Evaluation of Prototype Wood-Based Interior Partition Walls

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By:

Robert M. Knudson, Research Leader, Engineered Wood Products Manufacturing
Johannes Schneider, Post-Doctoral Fellow
Tony Thomas, Principal Technologist, Advanced Building Systems

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REVIEWERS
Conroy Lum,
Research Leader,
Advanced Building Systems

CONTACT
Robert M. Knudson
Research Leader
Engineered Wood Products
604 222 5738
Bob.knudson@fpinnovations.ca

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EXECUTIVE SUMMARY

Interior partition walls for non-residential and high-rise residential construction are an US$8 billion market opportunity in Canada and the United States (Crespell and Poon, 2014). They represent 1.6 billion ft² (150 million m²) of wall area where wood currently has less than 10% market share. To approach this market a new system would be needed to compete against the incumbent system (wood/steel stud plus gypsum). The system would need to have an installed cost before finishing of approximately US$5 per ft² or lower. The system would also need to meet several code requirements for strength, sound transmission and fire resistance (flame spread and burn through). Crespell and Poon further concluded that to be truly transformative, the system would also need to address major trends impacting the building industry including reducing labor, reducing skilled labor, reducing onsite waste, reducing call-backs, and easily recyclable with low environmental impact. A likely market entry point for wood-based interior partition systems may be in taller and larger wood buildings.

Work described in this report investigated the fabrication, installation, acoustic and combustion properties of prototype interior partition wall designs.

Two types of non-structural prototype interior wall panels designated Type A and Type C were installed between two offices in the FPInnovations Vancouver laboratory. Wood sill plates for mounting the prototype panels were fastened to the concrete floor, sides and top of the opening between the two offices to produce a frame for mounting the test panels. Panels were fastened to the frame using drywall screws. This same method of installation is envisioned in practice. The installation method makes it easy and fast to both install and remove the wall panels.

Acoustic tests showed the difference in ASTC rating measured between a double wall composed of Type A and Type C prototype panels compared with a double wood stud wall with gypsum board faces was approximately 6 ASTC points. A 6 point difference would be clearly noticeable. Although the results of this study are largely qualitative, they suggest that the prototype interior partition panels would have an acoustic advantage compared to stud wall designs.

In a related study summarized in this report, the combustion properties of three prototype interior panel constructions, including Types A and C evaluated in this report, indicated that any of the three types of partition constructions could be used in combustible construction in accordance with Division B of the National Building Code of Canada.

A second related study, also summarized in this report, estimated an installed cost of US$4.07 per ft² including overhead and profit for unfinished panel partitions comparable to panel construction Type C (gypsum/OSB/wood fibre insulation) as evaluated in this study. Thus, there would appear to be potential installed and finished cost advantages for the wood-based panel partitions compared to steel or wood stud walls with gypsum faces.

Other potential advantages of the prototype interior partition panels compared with the most common, currently-used systems (wood/steel stud plus gypsum) include ease and speed of installation, ease and
speed of removal, design flexibility, prefabrication including pre-finishing, and easy installation of services.

Based on the positive results of these exploratory studies, further development of wood-based interior partition systems including design, fabrication, installation and in-service performance would appear justified. Knowledge of the products and testing methods developed in these studies would be expected to speed further development.
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1. OBJECTIVE

The overall objective of this work was to develop prototype non-structural, wood-based interior partition wall systems for residential and non-residential construction. Specific objectives of this study were to fabricate, install and evaluate the acoustic performance of the prototype wood-based interior partition panels.

2. INTRODUCTION

Interior partition walls for non-residential and high-rise residential construction are an US$8 billion market opportunity in Canada and the United States (Crespell and Poon, 2014). They represent 1.6 billion ft² (150 million m²) of wall area where wood currently has less than 10% market share. To approach this market a new system would be needed to compete against the incumbent system (wood/steel stud plus gypsum). The system before finishing would need to have an installed cost of approximately US$5 per ft² or lower. The system would also need to meet several code requirements for strength, sound transmission and fire resistance (flame spread and burn through). Crespell and Poon (2014) further concluded that to be truly transformative, the system would also need to address major trends impacting the building industry including reducing labor, reducing skilled labor, reducing onsite waste, reducing call backs, and easily recyclable with low environmental impact. Finally, Poon and Crespell (2014) posed several key questions to encourage product development teams to come up with truly transformational product concepts.

