Feasibility study on further utilization of timber in China

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Abstract. The use of timber in building industry has expanded in many countries over last 20 years due mainly to its lightweight, little adverse impact to the environment, and strong anti-seismic properties. Despite the fast development of the construction industry in China in recent years, timber products utilization is still very limited. Therefore, the purpose of this study was to investigate the feasibility to further utilize timber based products in the building industry in China. A review of engineered wood products utilization in China, and overseas was conducted first. The general properties of timber products were followed. Based on this, a survey focusing on the current situation and suitability of localised grown timber products was carried out to study the feasibility. This paper concludes that timber based products have a great future in China. It recommends that is imperative to further research how to promote timber’s utilization in China to be in line with the sustainable development.

1. Introduction

Timber is a traditional material used for construction in ancient China. Wood as a material is natural, created during a tree growth, and mature trees of whatever type can be source of structural timber [1]. In general timber can be characterized by high strength, high durability and good finished appearance.

Timber resource distribution in China is uneven. There are three main forest regions: northeastern China and Inner Mongolia (28% of forest area), Sichuan and Yunnan provinces in southwest (19%), and 10 other provinces in southern China (36%), which total forest areas occupy 83% [2], see figure 1. The dominant timber species are fir, oak, pine, Yunnan poplar, birch, spruce and eucalyptus [3]. Compared with the northeast traditional forests that Coniferous trees like Pinus koraiensis, Larix, picea and red spruce, coastal region (southeast forest region) is an important forest region which produce the fast-growth trees and industrial material forests, such as cedar, eucalyptus and horsetail pine.

Figure 1. China’s three main forest area location (10 million ha) [2].
2. **Current utilization of timber in China and other parts of the World**

Based on the National Forest Investigation in 2014, usable forest is about 62.9308 million hectares. Compared with the seventh National Forest Investigation in 2008, it has increased by 2.8564 million hectares. However, China's average volume of standing timber per hectare is 73.13 m², which is just 69% of the world average. Having in mind the deforestation in the 20th century, the situation of forestry in China is described as having inadequate forest resources and declining in forest quality [3]. Besides, insufficient forest resources, the limitation of feeling trees adopted by the NFPP (Natural Forest Protect Program) also widen the gap of China's timber supply and demand [2]. During the Great Leap Forward (an economic campaign of P. R. China from 1958 to 1961), the number of forest resources began to decline and until the late 1970s the forest resources nearly depleted. Since 1980s, there is no development in timber construction field in China [4]. From then on, due to the shortage of timber resource, government set strict rules to limit the use of timber and appealed to use steel and concrete. Thus, the timber construction decreased rapidly and the relevant studies were stopped [5]. Nowadays, supply shortage of the wood resources has become the bottleneck of the further development of the national wood industry. The production of timber plantation cannot meet the increasing demand of wood consumption, so import is considered to be the primary solution to this issue.

When timber construction development stagnated in China, it progressed rapidly in other countries [4]. Take Canada as an example, timber industry has become one of the pillar industries; the standards and technology have developed well [6]. In China, merely 1% of new residences are built with timber; only 26% of wood based panels are used as construction materials and most are finishing material. In comparison, timber utilization rate in construction among Canada, USA and Japan are over 40% [5].

In USA vast majority of the low-storey apartments are timber or half-timbered structures [7]. 1.5 million residences are built in America annually and 70% are timber [8]. And in Japan, timber residences count for about 45% of the total residences, and apartments that under 4-storey are almost all in timber construction [7]. In addition, multi-storey and large-span timber constructions have become two focuses since the development of cross-laminated timber (CLT), Glulam and structural composite lumber (SCL). Many countries, such as Japan, Canada, USA and European ones, have set standards relevant to multi-storey and large-span timber construction to guide the design and construction [9, 10].

3. **Physical properties of timber**

Timber is a Visco-elastic solid material affected by instantaneous elastic and creep deformation, and its elasticity is primarily related to water content, density and angle between loading direction and grain. Due to the hygroscopic nature of timber, creep is accelerated by moisture variations, resulting in the mechano-sorptive effect [11]. Timber is anisotropic, making the properties have much higher stiffness and strength parallel to grain than across the grain. In addition, mechanical properties of timber vary with moisture content, density and type of loading.

