PROMOTION OF WOOD FRAME CONSTRUCTION IN CHINA

WITH A FOCUS ON OPPORTUNITIES AFTER THE SICHUAN EARTHQUAKE

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Abstract

In an attempt to diversify the marketplace for Canadian wood products, the forest industry, particularly in British Columbia, has been promoting the benefits of building with wood to China, one of the largest markets that has not widely adopted wood frame construction.

During this marketing campaign that started more than a decade ago, a number of demonstration projects were completed in order to promote wood in a various ways, such as being used as a building material or a landscaping component. Those projects play an important role in establishing the foundation for further developments of wood frame construction, as well as other applications using Canadian wood products in China on a much larger scale.

On May 12, 2008, a dreadful earthquake struck Wenchuan claiming the lives of hundreds of thousands of people and leaving many homeless. There was a massive number of building collapses and many buildings sustained permanent structural damage, most of the buildings being made out of masonry or concrete. Comparatively, the few wood frame houses within the earthquake region performed exceptionally well; some of them did not even sustain any superficial damages. The fact that wood frame construction possesses a better seismic characteristic, along with its other benefits, drew a lot of attention from people in China after this devastating earthquake. In addition, the Federal Government of Canada announced a donation of 8 million CAD to the earthquake region to build three demonstration projects all in the configuration of multi-storey wood frame construction buildings. This would not only provide tremendous help to people in dire need, but also further demonstrate the safety,
comfort and affordability of wood frame buildings in a much more visible way.

This report reviews some of previous demonstration projects in details and a number of current projects for the post-earthquake reconstruction. It also briefly examines why wood frame construction has better seismic performance, as well as discussing other benefits of building with wood, such as its limited impact on the environment.

In conclusion, all the efforts initiated by the forest industry of Canada will open the door for Canadian wood products to be used in China, one of the world’s largest and fastest-growing markets.

*Key words: wood frame construction, promotion, China, earthquake*
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Promotion of Wood Frame Construction in China

Background

In an attempt to diversify the market for forest products from British Columbia and Canada, the forestry industry has been promoting the benefits of building with wood in China for almost a decade. A number of marketing campaigns were presented in order to persuade developers and the general public that wood frame construction has more advantages than the dominating construction methods, such as steel or concrete. To support the promotion of wood construction, several institutions in Canada and China have conducted a number of technical research studies regarding the performance and economic feasibility of wood frame construction. One of the studies is the roof renovation project conducted by Tongji University. The project demonstrates building with wood trusses is a cost effective way to achieve better environmental performance for roof renovation. (Huang)

Previous Projects

Dream Home Canada Demonstration Centre (DHC)

As the very first project in China, the Dream Home Canada Demonstration Centre (DHC) aims to not only demonstrate the concept of building with wood, but also introduce the beauty of various Canadian wood products to Chinese consumers. This project showcases the technical information of wood frame construction, uses of wood as a landscaping material, and a wide range of remanufacturing applications of value-added wood products. The building also provides office spaces for the staff of Forest Innovation Investment (FII) China and Canada Wood Group (CWG), which serve as two governmental agents at both the provincial and federal
level to further promote Canadian wood products.

![Figure 1 Outside and inside of the Dream Home Canada Demonstration Centre](image)

**DHC Villas**

Two villas next to the demonstration centre were opened in January 2007 as the second DHC demonstration project. The design of the two villas focused on the integration of North American style wood frame construction and Chinese style of living. The two villas became a complementary addition to the demonstration project and served as additional office space for the growing number of CWG staff members in China. The increasing staff numbers is evidence of Canada’s commitment to position China as one of the most important marketplaces for Canadian wood products. In addition, those two villas provided real models where tests, such as energy efficiency of the building, could be conducted in an attempt to demonstrate the environmental features of wood frame construction.
Xin Zhuang Hybrid Construction Demonstration Project

The construction of Xin Zhuang hybrid townhouse started early 2006 in Shanghai as a joint project between Shanghai Research Institute of Building Science and CWG. This project was carried out in an attempt to study the feasibility and benefits of adding wood constructions on top of concrete buildings, which has been the dominating residential construction type in most Chinese cities.