- Can a system be developed that achieves a dramatic reduction in the labor associated with stick framing the wall and then manually attaching gypsum and finishing it?
- Can a system be developed that dramatically reduces onsite waste? Can the system eliminate landfilling of gypsum (both in new construction and in later years in construction demolition)?
- Can a system be developed that dramatically reduces the impact of interior partitions on the environment? Can the system be 100% recycled at the end of life?
- Can a system be developed that stops nail/screw pop? Can the system eliminate the nail/screw interface?

A subsequent study by Kus (2016) estimated an installed cost of unfinished multi-functional panel partitions (gypsum/OSB/wood fibre insulation) of US$4.07 per ft² including overhead and profit. Kus’ estimate suggests a potential installed and finished cost advantage for the multi-functional panel partitions compared to current practices.

Motivated by the work of Crespell and Poon (2014) and Kus (2016), the work described in this report investigated the fabrication, installation and acoustic performance of prototype interior partition wall designs. Combustion properties of the prototype interior partition wall designs are presented in a separate report by Dagenais (2017).
3. STAFF

- Robert M. Knudson, Research Leader, Engineered Wood Products
- Johannes Schneider, Post-Doctoral Fellow
- Tony Thomas, Principal Technologist, Advanced Building Systems
- Francine Côté, Principal Technologist, Engineered Wood Products
- Christian Dagenais, Senior Scientist, Advanced Building Systems
- John Hoffmann, Principal Technologist, Engineered Wood Products

4. MATERIALS AND METHODS

4.1 Materials

Materials used for fabricating the interior partition panels included:

- 40 mm thick (1.57 inch) Gutex Thermowall-gf wood fibre insulation board
- 6.4 mm (0.25 inch) thick performance rated aspen OSB sheathing panels
- 12.7 mm (0.5 inch) thick, 7-ply birch plywood, pre-finished on one side
- 12.7 mm (0.5 inch) thick gypsum wallboard
- Purbond HB E452 polyurethane adhesive

Selection of these component materials was based in part on FPInnovations research on the structural, combustion and acoustic performance of prototype multi-functional panels designed for exterior applications (Knudson et al 2014, Knudson and Hoffmann 2015, Dagenais et al 2016, Pirvu 2016).

4.2 Methods

4.2.1 Panel Fabrication

Two full-size prototype panel constructions were fabricated for installation in a double partition wall (Table 1). One of the objectives of the installation was to determine whether the acoustic performance of a double wall constructed in the proposed manner might eliminate the need to install resilient channels as a means to reduce sound transmission between adjacent rooms.

<table>
<thead>
<tr>
<th>Panel Type</th>
<th>Inner Layer</th>
<th>Middle Layer</th>
<th>Outer Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Finished Plywood Surface (Type A)</td>
<td>40 mm wood fibre insulation</td>
<td>6.4 mm OSB</td>
<td>12.7 mm pre-finished plywood</td>
</tr>
<tr>
<td>Gypsum Board Surface (Type C)</td>
<td>40 mm wood fibre insulation</td>
<td>6.4 mm OSB</td>
<td>12.7 mm gypsum board</td>
</tr>
</tbody>
</table>

Table 1. Prototype interior partition panel constructions.

Full size 1220 mm x 1440 mm (4 x 8 feet) sheets of the different panel types were used. All three layers were glued together in one step. Bonding surfaces were misted with water prior to adhesive application to speed the curing process. Glue was applied to the top surfaces of the wood fibre and OSB.
Approximately 1 kg of adhesive was applied evenly by hand to the surfaces of the wood fibre and OSB. This amount of adhesive was determined to be ample based on previous experience fabricating multi-functional panels (Knudson and Hoffmann 2015). Two panels were pressed at the same time using a full size veneer laminating press. Panels were pressed to approximately 90% of their combined component thicknesses for a minimum of two hours. These pressing parameters had been determined to be adequate in the earlier fabrication of multi-functional panels. Figure 1 illustrates the layering of the interior partition panels.

