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WOOD DURABILITY ISSUES IN CHINA

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Abstract

Wood durability is a relatively new issue in China, but it is becoming increasingly important, with the development of wood use in landscaping and light frame construction. The durability challenges in China are huge, especially in the south, due to the high moisture loads, prevalence of termites and high decay hazard. The early developments of wood frame construction in China have run into some durability problems, mainly caused by not paying attention to these climatic and biological challenges. Hence, it is extremely important to incorporate proper durability measures, including durability by nature, treatment, design and quality construction, into these projects right from the beginning.

1. Background

Traditionally wood was a very important construction material in China, and it was widely used to build prestigious palaces and temples, residential houses, and landscaping structures. But wood use for construction has been decreasing with the decrease of the domestic forest resources for decades, even centuries. Consequently, the local craftsmen are no longer familiar with the techniques necessary to build wood houses, especially durable houses. Currently durability is a relatively new issue even for the academic field in China, and many professionals think of it only in terms of creosote treatment for railway ties and mine timbers.

China now has one of the biggest forest plantation programs in the world. The objective is to counteract the severe over-logging, protect the already fragile environment, and also increase the domestic wood supply to meet the ever-increasing demand from the pulp and paper, construction, interior decoration, furniture and other industries resulting from China's rapid economic development. The Chinese government has implemented the National Natural Forest Protection Program including China's Plantation Program and other forest resources related programs for two decades. These programs have enabled China to increase forest coverage from about 14% in early 1990s to the current 18.21%, with total plantation areas over 30% of all forest coverage. The plantation forests have started to produce fast-growing and high-yield wood with species such as China fir, pine, poplar and eucalyptus. There is concern not only for the mechanical and physical properties of plantation wood, but also for its long-term durability. Although second-growth China fir is still evaluated as moderately decay resistant (Xing *et al.* 2005), other plantation species have only low decay resistance. Wood source changes should proceed with more emphasis on durability measures, including preservative treatment, in order to prevent premature failure in service.

Imported wood is an important source to relieve the gap between supply and demand in China, and import of precious tropical hardwood from South East Asia for structural and furniture uses dates back centuries. In 2004 imported wood accounted for over 35% of the wood supply in China, with a volume of approximately 110 million cubic metres (Jiang 2006). In recent years, the softwood imports for construction, pulp and paper and other uses are exceeding the hardwood imports for furniture and interior decoration, making Russia the top exporter of wood to China (Zhang 2006).

The big wood shortage and the heavy reliance on imports underscore the importance of durability in order to extend the service life of wood products.

The present paper aims to give a general idea about the issues related to wood durability in China, from the aspects of local climate, decay and termite hazards, traditional durability solutions, the current treated wood industry, new development of wood construction and related durability issues, as well as recommendations on development of wood-frame construction in China.

2. Durability challenges in China

China has greatly varied climatic and geographic features across the country. In general the southern areas experience relatively high temperatures and precipitation throughout the year, with highly favourable conditions for decay fungi, termites and other biological wood deterioration agents. In order to give a better idea of the durability challenges wood construction may face in China, we can select representative cities in China including Beijing, Shanghai and Guangzhou from the north to the south on the eastern coast, and compare the monthly mean temperatures and precipitation with those of Vancouver and Toronto (Fig.1 and Fig. 2). The three Chinese cities have similar temperatures in summer, but in winter the differing latitudes lead to about a 10ºC gap in temperature between Beijing and Shanghai, and between Shanghai and Guangzhou. Both Guangzhou and Shanghai are much warmer than Vancouver, with monthly temperatures in Guangzhou over 10 ºC higher than those of Vancouver through the year. Beijing is warmer than Toronto, both in winter and in summer.

In terms of rainfall and humidity, Toronto has relatively uniform precipitation at low levels through the year, mainly in the form of snow in winter. Vancouver has a relatively dry summer, but has the highest rainfall in winter among these cities. The importance of moisture control techniques has been demonstrated in Vancouver to prevent leaky condos, though the rain events mainly happen at lower temperatures. By comparison, both Shanghai and Guangzhou have high precipitation year round, mainly with drizzle in winter and thunderstorms in summer. Guangzhou has the highest rainfall in summer. Both Shanghai and Guangzhou also experience very high relative humidity most of the year. Such a climate makes it crucially important to apply moisture control, along with other protection techniques in order to ensure the durability of wood frame construction in southern China. Compared to Shanghai and Guangzhou, Beijing is very dry, and usually has limited rain events in summer and only a few snowfalls in winter, which makes the moisture loads on wood construction much lower.