Roof Renovation Projects

In September 2006, Xu Hui District of Shanghai became the home to the first roof renovation project using the wood truss system. This demonstration was jointly conducted by Forestry Innovation Investment (FII) China, Shanghai Municipal Housing, Land and Administration...
Bureau, and Shanghai Science and Technology Committee. The success of this project led to the approval that wood truss system can be used for many future roof renovation projects in Shanghai. (Canada Wood)

Meanwhile, another roof renovation project using the wood truss system was completed in January 2007 in Qingdao, a coastal city in Northern China. This project, which was the first to complete 18 buildings, was carried out with the partnership of a local developer of Qingdao and the Quebec Wood Export Bureau. (Canada Wood)

Following the success of several demonstrations, which were often partially or completely funded by Canadian associations or industry, a more recent research project focusing on renovating a building in Tongji University of Shanghai followed. This project proved to be
commercially competitive and thus allowed for further developments of the use of wood truss on a larger scale. The project was competitive because of a number of design adjustments, mostly done by Tongji University, in an attempt to introduce a more China-specific standard of roof construction using North American style wood trusses. Later section of this report will examine the cost-savings in more details.

Furthermore, FII China is working with the Tianjin Fire Research Institute (TFRI) in an attempt to eliminate the current regulatory barriers for using the wood truss system for a wider range of applications. If the authority eventually approves the use of wood trusses and establishes a corresponding building and fire code, it will allow the wood truss system to tap into an even larger market.

**Guangzhou Landscaping Project**

FII China’s landscaping demonstration project was announced as a part of the Guangdong and British Columbia Pacific Gateway Park Project after a visit by British Columbia’s Premier, Campbell, to Guangdong on November 24th, 2006.

The demonstration project will be located on a plot approximately 100,000 sq. ft. inside the Zhujiang Park in Guangzhou. The project will highlight landscaping wood products from British
Columbia, such as treated hem-fir and western red/yellow cedar. It is expected that this demonstration project will establish the foundation for further market development of outdoor wood products in China.

**DHC Multi-storey Hybrid Buildings**

The main objective of the DHC multi-storey hybrid project is to demonstrate how to combine wood frame construction with other types of construction, such as concrete or steel to build multi-family residential structures. Another purpose of the project is to provide models for the establishment of Chinese buildings codes for hybrid construction. The project focuses on two major marketing opportunities: one is to build new multi-storey hybrid apartments or townhouses, while the other is to meet the demand for renovating existing concrete apartment buildings.

New hybrid constructions may vary in configurations. One option is to build the first floor with concrete and add three to five stories of wood frame on top of it. Another option is to build the exterior and structural components with concrete while internally divided by non-structural wood partition walls.

The renovation of existing concrete apartment buildings focuses on the upgrade of the building by adding in either a roof using wood trusses or an external skin of wood frame. Both methods will improve the insulation of the building and result in an increase of the overall energy efficiency of the structure.
Post-earthquake Opportunities for the Development of Wood Frame Construction

The Sichuan Earthquake

Less than 180 days before Beijing hosted the 2008 Summer Olympics, a deadly earthquake struck Wenchuan, a county in Sichuan province 1,500 km away from the nation’s capital.

This earthquake, later known as the Great Sichuan Earthquake, or the Wenchuan Earthquake, measured 8.0 in terms of the surface wave magnitude or 7.9 in terms of the moment magnitude scale and claimed at least 69,000 lives, excluding repeating aftershocks which further added to the number of casualties. It left at least five million people homeless. (Hooker) The earthquake not only claimed hundreds of thousands of lives, but also destroyed numerous buildings and communities.
Post-earthquake Reconstruction Projects

Immediately after the earthquake, the Federal Government of Canada announced its donation plan to help rebuild the area. Three projects, funded by 8 million CAD donation to China, were proposed in Dujiangyan City, Mianyang Municipality, and Beichuan County.