Panels were then trimmed to size and tongue and groove joints were machined along the 2440 mm long edges of the panels as shown in Figure 2. The tongue and groove joints were used to fit the panels together for installation. This joint design should be considered a prototype suitable for this evaluation, but not necessarily an ultimate solution. Prototype panel fabrication methods used in this study would be readily transferrable to a commercial manufacturing operation.
4.2.2 Installation

Prototype interior wall panels were installed between two offices in the FPInnovations Vancouver laboratory. Figure 3 shows a plan view of the offices including dimensions. The panels were mounted in a 2440 x 2440 mm (8 x 8 foot) opening between the offices. The surrounding portions of the common wall between the offices were constructed with sand fill between the outer and inner sheathing layers of the wall section facing room S117 to provide a high-mass sound barrier between the rooms in order to facilitate acoustic testing of the prototype wall panels. Wood sill plates for mounting the prototype panels were fastened to the concrete floor, sides and top of the opening along both sides of the common wall to produce a frame for mounting the test panels. A single vertical stud was affixed to the top and bottom sill at the midpoint of the wall opening on each side to facilitate the mounting of the test panels and to provide additional lateral stiffness along the joint. Panels were fastened to the frame using 80 mm long drywall screws at 150 mm spacing. The gypsum board faced prototype panels were mounted facing room S117. The finished birch plywood faced prototype panels were mounted facing room S118. The gypsum board faced prototype panels were finished by taping and painting the panels to blend in with the rest of the wall in room S117. Matching birch plywood trim, 70 mm wide, was fastened around the 2440 x 2440 mm opening to hide the joint between the prototype panels and the rest of the wall in room S118. A suspended or false ceiling to match the design of the rest of the building was re-mounted in both rooms to complete the installation. Figure 4 is a schematic showing how the panels were mounted in the 2440 x 2440 mm opening between rooms S117 and S118. Figure 5 details of how the panels were mounted.
Figure 3. Plan view of offices where prototype panels were installed

Figure 4. Schematic showing mounting of prototype panels in opening between rooms S117 and S118
4.2.3 Acoustic Testing

*Test Equipment.* For measurement of the airborne sound attenuation, the sound source generating pink noise was connected to a Larson Davis 500 omnidirectional (dodecahedral) loudspeaker Model BAS001 through a Larson Davis 500 Watt 110-125 VAC noise source amplifier Model BAS002, which was remotely controlled. A single sound level meter Larson Davis Model 831-R1 Type 1 was used to measure sound levels during the tests. The sound level meter was equipped with a 12.5 mm (1/2 in.) PSB microphone Model 377B20 with pre-amplifier. The calibration data sheet provided by Larson Davis, when the instruments were purchased in 2010, indicated that the sound level meter was laboratory calibrated to the appropriate standards. Sensitivity checks on the sound level meter were performed with a Larson Davis field calibrator Model CAL200.
Data analysis was carried out with post-data software, Larson Davis DNA4 version 4.6.0 that interfaces with the sound level meter. The software performs the frequency analysis to obtain the spectrums, single number ratings, and reverberation time spectrums.

Test Methods. Airborne sound insulation performance of the walls built with prototype interior partitions was determined in place according to the principles in ASTM E336-16 (ASTM 2016). This test method allows for measurement of airborne sound attenuation between rooms in buildings due to direct sound transmission through the wall, recognizing that there may be some flanking through indirect sound transmission paths. The tests were carried out with a single sound source which was placed approximately in the centre of the source room. The tests were carried out with the sound level meter positioned at six fixed positions at minimum 1 m apart in each room with the sound source operating at a constant level. The average sound pressure level at each frequency was measured in the receiving room. Similarly, with the sound source operating at a constant level, the average sound pressure level at each frequency was measured in the source room. The measurements were carried out in a single direction, from the source room to the receiving room. With the sound source shut off, the average sound pressure level at each frequency was measured in the receiving room for an averaging time of 1 min. at a single microphone position located approximately in the centre of the room.

Sensitivity checks were performed on the sound level meter before and after the measurements with a Larson Davis field calibrator Model CAL200. The calibration values were within the requirement of the ASTM E336-16 standard.

Decay rates were measured according to ASTM E2235-04 (ASTM 2016). Fifteen decay rates were collected (3 microphone positions, 5 decays) per each test.

The ASTC ratings of the wall assemblies in this report were determined as per the classification in ASTM E413-16 (ASTM 2016) by using the DNA4 analysis software described previously.