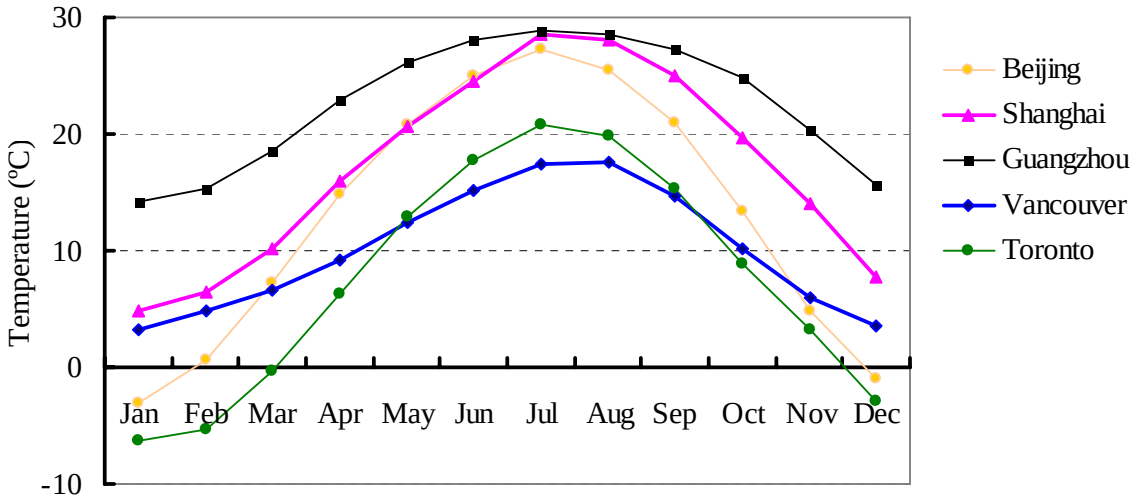

Fig. 1 Mean monthly temperatures of Beijing, Shanghai, Guangzhou, Vancouver and Toronto

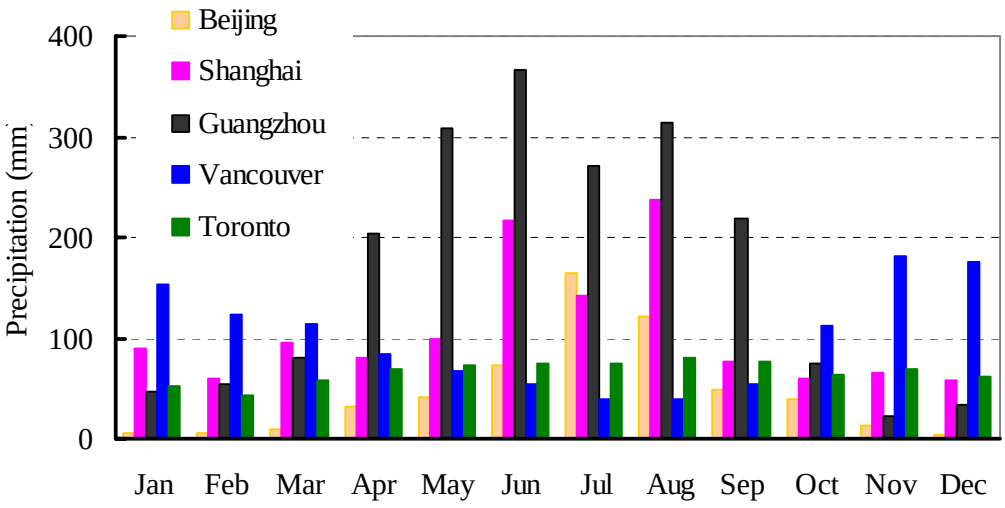

Fig. 2 Mean monthly precipitation of Beijing, Shanghai, Guangzhou, Vancouver and Toronto

