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# Research in Japan #1

# sustainability
# timber structures in cities

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Seismic Performance of Wooden Buildings

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## 1. Background: Japan and its forests

Japan can be said is one of the most densely populated countries in the world. Most of the population is living in cities in the crowded lowland plains along the coast, which however account for only 16 percent of the total land area. On the other hand it is a land of mountains and dense forests. Hilly country and steep mountains make up nearly 80 percent and approximately 67 percent of the land area is covered with forests. In these upland and highland areas the population density is very low.[1]

A particularly interesting aspect in the Japanese uplands is called *satoyama*, which is an area encompassing human settlements and ecosystems, a rural environment mostly comprising of secondary forests surrounding villages intermixed with farmland, ponds as water reservoirs and grasslands or meadows, all of it cultivated and carefully stewarded by human activity. *Satoyama* is located between urban areas and primitive natural areas or forests starting at the foot of a mountain (*sato* means village and *yama* means mountain). This beneficial environment has traditionally provided food, charcoal as fuel and other material goods to the rural community, as well as helped in preventing natural disaster such as landslides or floods. Here the people developed successfully a sustainable system between nature, forestry, agriculture, and community.[2]

The use of wood and its products like timber and paper from everyday products to houses, shrines and temples is deeply rooted in the Japanese culture, in contrast to the dominant use of stone or metal as in other cultures. But despite the high percentage of land area covered with forests the domestic forest industry is in steady decline since its peak output in 1967, when it became more economical to import cheaper wood from abroad. The self-sufficiency rate for wood and wood products was just 20.3 percent in 2006, which means that Japan depends mostly on imports.[3] Furthermore the absence of human intervention and forest management has rendered many neglected or abandoned forests even more economically unviable. The majority of the rural population has moved to the large cities in the postwar period. Subsequently the overall functioning of *satoyama* has been in steady decline over the last half a century.

## 2. Challenges for timber structures

Timber is one of the oldest building material used for construction.

The natural availability of wood and the regenerating capacity of forests has secured the supply for thousands of years. At the Horyu-ji temple area in Nara prefecture some of the oldest surviving wooden buildings not only in Japan but in the whole world are still standing. The wood used for the *shinbashira* or center pillar of the five-storey pagoda is estimated to have been felled in A.D. 594, which makes it the oldest surviving timber structure in the world.[4] This example illustrates how long-lasting wood can be.

But despite this outstanding example of fine and long-lasting timber architecture, wood is very often regarded as weak in terms of fire safety or seismic stability in comparison with buildings made of concrete for example. In Japan, a country prone to earthquakes the fires that follow a major earthquake are the most devastating. When multiple fires start simultaneously covering a large area and spreading quickly in densely built areas, they easily exceed the capabilities of firefighting services, as happened during the 1923 Kanto Earthquake and the 1995 Hanshin Awaji Earthquake.[5]

But even so wood is a burnable material it has a much better performance in case of fire when compared with steel on the other hand. The reason, why wooden, especially older buildings are very often regarded as not being safe enough has many reasons. At the time of construction the fire regulations were supposedly less stringent than nowadays, which account very often for a lack of fire resistant doors, windows, stairways, walls and floors. Furthermore these buildings have very often a limited access in general and especially for a modern fire brigade, which makes it difficult to limit the damage imposed by a fire.[6]

Subsequently very often legal restrictions have been imposed that limit the use of timber as a structural member. So the possibilities to use wood or timber as a building material not only for surface treatments but for the structural and load-bearing elements depend mostly on the building regulations and vary greatly between different countries. Whereas in America and Scandinavia almost 90 percent of all housing buildings are made of wood, in Switzerland on the contrary, otherwise a country proud of its forests, the market share of wooden housing buildings was only 10 percent in 2003.[7]

To increase the fire safety of wooden buildings different approaches are possible.

A) A traditional approach, which was mainly used in historic buildings, like timber frame houses in Europe, is to overdesign the loadbearing elements. By doing so and in case of a fire the reduction of the loadbearing section will not have any severe impact on the stability of the structure.

B) The use of flame retardent oils or paints can increase the fire safety, but the risks for health and / or the environment when applying these oils or paints need to be considered.

C) Smart fire fighting concepts utilizing automatic fire detection and fire sprinkler systems will help in increasing the fire safety. The large difference of up to 90 percent of housing buildings made of wood in

America and Scandinavia but less then 10 percent in Switzerland could be explained with the installation of sprinklers, which are common in America and Scandinavia but not so in Switzerland.[8]

D) To cover structural elements like ceiling, beams and columns made of timber with fire resistant materials, commonly used are plasterboards or gypsum boards. By encapsulating they increase the performance of the loadbearing structure but render the wood surface virtually invisible.

E) Composite structural systems of timber with a fire resistant material like concrete, for instance in ceilings where timber is used as a self-bearing formwork and lower half of the composite floor system (see example 'Esmarchstrasse 3, Berlin, Germany' in chapter 5.1).

F) The required fire resistance may not be the same overall in a building, it may be higher for evacuation routes than for other parts. In this case the parts with the higher demand may be build in concrete, but the other parts in timber. Sometimes only partial elements like the facade may be build in timber (see examples in chapter 5.1).