Xiang’e primary school

Located in the suburban area of Dujiangyan City, Xiang’e primary school was almost completely demolished by the earthquake and claimed lives of thousands of students and teachers. Following the visit by Prime Minister Wen Jia Bao, the school was extensively reported on national TV and became the centre of attention.
After the earthquake, the Chinese central government assigned reconstruction responsibilities to many cities in China. As the partner city of Dujiangyan, Shanghai selected the school to be the first project to rebuild. The project was led by Shanghai Ministry of Construction and the Shanghai Education Bureau, together with assistance from the government of Dujiangyan City and Tongji University, a leading civil engineering university in China who took responsibility for the design and construction.

This project was also partially funded by a donation from the Federal Government of Canada, therefore Canada was involved in the project by donating wood material and contributing design and construction consulting services. This is a result of the long-term relationship between Canadian forest industry and Shanghai Ministry of Construction and Tongji University.

The design of the new school, as shown in Figure 9, aimed to “closely approximate multi-storey, multifamily apartment buildings” which is “a key target for the Canadian forest sectors’ future market development in China”. This is a change from the previous strategy to promote wood frame construction as a high-end and a super luxurious construction type, which is usually associated with single-family villa.
By being involved with this project, which caught much attention from the public as well as government officials, the Canadian forest industry can further demonstrate benefits of modern wood building systems, particularly its seismic performance to address the importance of building safety during earthquakes. In addition, working with the Shanghai Ministry of Construction and Tongji University will positively increase the impact of the credibility of wood frame construction, since both parties are nationally recognized as pioneers of new construction technologies. In the long-term, this project will facilitate the development of more multi-storey apartment buildings made out of wood frame in the Yangzte Delta and even national wide.

**Mianyang Municipality rehabilitation centre**

Beichuan County of Mianyang Municipality was another community direly struck by the earthquake, which left more than 13,000 children and adults disabled. (FII China) Three major reconstruction projects were proposed, which included a recovery and rehabilitation centre, a school for disabled students, and a vocational training centre for disabled adults.

As a part of a number of reconstruction initiatives, a special education school for those victims was planned by the Mianyang Municipal Government. Canada’s involvement in the project includes the contribution of wood material and the provision of technical support during the
design and construction phases. As of now, the design has been approved by the local authority and construction is scheduled to start by June 2009. (Canada Wood)

Similar to the Xiang’e primary school, Mianyang special education school for the disabled was designed to resemble multi-storey apartment buildings and to demonstrate benefits of wood being used in public construction. This is to assist the future market development strategy of the industry, which is to focus on the promotion of multi-family dwellings built with wood frame.

The selection of this reconstruction project has gone through careful consideration in order to help people who are the most in need while maximizing its exhibition value. Firstly, Mianyang Municipality was one of the most devastated communities by the earthquake and therefore drew lots of attention from media and the government. A National Earthquake Memorial Museum was proposed to be built in Beichuan Country close to the site of this project, which will be visited by a large number of people including government officials every year during the traditional Qingming Festival, also known as the Spring Remembrance Day. Furthermore, the site of this project is close to a number of national academies and research institutions, which will increase
the chance of the project being studied in the future and thus expose wood building technologies to more people. In addition, this project could gain national exposure due to the fact that it had a high level of governmental cooperation between China and Canada, including National Ministry of Civil Affairs and Sichuan Provincial Civil Affairs. (Canada Wood) Lastly, as a twin city of Kingston, Ontario, a project in Mianyang will reinforce the ties between China and Canada. (Government of Canada)

**Leigu Town elderly care centre**

Before it was destroyed by the Wenchua earthquake, the Leigu Town Elderly Care Centre in Beichuan County used to provide accommodation for 75 elderly people who did not have children to depend on. The earthquake left 202 elderly, after adding in another 127 elderly who lost their children during the earthquake, without shelter. (Canada Wood) As a result, the government of Beichuan County has prioritized the reconstruction of the elderly care centre in order to provide accommodation to those who have no one to depend on.