Timber is the only primary material that comes from a renewable resource. Timber is reusable, recyclable and biodegradable and the growth cycle is repeatable. Compared with other commonly used construction materials, timber possesses the characteristics of low thermal conductivity, high strength to weight ratio resulting in less labour and machinery when using in construction shown in table 1. Besides, manufacturing of timber products needs much less energy than other materials [1].

| MATERIAL            | DENSITY (kg/m³) | STRENGTH (MPa) | STRENGTH/DENSITY $[10^3$ MPa.m³/kg] |
|---------------------|-----------------|----------------|-------------------------------------|
| Structural steel    | 7800            | 400-1000       | 50-130                              |
| Concrete (compression) | 2400       | 30-120         | 13-50                               |
| Clear softwood (tension) | 400-600   | 40-200         | 100-300                             |
As for the disadvantages of the timber, its moisture content and anisotropic nature can influence the strength of timber. The dry shrinkage and wet expansion characteristics will change the size of the timber, and the difference of shrinkage and swelling in each direction can cause the cracking and warping due to its anisotropy. Additionally, according to tests on large numbers on small clear specimens, there is a significant variation in strength of similar specimens [12]. Hence, the large variability of timber is another disadvantage that needs to be considered. Moreover, timber has high tendency to deteriorate, from bacteria, fungi, insect, chemicals, mechanical, sunlight, water and fire. To mitigate these processes, some measures have to be adopted such as seasoning process, so that to prevent the timber from possible decaying and make it suitable for use. Beyond that, timber itself has natural defects due to abnormal growth; shakes, rind gall, and wane-edges. All of them can weaken the applicability of timber [1].

4. Challenges and potentials with new developments

4.1. Engineered wood products

In the traditional Chinese buildings, logs and sawn timber are normally used for roof, floor, and wall framing. Recently, engineered wood products are produced, by processing the natural material, to maximize the properties. It results in improvements of technologies and new products of better parameters than of natural product allowing utilization of species that were not considered before [3].

Engineered wood products consist of broad class of structural wood products that are commonly used as structural materials in construction. These products are made from veneers, strands and sliced wood, which are grouped into a specific structure and then bonded together with adhesives to make panels, timber-like or shaped structures by high-pressure and/or high-temperature. There are several typical engineered wood products, like veneer-based material such as plywood, composite material such as oriented strand board (OSB) and laminates such as cross laminated timber (CLT) [12].

4.2. Challenges from Chinese perspective

A few reasons explaining why timber is not widely utilized in constructions in China have been identified. First of all, there is no proper policy to support timber constructions in China. According to Design of Timber Structures GB 50005-2003 [13] the number of stories is confined to only three, and the maximum length as well as area of building are also limited. Chinese designers have been familiar with concrete and masonry construction rather than timber constructions. Thus, if developers want to build using timber, it will cost much more than with traditional materials, because they need to employ designers with high expertise, mainly from abroad. Moreover, complex technology and trained employees are required for production, construction, and maintenance, which increase costs of these further steps. Currently the technology of timber and engineered-wood is not suitable for skyscrapers. Until now, the highest wooden building using CLT in the world, is 53 meters tall; Brock Commons which located in Vancouver at the University of British Columbia [14]. And China has the significant acceleration of urbanization, and there is huge demand for very high buildings. Lastly, common perception on timber, as being not a solid material and there are doubts about its fire resistance, especially in comparison to reinforced concrete, is also a barrier [10].

4.3. Potential to be used in China

First of all, concrete as a main resource of construction in China, has caused a severe problem to the environment. To mitigate the problem of vast energy consumption and severe environmental impact, timber can be used as construction material since it is renewable, durable, energy-efficient and cost-efficient, acting as substitutes of concrete to some extent. Concrete buildings in China are more than 99% of the total amount [5], therefore the potential for timber is great enough, even due to possibility
of changing this monotony in using mainly concrete. Furthermore, since natural forest recovery, artificial forest, timber resources are abundant enough to resume the utilization in China.

New technologies within engineered-wood products have been researched and developed recently in China and other countries. Products such as glulam, OSB and CLT rely mainly on import, so there is a gap for local producers. With the more advanced technology, engineered-wood products are more likely to be competitive, in cost, suitability and sustainability, than other traditional materials. In addition, a series of standards related to timber buildings are under development and review in China. In 2015, the policy was introduced that 30% of prefabricated materials should utilize wood in Chinese construction industry by 2025 [15]. Furthermore, the height limit is being to be increased from three to four for timber buildings soon in China. With these specific construction standards, timber is more suitable for the particular areas of China, especially those urban areas where low-rise house is allowed only and suburb areas with lower land price and beautiful scenery.