How to improve the seismic stability of buildings has been largely tested by the Japanese National Institute for Earth Science and Disaster Prevention (NIED)[9] ranging from one family houses to a seven-storey wooden building. The low dead load of wooden buildings has a positive effect as the forces onto the structure are much lower in comparison to concrete or stone buildings. The results have been impressive, showing that earthquake resistance can be achieved with timber structures.[10]

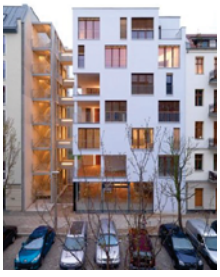
3. Prospects

Even so there have been many reservations against the use of timber as a reliable structural building material mainly due to concerns of fire safety and seismic stability, recent research in these fields has on the contrary proved the reliability of timber structures. National building regulations have started to include the research results and opened the door for a wider use and application. For instance in the case of Switzerland, new building regulations were introduced in 2005, that allow for wooden buildings up to six storeys and wooden facades up to eight storeys in height. These new building regulations are expected to boost the market share of timber structures, as for multi-storey buildings it was virtually zero.[11]

But also in terms of construction cost, wood performs well. Timber frame construction shows a 10 to 20% cost advantage over the equivalent concrete or steel construction. It is lighter and easier to work with, reducing the need for heavy machinery. Timber structures can be largely prefabricated, which helps in making the whole construction process faster. Furthermore there are no wet trades that are time consuming like waiting for concrete to cure as an example.[12]

Another important issue is the discussion about sustainability and environmental friendliness of building materials, where wood has many major advantages in comparison to all the other standard materials like steel or concrete.

Picture 1



Picture 2

Picture 3

First of all it is a renewable resource. Secondly, during their lifespan trees are absorbing large quantities of carbon dioxide, which they process and partially store as carbon in their biomass and partially release as oxygen into the atmosphere. As long as the biomass is not decomposed or burned they act as natural carbon stores or sinks. The substitution of sustainably produced wood material for other construction materials can reduce greenhouse gas emissions cheaply, efficiently and quickly.

Furthermore wood in form of trees and forests is widely and locally available. It doesǹt require a lot of energy for transport or large facilities for production and treatment. An increase in the demand of wood can create new employment opportunities in the manufacturing industry which are very often located in rural areas. This may help the domestic forest and wood industry to regain some of their lost market shares and improve the viability of the Japanese forests. It will also enhance the availability of other raw materials like sawdust and wood chips, that could be used in the bioenergy sector. Thus the wood industry can even partly produce the needed energy for processing in a sustainable way.[13]

On the other hand the Japanese wood and forest industry is working hard to regain some of its lost market share and become more competitive against imports. One issue is to reduce production costs. Due to the steep mountainous areas of the forests the production costs were in general much higher than in rather flat countries like Canada or northern European countries. A higher grade of mechanization is expected to dissolve this problem.[14]

## 4. Conclusion

So should we build timber structures in cities?

The answer is definitely yes. In some countries it is already the dominant building material for housing buildings. The ongoing research has proved the reliability of timber also in case of fire safety and seismic stability. A wider application can provide new opportunities for wood and forest industry in especially rural areas and increase the overall functioning and sustainability of forest management.

## 5. Examples of multi-storey wooden buildings

### 5.1 Germany

(Picture 1)
Residential and office building
Wiesbaden, Germany, 2001
six-storey wooden facade
architects: Altmann und Zimmer, Wiesbaden, http://www.a-z-architekten.de/

(Picture 2)
Esmarchstrasse 3, Berlin, Germany
seven-storey building, combined wood, steel and concrete structure
architects: Kaden + Klingbeil, Berlin, http://www.kaden-klingbeil.de/

### 5.2 Switzerland

(Picture 3)
Holzhausen MFH, Steinhausen ZG, Switzerland, 2005-2006
six-storey building, the first in Switzerland, 9 apartments[15]
architect: Scheitlin_Syfrig+Partner Architekten AG, Luzern, http://scheitlin-syfrig.ch/

5.3 Austria

(Picture 4)
INFRACOM, Griffen, Austria, 2000
elevated three-storey office building[16]
architect: Edmund Hoke, Grafenstein, http://www.hoke.at/

5.4 Sweden

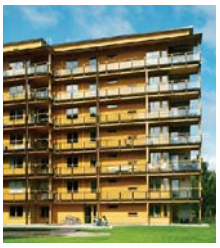
(Picture 5)
Välle Broar (Limnologen), Växjö, Sweden, 2006-2009
4 eight-storey buildings, 134 apartments[17]
architect: Ola Malm, Arkitektbolaget, Växjö

(Picture 6)
Inre Hamnen (Inner Harbour), Sundsvall, Sweden, 2004-05
5 six-storey buildings, 94 apartments[18]
architect: Susanne Åström, White Arkitektkontor, http://en.white.se/

For information on further realised multi-storey wooden buildings in Austria since 1996 see http://www.proholz.at/werke_holz/holzbauten1.htm

For information on further realised multi-storey wooden buildings in Germany and other European regions see http://www.wegezumholz.de/index.php?id=41

Picture 4


Picture 5


Picture 6

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Pictures

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