Although the design of the elderly care centre has not been finalized and approved, it will resemble the configuration of multi-family apartment buildings, for the same reasons explained before. Since the location of the reconstruction site is within the Qiang Minority area, it is expected that the design, particularly the design of landscaping, will integrate traditional elements of Qiang-style construction with modern wood frame buildings. This provides the coastal forest industry of British Columbia with an opportunity to introduce its value-added wood products for outdoor uses, such as the treated hem-fir and western red/yellow cedar.
Again, the selection of the site for this reconstruction project is also to increase the visibility as a major highway to the future earthquake memorial museum passes through Leigu Town. The same highway also leads to Jiuzhaigou, one of the top tourist attractions in Sichuan. Similar to the first two reconstruction projects, the Leigu Town elderly care centre also involves many national and provincial levels of governments in order to achieve a higher profile.

**The Qingchuan "Vancouver Village" Sustainable Housing Project**

**Project Background**

In November, 2008, Canada Wood signed a Memorandum of Cooperation (MOC) with the Qingchuan municipal government regarding the joint development of ‘Vancouver Village’ Sustainable Housing Project. (Canada Wood) The signing of the MOC is a strong addition to the announcement of 8 million CAD worth of donations to the post-earthquake reconstruction projects from the Federal Government of Canada.

Based on the MOC, the “Vancouver Village” Sustainable Housing Project will follow three phases:

1. Construction of three wood frame houses in Guanzhuang Township immediately;
2. Construction of 300 to 500 wood frame houses in Guanzhuang Township by the end of 2009;
3. Construction of more multi-family wood frame buildings in other townships of Qingchuan County (Guanzhuang Township is one of them).

The purpose of phase one is to introduce North American style residential houses by building three demonstration houses in Guangzhuan Township, which will provide places for technical
support and training of wood frame construction to the local community. The objective of phase two is to build wood frame buildings in Guanzhuang Township on a much larger scale and to help the local community to recover as much shelters as possible, if not all. Base on the success of phase one and two, it is expected that more wood frame houses will be built in the Qingchuan County and for the reconstruction of other townships, or even expand its reach to other counties.

According to the MOC, Canada Wood will provide technical support such as on-site training and quality assurance. It will also fund the first three demonstration houses of phase one. An important reason for the selection of the location to build those demonstration farmhouses is because Qingchuan County traditionally has a strong wood culture. After the earthquake, people are expecting seismically safe houses which are in line with their building traditions.

![Figure 11 Demonstration Houses of 80 m², 120 m², and 240 m²](image)

**Implementation**

In order to collect information on the latest development and implementation of the “Vancouver Village” project, a personal interview was conducted with the Vice President of Marketing of Canfor Corporation, Mr. Don B. Kayne. According to Mr. Kayne, who recently visited the earthquake region including the Qingchuan County (he also provided pictures of this project which are presented in the Appendix), phase one of the “Vancouver Village” project had already
been completed and construction of 2,000 new farmhouses were about to begin. Several reasons contributed to the commercialization of this project:

1. Building cycle of wood frame houses, which now takes approximately one month, is significantly shorter than concrete ones, which usually takes at least one year. This is essential for people who need safe shelter as soon as possible.

2. Government’s support after the signing of MOC encouraged local residents to purchase wood frame houses. The government provided a cash rebate payable towards people who purchase a wooden farmhouse.

3. Commitments of Canadian industry ensure the timely delivery of building materials to the job site. Since transporting lumber from mills in Northern British Columbia to Sichuan requires a high level of logistic arrangement, those commitments are important for residents in the earthquake region to believe that this industry is here to help.

**Seismic Performance of Wood Frame Constructions**

This section will look at two historical earthquakes as examples to demonstrate the performance of wood frame construction and why it has been proved to be a safer type of construction during earthquakes than concrete or steel construction.

**Performances of wood frame construction during pervious earthquakes**

**Prince Williams Sound, 1964**

On Friday, March 27, 1964, a dire earthquake occurred in Prince William Sound of the Gulf of Alaska, which was later known as the Great Alaska earthquake or the Good Friday quake. With a registered magnitude of 8.4 on the Richter scale, it became the most powerful recorded earthquake in the history of North America. (Snyder) Despite of its huge magnitude, the
earthquake caused only 131 deaths, (FII China) compared to more than 15,000 casualties in the Turkey earthquake of 1999 with a magnitude of 7.4 on the Richter scale. (U.S. Geological Survey)

![Figure 12 Earthquake Damage](image)