5. RESULTS

5.1 Installation

Panel installation as described in section 4.2.2 was fast and easy. Once the sill plates were secured to the perimeter of the wall opening the prototype panels were fastened to the sill plates using drywall screws. The method of installation also makes it easy and fast to remove the wall panels.

Because the prototype panels were installed between existing offices that are in use, it was not feasible to carry out destructive testing to determine their resistance to out-of-plane lateral loading. As a rough qualitative measure, several experienced engineers, technologists and scientists were asked to push against the walls to assess their resistance to lateral loading. All of those asked to do so judged that the walls seemed stiff and suitable as non-load bearing partitions.

Quantitative assessment of out-of-plane loading behavior is something that will need to be carried out if work is to continue beyond prototype wall panel design. Results of these preliminary qualitative
assessments suggest that the vertical stud at 4 foot (1.2 m) intervals used when installing the prototype panels may not be necessary if there were an engineered panel-panel joint designed to resist lateral loads.

5.2 Acoustic Testing

A series of acoustic tests were performed to compare different wall partition designs. Figure 3 shows the design of the adjoining offices where the tests were carried out. Figure 4 shows how the different wall partition designs were mounted in the 2440 x 2440 mm (8 x 8 foot) opening between the offices. Results are summarized in Table 2.

<table>
<thead>
<tr>
<th>Test Number</th>
<th>ASTC Rating</th>
<th>Test Parameters</th>
<th>Purpose of Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>41</td>
<td>Gypsum wall board installed on surface of stud wall facing room S117; minimal screws used to fasten gypsum; the original wall facing room S118 remains; source room S117, receiving room S118</td>
<td>Measure properties of double stud wall as control</td>
</tr>
<tr>
<td>2</td>
<td>37</td>
<td>Gypsum wall board installed on surface of stud wall facing room S117; extra screws 150 mm o.c. (perimeter) and 305 mm o.c. (interior) to fasten gypsum; the original wall facing room S118 remains; source room S117, receiving room S118</td>
<td>Measure properties of double stud wall as control</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
<td>Same as Test 2 except source room S118, receiving room S117</td>
<td>Measure repeatability of testing procedures</td>
</tr>
<tr>
<td>4</td>
<td>44</td>
<td>Type C prototype panels (gypsum-OSB-wood fibre) installed facing room S117; the original wall facing room S118 remains; source room S117, receiving room S118</td>
<td>Measure properties of 1 prototype wall and 1 stud wall</td>
</tr>
<tr>
<td>5</td>
<td>47</td>
<td>Same as Test 5; wood fibre insulation placed over doors of rooms S117 and S118 to reduce noise flanking</td>
<td>Measure effect of sound flanking</td>
</tr>
<tr>
<td>6a</td>
<td>25</td>
<td>Type C prototype panels (gypsum-OSB-wood fibre) installed facing room S117; the original wall facing room S118 removed; source room S117, receiving room S118; noticeable dip in sound attenuation at 1250 kHz</td>
<td>Measure properties of a single prototype wall</td>
</tr>
<tr>
<td>6b</td>
<td>23</td>
<td>Same as Test 6a; retest to confirm sound attenuation drop at 1250 kHz</td>
<td>Measure repeatability of test 6a</td>
</tr>
<tr>
<td>7</td>
<td>43</td>
<td>Type C prototype panels (gypsum-OSB-wood fibre) installed facing room S117; Type A prototype panels (pre-finished plywood-gypsum-wood fibre installed facing room S118); source room S117, receiving room S118</td>
<td>Measure properties of double prototype wall</td>
</tr>
<tr>
<td>8</td>
<td>44</td>
<td>Same as Test 7; wood fibre insulation placed over doors of rooms S117 and S118 to reduce noise flanking</td>
<td>Measure properties of double prototype wall with reduced sound flanking</td>
</tr>
<tr>
<td>9</td>
<td>29</td>
<td>Tested adjacent offices S119 and S120; adjacent offices with open plenum above false ceiling</td>
<td>Measure properties of typical double stud wall design in FPInovations building</td>
</tr>
<tr>
<td>10</td>
<td>42</td>
<td>Tested between adjacent offices S129 and S130 with plywood shear wall separating the offices; no open plenum above false ceiling</td>
<td>Measure properties of double stud wall design without open plenum above offices</td>
</tr>
</tbody>
</table>
Tests numbers 1 through 8 were carried out between adjacent offices S117 and S118. The common wall between the offices was constructed with sand fill between the outer and inner sheathing layers of the wall to provide a high-mass sound barrier between the rooms. This was done to facilitate comparative acoustic testing of the different wall designs through a 2440 x 2440 mm (8 x 8 foot) opening between the offices (Figure 4).