Wood decay hazard is closely associated with climatic conditions, and Scheffer's climate index is a relatively popular index for quantitatively indicating decay potential for exterior above-ground wood structures (Scheffer 1971) (Table 1). Based on the calculation from climate data, Guangzhou has the highest Scheffer Index value of 131 among all these cities, indicating it is in a severe decay hazard zone for above-ground wood structures. Shanghai has a climate index just below 70, indicating moderate decay potential according to the adjusted classifications (Degroot and Esenther 1982). Beijing has a climate index of 35, just on the boundary between moderate and low decay hazard. By comparison, both Vancouver and Toronto are in moderate decay hazard zones (Setliff 1986). Despite the severe decay potential, the biggest threat to wood construction still comes from the prevalence of termites in southern China. Areas including southern Liaoning and Jilin, Hebei, Beijing, down to Sanxi, Shanxi, Sichuan and any other southern areas are in termite hazard areas. Areas including Shanghai, Wuhan and Chongqing are within the northern limits of one of the most aggressive termites, *Coptotermes formosanus* (Li 2002). The risk of termite attack on buildings in much of China is incredibly high. It is estimated that in Guangdong province 90% of houses are infested, in Guangxi, Hunan, Fujian, Hubei and Zhejiang province, 60% of houses are infested, and even steel and concrete highrises are attacked by termites (Zhong and Liu 2001). Hence, effective and practical termite management methods must be properly incorporated into the protection system of wood frame structures in China.

Table 1 Scheffer Index for Beijing, Shanghai, Guangzhou, Vancouver and Toronto

Cities	Scheffer's climate index	Remarks
Guangzhou	131	Severe decay hazard
Shanghai	68	Moderate decay hazard, close to severe decay hazard
Beijing	35	Moderate decay hazard
Vancouver	46	Moderate decay hazard
Toronto	37	Moderate decay hazard

3. Traditional wood construction and durability solutions

As a major construction material in China, especially in old times, people used wood widely to build structures including prestigious palaces and temples, landscaping in gardens and ordinary residential houses. The long historical use of wood and especially the use for prestigious construction helped develop sophisticated construction techniques. Durability must have been taken into serious consideration by skilled and experienced craftsmen, since lots of these structures last a long time even in the south, and some of them even exist today with maintenance and repair. Traditionally most palaces, temples and landscaping pavilions had post and beam structure in China. Compared with North American-style light frame wood construction, such a wood structure doesn't have complicated wall and roof assembly, and is relatively open with better ventilation, so moisture is less likely to get trapped and accumulated in wood. Large overhangs were also commonly built for these structures to prevent rain penetration.

Traditional wood construction in China usually had mixed structures together with mineral materials such as mud, brick and stone. It is more common for wood to be used for the top parts of structure, sometimes just for the roof, with stone and brick as bottom parts or as foundations. Wood columns were also usually placed on brick or stone materials instead of in direct contact with the ground.

Another important feature of traditional wood use in China is that durable species were preferably used for both wood structures and interior furniture and decoration. The heartwood of a few specific species from genera *Pterocarpus*, *Dalbergia* and *Diospyros* (ebony), with very dark color and specific gravity close to or even above 1 were taken as the highest grade wood with a specific name of "old rosewood". It includes Zi Tan, Hong Hua Li, Huang Hua Li, Wu Mu, Wu Wen Mu in Chinese. Meanwhile, other durable species such as *Phoebe* and China fir, were also builders' favourite choices. However, the forest resources for precious species were never bountiful in China, so people had to turn to the neighbour countries in South East Asia, even Africa, for durable wood. The traditional preference for durable wood for furniture and interior decoration use still exists today, and the processing techniques for precious wood species such as "old rosewood" have become so advanced and so elaborate that each small wood piece can be used to form bigger pieces of art work. But for developing modern wood frame construction for residential use in China, using preservative-treated wood where necessary, instead of naturally durable wood, is certainly more practical and affordable.

4. Treated wood industry in China

Compared with using naturally durable wood species, the wood preservation industry in China has a much shorter history. It started in Northeast China in the 1930s for treating railway ties. Affiliated with the original Ministry of Railway, dozens of state-owned treating plants across the country boomed between the 1950s and 1970s, with peak production of about 1 million cubic metres of treated railway ties in the 1970s (Zhang *et al.* 2004). However, the production of treated railway ties has been declining since the 1980s due to the increasing timber shortage and the high cost of timber imports. The government turned to the use of concrete railway ties instead of treated wood except for railways at critically important points. Currently there are a few of the original large-scale treating plants still operating. Some of these treating plants have transformed to include water-based preservatives instead of creosote only, and are competing with foreign treated wood companies and dozens of private treating mills in the landscaping-use treated wood market.