After the earthquake, the Geographical Institute of the University of Alaska conducted research and assessments of the earthquake, in which they explained the relatively small number of casualties and minimal damages as follows:

“The number of deaths from the earthquake totaled 131; 115 in Alaska and 16 in Oregon and California. The death toll was extremely small for a quake of this magnitude due to low population density, the time of day, and the fact that it was holiday, and the type of material used to construct many buildings (wood).” (Alaska Earthquake Information Centre)

**Northridge, 1994**

On January 17, 1994, the Northridge earthquake with a magnitude of 6.7 struck the Los Angeles region. Although the magnitude was moderate compared to other major earthquakes, the peak ground acceleration of the earthquake measured was one of the highest ever recorded in an urban area in North America and significantly exceeded the specified ground acceleration of the
building codes of the time. It resulted in death of 57 people, in an area with population of more than 10 million. (U.S. Geological Survey) One of the most important reasons for this extremely low casualty number was concluded as below:

“The earthquake occurred at 4:31 a.m. when the majority of people were sleeping in their wood-frame single family dwellings, generally considered to be the safest type of building in an earthquake. If the earthquake had occurred during the day, say at 11:00 a.m., several hundred people would have been killed at the retail store and parking garage of the Northridge Fashion Mall alone, where actually only one person was killed. Also, due to timing of the earthquake, people were not present on sidewalks to be injured from falling debris, particularly from unreinforced masonry and tilt-up buildings or falling facades from other buildings” (Canadian Wood Council)

![Figure 13 Street Damage after the Northridge Earthquake](image)

There are more than 400 million sq. ft. of public schools in California and approximately 80% of those are wood frame constructions. Numerous assessments of the damage of those buildings led us to the conclusion that:

“Considering the sheer number of schools affected by the earthquake, it is reasonable to conclude that, for the most part, these facilities did very well. Most of the very widespread damage that caused school closure was either nonstructural, or structural but repairable and not life-threatening. This type of good performance is generally expected because much of the school construction is of low-rise wood-frame design, which is very resistant to damage regardless of the date of construction” (WoodWorks)

**Why wood frame constructions are safe during an earthquake**

A number of features of wood frame construction contribute to its outstanding seismic
performance. Some of the most important features are described below to demonstrate why the modern 2x4 wood building system performs well during earthquakes:

1. Typical wood frame houses are constructed by attaching sheathings and walls to plenty of wood studs and joists. This method allows the earthquake force to travel through numerous load paths, therefore minimizing the load each studs and joists need to bear. Thanks to its large number of connections, wood frame constructions can share the load on every single connection and thus prevent structural failures in the event of the overloading on some components.

2. “Wood has high strength to weight ratio.” In other words, wood components can provide the same strength without introducing more weight to the structure. Weight not only decides the performance of a structure during an earthquake but also makes the rescue efforts after the earthquake much easier.

3. Wood frame construction has great structural flexibility as a result of its nailed connections. Consequently, wood buildings are able to flex when energy of the earthquake passes through the structure.

4. The use of structural panels such as plywood or OSB creates shear walls and diaphragms, which are very effective structural engineering systems to resist lateral loads imposed by seismic forces. (Huang)

Figure 14 illustrate when the ground movement caused by the earthquake generates inertial forces, the building is mostly hit by lateral forces which concentrate on the roof and floors due to the fact that they account for majority of the structure’s mass. Walls of the building must be able
to resist those lateral forces and the structure must have sufficient connection with the foundation to prevent failure. Many characteristics of wood frame construction contribute to its superior seismic performance. (Huang)

![Figure 14 Lateral movement of the structural caused by lateral forces during the earthquake](image)

In addition, the design of shear walls and diaphragms are equally critical to the resistance of seismic forces. For example, the structural wood sheathings, made out of either plywood or OSB, need to be thick enough to provide adequate resistance. Also, nailing capacity needs to be properly calculated to ensure shear forces imposed on the sheathing can be transferred to the floor or wall framings. Last but not least, wall framing needs to be sufficiently strong to take on tension and compression forces.