Test numbers 1 through 3 were carried out to evaluate variations of a typical partition wall which is a double wall composed of two 2 x 4 wood stud walls separated by an approximate 50 mm (2 inch) gap, with 12.7 mm gypsum board fastened to the sides facing the offices. These will serve as the control for comparing walls made with other wood based panels and/or with wood fibre insulation. Test number 1 used minimal screws to fasten the gypsum wall board to the stud wall facing the source room S117. This gave an ASTC rating of 41. In test number 2, when extra screws were installed to more firmly attach the gypsum wall board to the studs, the ASTC rating dropped to 37 indicating that there was less acoustic energy attenuation by the wall system. In test number 3 where the sound source and receiving rooms were reversed, the ASTC rating of 38 was nearly identical to test number 2. This would suggest that the testing procedures and results were repeatable. For the purpose of this study an ASTC rating of 37 or 38 could be considered a control condition.

For tests 4 and 5 the wall section facing room S117 was replaced with Type C prototype wall design composed of an outer layer of 12.7 mm gypsum board, a middle layer of 6.4 mm OSB and an inner layer of 40 mm wood fibre insulation. Test number 4 gave an ASTC rating of 44. When wood fibre insulation was placed over the office doors (see Fig. 3) to reduce noise flanking the ASTC rating increased to 47. This finding indicated that noise flanking had an influence on the results. As a consequence, the results have an element of being qualitative rather than fully quantitative. However, the results from this series of tests provide useful comparisons between the different wall designs.

Tests 6a and 6b were carried out with a single Type C prototype wall design facing room S117. The original stud wall facing room S118 was removed. The purpose of these tests was to get an idea of the acoustic performance with a single wall only. The ASTC rating dropped to 25 with the single wall. An interesting characteristic noted in test 6a was a noticeable drop in the ASTC rating in the 1250 Hz region. This behaviour is shown in Figure 6. Test 6b was a repeat of test 6a and confirmed the same drop in ASTC rating in the 1250 Hz region. The reason for this behavior was not investigated.
Classification based on ASTM E413 – 04
ASTC = 23

Figure 6. Results for Test 6a showing ASTC rating drop in the region of 1250 Hz

Test 7 was carried out with a Type C prototype wall design facing room S117 and a Type A prototype wall design facing room S118 (see Figure 4). Test 7 had an ASTC rating of 43. Placing wood fibre insulation over the office doors to reduce noise flanking had at best a marginal effect with an ASTC rating of 44 for Test 8.

Test number 9 on a double wall composed of two 2 x 4 stud walls separated by an approximate 50 mm (2 inch) gap, with 12.7 mm gypsum board fastened to the sides facing the offices, and an open plenum above a false ceiling gave an ASTC rating of 29. The open plenum above the false ceiling was the principal difference between test number 9 and test numbers 2 and 3. The ASTC rating for test number 9 would be considered typical for the FPInnovations Vancouver laboratory. Test number 10 measured adjacent offices where there was a plywood shear wall separating the offices with no open plenum above the false ceiling. The ASTC rating of 42 for test number 10 would be considered as another reference point for a condition where there was a double stud wall and no open plenum above the false ceiling. Test number 10 was similar to tests 1 and 2 except that there was no opening designed to mount test panels, and no sand fill in the wall surrounding the opening.
6. DISCUSSION

6.1 Installation

The design of the prototype panel system which includes a perimeter sill plate method for mounting the panels allowed for easy and rapid installation of the panels. These same advantages would apply to removal of the wall system if there was a desire at some time to change the interior partition configuration in a building, or at end-of-life.

6.2 Acoustic Properties

The acoustic test results would roughly group themselves as follows:
- Double wood stud wall with gypsum board faces – ASTC rating 37-38
- Single wall with Type C prototype construction – ASTC rating 23-25
- Double wall composed of Type A and Type C prototype constructions – ASTC rating 43-44

Omeranovic (2018) gives the following general relationship between changes in ASTC rating and changes in apparent loudness.

