used in the assembly of prefabricated wall panels are summarized below:

- The prefabricated building component industry should work closely with connector manufacturers to develop new and innovative connection systems that are reliable, easy to assemble and cost effective.
- It is recommended that a review of practices in other industries be conducted in an attempt to identify efficient proprietary types of connection systems and technologies that have been developed elsewhere (e.g., Murus SIP's Cam

lock system, connection systems used in the assembly of prefabricated concrete components on-site). Many such systems are suitable for the assembly of prefabricated wall panels.

- The development of standardized wall elements, and efficient and more automated manufacturing processes that allow for finalizing the installation of most connections' systems and components under controlled environments (in plant) should be investigated. This will ultimately reduce the assembly time on-site and lead to improvement in the connection systems in terms of precision and overall structural performance.



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