Other inherent features of wood and wood frame construction play critical roles to enhance the structure’s performance during the earthquake. Some of those features include:

- **Ductility**: wood is more ductile than concrete or masonry.
- **Weight**: wood is lighter than concrete therefore carries less force during the earthquake (due to the fact that earthquake forces on a building is proportional to the weight of the structure).
- **Redundancy**: wood frame construction typically consists of numerous structural
components and nailing connections. In other words, failure of one or a few structural components will not result in the failure of the entire building because those loads can be picked up by adjacent elements.

- Connectivity: strong connection with the foundation makes a wood frame structure perform as a single structural unit during the earthquake therefore prevents sliding or overturning.

As a result, together with proper design practices, wood frame construction has proved to be a safer construction type in earthquakes.

**Feasibility Study - Wood Trusses for Roof Renovation**

Price is always critical to any marketing campaign. However, due to the relatively low purchasing power of most Chinese families, and the fact that many materials used for building wood frame construction need to be imported, the cost factor has been a hurdle to overcome before wood frame constructions can be widely adopted in China. Following section is a summary of the cost analysis conducted by Tongji University, taken from the senior Co-op report prepared by Yi Huang.

Table 1 in Appendix demonstrates the cost structure of building a roof system and potential cost-savings by using adjusted techniques. From the table, we can conclude that costs of roofing panels and wood trusses are the majority of the total cost, which account for 44.07% and 26.71%, respectively.
Accordingly, several adjustments were made in order to reduce the total cost: Using locally manufactured plywood to replace imported OSB for the sheathing; increasing the space between each truss from 0.61m to 1.22m; adding purlins and bracings to compensate the structural strength. Table 2 in Appendix summarizes cost savings resulted from above adjustments. Total saving accounts for 28.7% of the total cost. Therefore, the improved technique has been proved to be a more cost-effective way for roof renovation and has the potential to be adopted in a larger scale.

Other Benefits of Building with Wood

In addition to its strong seismic characteristics, which has been the focus of this report, wood frame construction performs equally well in other aspects. For example, since wood is the only renewable building material, it imposes less environmental impact throughout its life cycle. The following section, partially taken from the senior Co-op report prepared by Yi Huang, will examine the environmental aspects of wood as a building material by comparing it with steel and concrete.

The wood frame construction needs less energy to warm up the same space and performs better in terms of heat retention. In other words, wood frame buildings lose their heat slower than other construction types. In addition, the production process of wood requires less energy and produces less waste therefore minimizes its impact on air, water, and soil. According to the latest research done by Tsinghua University, the wood frame construction is the most environmentally-friendly compared to other major types of construction. Its impact on the environment is less than 1/2 of concrete's and approximately 2/3 of steel's. It saves 45% and 28% energy cost of
running the building compared to concrete and steel, respectively. Given the thickness being the same, heat retention rate of wood is 16 times the rate of concrete and 400 times the rate of steel. Please refer to Figure 15 for more details.

![Figure 15 Environmental Impact – Comparison between Wood and Steel/Concrete](image)

Note: Conducted in China, this research presented a more localized result after taking weather and user’s behaviors into account.

### Conclusion

This report provides insights into how the Canadian forestry industry is promoting the benefits of building with wood in China by reviewing of a number of pre-earthquake demonstration projects and post-earthquake reconstruction projects. With the increasing awareness among Chinese people about the safety, comfort, environmentally-friendliness, and affordability of North American style wood frame houses, it is expected that the door to one of the world’s largest and fastest-growing markets will eventually open for Canadian wood products.
References


April 14, 2009
## Appendix

<table>
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<th>Parts</th>
<th>Unit Price</th>
<th>Cost (RMB)</th>
<th>Unit Cost/ Total cost</th>
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</thead>
<tbody>
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Table 1 Cost Structure of Building a Roof Using Wood Trusses
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<th>Truss</th>
<th>Decrease Truss Unit Price ( RMB/Truss )</th>
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**Table 2 Cost-saving from Adjustments of Building Techniques**
Figure 16 Construction of "Vancouver Village" in Qingchuan 1

Figure 17 Construction of "Vancouver Village" in Qingchuan 2
Figure 18 Construction of "Vancouver Village" in Qingchuan 3

Figure 19 Construction of "Vancouver Village" in Qingchuan 4