<table>
<thead>
<tr>
<th>Change in ASTC Rating</th>
<th>Change in Apparent Loudness</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 1 STC point</td>
<td>Almost imperceptible</td>
</tr>
<tr>
<td>+/- 3 STC points</td>
<td>Just perceptible</td>
</tr>
<tr>
<td>+/- 5 STC points</td>
<td>Clearly noticeable</td>
</tr>
<tr>
<td>+/- 10 STC points</td>
<td>Twice (or half) as loud</td>
</tr>
</tbody>
</table>

The difference in ASTC rating measured between the double wood stud wall with gypsum board faces and the double wall composed of Type A and Type C prototype panels was approximately 6 points. Following Omeranovic’s guidelines, a 6 point difference would be clearly noticeable. Although the results of this study are largely qualitative, they suggest that the prototype interior partition panels would have an acoustic advantage compared to stud wall designs. Specific wall systems will need to be designed and evaluated for sound control in actual buildings.

Test results should not be considered definitive as ASTC ratings can vary widely depending on design details. They do indicate, however, that acoustic performance of a double wall partition using the prototype interior partition designs incorporating wood fibre insulation in combination with OSB, plywood and/or gypsum wall board may likely perform better than a double stud wall design with gypsum wall board facings.

6.3 Combustion Properties

Combustion properties (reaction to fire) of three prototype partition designs as evaluated by cone calorimeter method ISO 5660 are described in a separate report (Dagenais, 2017).

- Partition A - 12.7 mm pre-finished plywood (exposed surface), 6.4 mm OSB, wood fibre insulation
• Partition B – 12.7 mm pre-finished plywood (exposed surface), 12.7 mm gypsum board, 6.4 mm OSB, wood fibre insulation
• Partition C – 12.7 mm gypsum board (exposed surface), 6.4 mm OSB, wood fibre insulation

Dagenais concluded that any of the three (3) types of partition constructions could be used in a combustible construction in accordance with Division B of the National Building Code of Canada (NRCC, 2010). Partition designs A and C were evaluated in the tests described in this report. None of the prototype partition constructions could be used in a building required to be of non-combustible construction, unless low-combustibility materials are used and demonstrate a flame spread rating no greater than 25. Dagenais further stated that a performance-based fire engineering design could be developed to demonstrate that their use would fulfill the National Building Code of Canada’s objectives and functional statements.

6.4 General Comments

Potential advantages of the prototype interior partition panels compared with the most common, currently-used systems (wood/steel stud plus gypsum) include:
  • ease and speed of installation,
  • ease and speed of removal,
  • design flexibility,
  • prefabrication including pre-finishing,
  • easy installation of services, and
  • cost.

On cost alone, Kus (2016) estimated an installed cost of US$4.07 per ft² including overhead and profit for unfinished panel partitions comparable to panel construction Type C (gypsum/OSB/wood fibre insulation) as evaluated in this study. Thus there would appear to be potential installed and finished cost advantages for the prototype panel partitions compared to current practices.

All of these potential advantages will need to be investigated further. However, all initial indications are positive.

7. CONCLUSIONS

The following conclusions are drawn from this and related studies of the prototype interior partition system described in this report.

1. The design of the prototype panel system which includes a perimeter sill plate method for mounting the panels allows for easy and rapid installation or removal of the panels.

2. Test results suggest that the prototype interior partition panels may have an acoustic advantage compared to stud wall designs.

3. In another report, Dagenais (2017) tested three prototype interior panel constructions, including Types A and C evaluated in this report and concluded that any of the three types of partition
constructions could be used in a combustible construction in accordance with Division B of the National Building Code of Canada.

4. Also in another report, Kus (2016) estimated that the prototype interior panel constructions have potential installed and finished cost advantages compared with commonly used stud wall designs.

5. Evaluation methods employed in this study will help to facilitate further development of prefabricated interior partition designs and systems.

8. RECOMMENDATIONS

Based on the positive attributes of the prototype interior partition designs evaluated in this study, the authors recommend further development of the concept. Such further development should encompass not only technical and economic assessments, but also include protection of intellectual property where necessary for commercial implementation.

9. REFERENCES


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