There is an increasing demand for the villa-type wooden structure houses in metropolitans such as Shanghai, Beijing and Shenzhen, and timber structures. Furthermore, because of living habits, foreigners who work in China are another potential group that inclines to timber-framed building. Another possible potential for timber is related to active seismic zones in China. Light weight and ductility of timber allows it to absorb seismic energy without collapse. This has been proved only timber-framed structures were intact in Wenchuan earthquake in 2008, while other buildings were damaged badly [16].

5. Survey results and analysis

To investigate the current situation and suitability of Chinese-grown timber for the manufacture of laminated panel a survey of the construction industry was made. A questionnaire was designed (in Chinese and English language) consisting of over 20 questions related to current usage of different materials for construction projects, and predictions for future, based on the current trends. Feedback was obtained from carefully selected 9 industry members representing consulting and architecture companies who are the main decision-makers on the type of the construction material used for the projects.

From feedback, participants were mainly from private companies (7 participants) with less than 300 employees and the other two participants represented public company and public institution. Their field of business covers consulting (5 of 9), architecture (3 of 9) and research (1 of 9). Although area served are national (77.8%) or worldwide (22.2%), their companies are concentrated on Shanghai and Suzhou, Yangtze Delta Region. As presented in figure 2, almost all participants (8 of 9) mentioned that they used solid wood before, and some used Glulam (4 participants), laminated-veneer lumber (3), I-joist (2) and OSB (2) on their projects. Also recently developed composites: CLT (1 participant) and bamboo structural elements (2 participants) were used in their projects in China.

The three most important characteristics that participants take into consideration when selecting materials are strength (66.7%), durability (55.6%) and fire resistance (55.6%), see figure 3. However, material cost (44.4%) and construction cost (44.4%) are also important for these companies. In terms of the familiarity with engineered-wood products, more than half (5 participants) only heard about them but have never used; two participants had limited contact with engineered-wood products and know the functions and three are familiar with engineered-wood products well.

![Figure 2. Participants’ response on ‘Wood-based products that used before’.

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Based on results, CLT is seldom used, which is consistent with the current situation in China. Moreover, there is no specific answer about which type of construction has the highest potential for using CLT. With regard to the possibility of using CLT in the future, three participants think CLT will not be used and five consider the possibility is less than 50% in the next two years, while one people expects it is high possible (larger than 50%) to use CLT in the next projects. From the perspective of the companies, availability in the market and material costs are the biggest barriers that limit the use of CLT, which was pointed out by seven participants. Other factors include technology (2 of 9) and strength performance (2 of 9). In addition, both literature review and questionnaire results have highlighted lack of knowledge of the material has limited its usage.

The participants of the survey were asked to rank the materials: CLT, engineered bamboo, steel, concrete, masonry and timber-frame from the different aspects. According to overall tendency of the feedback, the characteristics of these construction materials can be concluded generally in a way as shown in table 2. Timber products were considered as well performing in the aspects of aesthetics, maintenance cost and environmental friendliness. It was found that engineered-wood products can be cost-efficient. In addition, its durability and strength performance can be as good as concrete and steel; some are even better with the special manufacturing. And for fire resistance, although fire will ignite timber, it takes time to burn the structure to collapse.

Table 2. The characteristics ranking of construction materials.

| CHARACTERISTIC                          | BEST             | WORST            |
|----------------------------------------|------------------|------------------|
| Acoustic performance                   | Concrete         | Steel            |
| Aesthetics                             | Engineered bamboo| Steel, Masonry   |
| Availability in the market             | Concrete         | CLT              |
| Material cost (low to high)            | Concrete         | Steel            |
| Construction cost (low to high)        | Masonry          | Steel            |
| Maintenance cost (low to high)         | CLT              | Steel            |
| Durability                             | Concrete         | Timber-frame     |
| Strength performance                   | Steel            | Timber-frame     |
| Fire performance                       | Concrete         | Timber-frame     |
| Environmental friendliness             | Timber-frame     | Concrete         |

6. Conclusions

The results presented in this study clearly demonstrates that engineering timber could be further used in construction industry in China due to its advantages. It should be noted, however, there are many obstacles resulted from engineering timber technology development and lack of relevant legislations, design and construction codes. To improve the situation, it is suggested that more research effort from the main stakeholders, such as government and universities, in the construction industry in China should be made to address different aspects of timber’s further utilization. Moreover, the industry survey revealed that bamboo can have great potential in China due to the availability and properties. It
is recommended that comprehensive studies on utilization of bamboo in constructions should be performed.

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