Current applications of treated wood in China mainly include creosote treatment of timber for key parts of railways, boric acid treatment of rubber wood for furniture, and CCA and ACQ treatment of lumber for construction and landscaping, with the domestic treated wood volumes about 200, 200, and 250 thousand cubic metres, respectively (from conversation with Dr. Mingliang Jiang, Chinese

Academy of Forestry). Despite the phasing out of CCA for most residential uses in North America and other countries, CCA is still the dominant water-based preservative in China, and ACQ is only used for specific demand with very limited production. Professionals in China still have concerns about ACQ in terms of efficacy, reliability, appearance, and long-term durability performance, as well as the higher cost of using ACQ in the absence of strict environmental laws. In contrast to the systems in other countries with preservatives used by treating mills supplied by big professional chemical companies, most preservatives in China are formulated and made by treating plants themselves, by research institutes, or by bigger treaters in the case of small plants. As a result the quality of preservatives is always a big concern. Two industry standards on wood preservation, one on wood preservatives and the other on use category and specifications, have been issued in China in early 2006. Dr. Paul Morris of Forintek participated on the drafting committee. However, it takes time for these standards to be implemented and followed by the domestic treated wood industry to improve the quality of treated wood and preservatives.

The development of the domestic treated wood industry using water-based preservatives has been stimulated and accelerated by the marketing and branding efforts of foreign companies profiting from the economic boom in China in recent years. Before that, CCA was only occasionally used for treating railway ties and utility poles by individual mills with very limited production. The use of treated wood for exterior construction and landscaping such as walkways, pavilions, street side benches and planters, is really catching on in cities in recent years. Wood, even with preservative treatment, really brings natural beauty, lightness, and relief from heavy and crowded concrete blocks, together with the special familiar feeling of rehabilitating historical wood use. Such a concept has been adopted and incorporated into city greening programs by more and more Chinese cities, mainly on the relatively developed east coast. There are several foreign players in the Chinese treated wood market. FinnForest was the pioneer and started in China early in 1997. It was followed up by Hoover with treated southern yellow pine, then by companies from Canada, New Zealand, and France. Imported treated wood was almost the only source of water-based-preservative-treated wood for exterior construction use before 2002. Currently with the catching-up by the domestic industry, despite the much higher price, imported treated wood is still widely accepted due to the marketing and branding efforts by foreign companies, high treated wood quality, and good service. It is estimated that the volume of imported treated wood in 2005 was about 100 thousand cubic metres, five times the imports in 2002 (Zhang *et al.* 2004; Chreod Ltd. 2006). However, the competition from the domestic industry is increasing.

5. New light frame construction and related durability issues

North American-style wood frame construction development in China can be traced back just to the late 1980s and early 1990s. Canadian companies have been heavily involved in designing, building, education and training in China. As of 2006, there have been over one thousand house units built in China, mainly in Shanghai, its surrounding areas and Beijing. The characteristic feature of the early development is almost all building materials including lumber, sheathing materials, shingles, siding, doors, windows, plumbing materials, even electrical appliances and furniture, together with drawings, were shipped from North America, and the construction was even done or at least supervised by people from North America, forming so-called one-package projects. Based on Forintek's house survey project funded by BC's Forest Innovation Investment Ltd., the biggest durability problem with early developments in China is that they were not built for the specific climatic and biological hazard in certain Chinese cities, mainly due to the very dissimilar climate, decay and termite hazard from Canada. Most people involved may not have had much awareness for the potential impacts of climate and other wood deterioration agents on the performance of wood houses, though they may have taken structural issues very seriously. The overlooked details included improper wall, roof, foundation and other assembly design and construction, which led to problems such as leakage and condensation, and other systemic moisture control problems.

Moisture-related problems could also have been caused by detailing such as poor, even absent, flashing between different roof surfaces, between roof projections and roof, between wall and slabs, between window and adjacent walls, etc. Durability problems could also have arisen from little attention to potential termite attack, and improper use of wood materials such as using interior-use particleboard for sheathing, and using untreated wood outdoors in severe decay and termite hazard areas. More attention should also have been paid to the reality in China that most people are not used to and not prepared to do maintenance work for houses to achieve durability.

Considering the severe decay and termite hazard, as well as other issues with wood-frame construction development, the most suitable applications of wood construction in China, especially in the south, have been suggested to be hybrid structures including wood roof and wood frame construction on concrete buildings, using wood for exterior and interior decorative uses and treated landscaping. The hybrid structures reduce the durability challenges greatly and are consistent with the traditional durability solutions for wood structures in China.

6. New landscaping uses of wood and related durability issues

While the image often associated with China's boom is a forest of cranes and highrises, new parks are a key component of China's strategy to keep cities liveable. In Shanghai and Hangzhou especially, entire city blocks of old buildings have been torn down to create parks and squares. While many of the earlier greening projects used all concrete landscaping, including fake wood-look components, more recent efforts have used considerable amounts of treated wood and tropical hardwoods. Typical uses include boardwalks, bridges, observation decks, gazebos, raised beds and retaining walls. Most of the wood used is CCA treated Scots pine treated in Finland, Russian or Chinese Scots pine treated in China, SPF treated in Canada and Southern pine treated in the USA. Some of the Canadian SPF has been incised to improve penetration for ground contact uses but this has not been done with Finnish or locally treated wood. Other than the southern pine, all this material has untreated non-durable heartwood which is commonly exposed in fabrication of structures and rarely if ever field treated. As a result there have already been some early failures of treated wood in parks in China (Chreod Ltd 2006).

Observing treated wood use in China is a bit like standing on the Indonesian coast and watching the sea sucked away. You just know there is going to be a Tsunami coming back the other way. Right now China is importing large amounts of treated wood but their domestic industry is developing in leaps and bounds. Paul visited a company that had been importing treated wood from Canada. They made enough money to build a treating plant. They imported untreated wood from Canada and made enough money to build a sawmill. They imported Russian logs, sawed them up, treated the lumber and had just made enough money to build two new treating plants. In our view, the importance of ensuring China gains confidence in the durability of wood is less about creating markets for Canadian lumber and more about creating markets for cheap Russian lumber to stop it swamping our existing markets.

7. Canadian and Forintek's efforts on ensuring durability in China

As mentioned above, Canadian organizations have been playing a leading role in helping develop North-American style wood frame construction in China. Earlier involvement was by individual Canadian companies, probably with support from the government. With the launch of the Canada Wood Export Program by the federal and provincial government in 2002, in partnership with some wood products associations, Canada Wood offices have been established in both Shanghai and Beijing. This has turned the Canadian efforts into a team effort and individual companies' brands to a collective brand of Canada to promote wood-frame construction and wood products in China. Our Canada Wood colleagues have been making tremendous efforts in promoting Canadian products,

eliminating market barriers, providing technical support, and helping China develop relevant codes and standards, as well as providing training and education in China.

As Canada's national wood products research institute, Forintek has been playing a very critical technical role in developing wood-frame construction in China. The core work of Forintek's involvement in China is helping develop relevant standards and codes, and Forintek scientists have been involved in developing codes including the National Code for Design of Timber Structures (GB50005-2003) and the National Code for Construction Quality Acceptance of Timber Structures (GB 50206-2002). Currently they are heavily involved in developing Shanghai local wood frame construction code. Forintek's Durability and Protection Group, led by Dr. Paul Morris, has been trying to ensure the durability of wood frame construction in China. In addition, some Canadian companies, especially treated and untreated lumber suppliers, have also been providing technical support for proper use of wood in China. The opening of the Canfor Centre of Wood Frame House Construction, in collaboration with the Shanghai Institute of Technology and other Chinese organizations, has created a unique approach for delivering the necessary education and training on wood frame construction.

7. Recommendations and future work

Most Chinese people are not familiar with modern wood-frame construction and also lack confidence in its durability. Hence, it is critically important to protect wood frame construction from moisture, decay and termites right from the beginning of the development. In doing so, it is important to continue to assemble a database on climate, decay and termite hazard for different areas of China, and it is particularly important to properly adapt the building envelope design to the specific climate in terms of effective moisture control, use treated wood where necessary, and incorporate integrated termite management methods in termite hazard areas. It is fundamental to provide good and straightforward practice in terms of effective durability measures, and eventually reinforce it into relevant codes and standards. Education and training are also critical to implement the good practice, relevant standards and codes, as well as instilling confidence in wood frame construction in China.

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