Tall wood, strategies on sustainability for the cities of the future

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ABSTRACT
The growth of cities and population is leading to an increase in housing demands around the world. The challenge lies in how to satisfy that demand by minimizing the environmental impact. The reduction of greenhouse gas emissions needed to minimize climate change cannot be performed by the simple repetition of old solutions. This challenge means that new solutions have to be implemented. Wood is the only construction material that is grown by the sun and has the capacity to store carbon. Sequestering carbon dioxide from the atmosphere is an attribute that may prove relevant in the future of architecture. Wood derived products are increasingly technological, and while regulations slowly adapt to the new situation, architects are becoming more interested in designing wood buildings. In Michael Green Architecture we have been leaders of the revolution that involves building with wood. We have demonstrated that it is technically possible to build a 35 storey wood high-rise. The positive effect of the change in paradigm in new architecture can reach beyond the environmental benefits.

Wood is a special material that comes from nature. Just as snowflakes, no two pieces of wood can ever be the same. Wood is like mother nature's fingerprints. Wood construction incorporates those fingerprints in our buildings connecting us to nature.

Today, half of us live in cities (United Nations, Department of Economic and Social Affairs, Population Division, 2016) and that number is expected to grow to 66 per cent by 2050 (United Nations, Department of Economic and Social Affairs, Population Division, 2014). As a consequence, 2,5 billion people in the world will need a new home over the next 25 years, a number that represents 36 per cent of the world population (United Nations, Department of Economic and Social Affairs, Population Division, 2014). Nearly one out of three people living in cities today, live in slums (UN Habitat, 2016) and 100 million people in the world are homeless (Kothari & UN Commission on Human Rights, 2005). The challenge for designers and society is to find a building solution to house this people.

In addition to the necessity to solve the housing problem for so many people, we have to consider the environmental impact of the selection of materials, the construction systems and architectural design. Cities are built mostly with steel and concrete. Steel is a material of the 19th Century and concrete was incorporated to architecture in the beginning of the 20th Century. Both materials are widely used in construction today and involve very high energy and greenhouse gas emissions in their processes. Steel represents about four per cent of man's greenhouse gas emissions (Worldsteel Association, 2016) and concrete is over five per cent (US Energy Information Administration, 2011). The overall emissions of building industry in the USA represent 47 per cent of total emissions (US Energy Information Administration, 2011).

Ultimately, the clash of climate change and how we solve the problem of serving those 3 billion people that need homes are a head on collision about to happen or already happening. The reduction of greenhouse gas emissions needed to minimize climate change cannot be performed by the simple repetition of old solutions that have demonstrated their effect. This challenge means that we have to create new solutions.

The first question we have to address is: what are those alternatives? Any alternative we think about ultimately has to do the two things that we always have to do when we are talking about tackling climate change. Those are, to reduce our emissions and to find ways to store carbon. In the building industry there are few materials that do that. Wood does both. Together with high speed of construction, accuracy and technical and structural performance, building with wood offers low emissions while sequestering CO_2 from the atmosphere (Figure 1).

Wood is the most significant material that we can build with that is already grown by the power of the sun. A tree that grows in the forest gives off oxygen and sucks up carbon dioxide. When it dies and falls to the forest floor, it gives that carbon dioxide back to the atmosphere.

If it burns in a forest fire it will give the carbon dioxide back to the atmosphere as well. But if that wood is properly cut and made into a building, a piece of furniture, or a toy, it will keep that carbon stored during its operating life. In other words, wood used in construction provides us with a sequestration of carbon from the atmosphere. The capacity to store is such that a single cubic metre of wood can remove from the atmosphere up to a tonne of carbon dioxide (Frühwald, 2007)[1]. The wood in a single typical Canadian home sequesters 28 tonnes of carbon dioxide from the atmosphere (Green, 2011).

In this century, we have to move towards a new building ethic that relies on the earth to grow our homes. How can this be achieved if we only build four storey wood structures? To achieve reduction of greenhouse gas emissions, there is a need to reduce the use of concrete and steel and design bigger wood buildings.

During the last decades the evolution in wood products has provided architectural possibilities we didn't have before. The invention of glulam in 1872 by Otto Hetzer in Weimar, Germany, ignited a radical change in the design and building of wooden structures. New products have been engineered and incorporated to the architect's palette, among them, mass timber panels. These are panels made with young trees, small grown trees and small pieces of wood glued together to make panels that are enormous: Those panels are named CLT (cross laminated timber), their dimensions being 8 feet wide, 64 feet long with various thicknesses (Figure 2).

In North America, we are used to thinking in terms of 2 x 4" construction when we talk about wood. This is a standardized system with which most of the housing has been built in the USA and Canada. Building regulations have been limiting the height of wood buildings in British Columbia to a maximum of 4 storeys until 2008. The following year regulations were modified to allow buildings to reach 6 storeys. Site-specific building regulations have been created since, for special cases[2].

Mass timber panels involve a change in the scale of what we can build with wood (Figure 3). Wood construction is in the midst of a changing process: the evolution in materials results in an evolution in design and possibility. In 2009, with the use of CLT panels as the structural system, Waugh and Thistleton designed a 9 storey building in London that reached 28 meters height (Waugh, Heinz, & Wells, 2009). In 2014, Michael Green Architecture designed the Wood Innovation and Design Centre (WIDC, Figure 4) in Prince George, British Columbia. WIDC was designed with a system that combined a central core of CLT panels with a post and beam glulam structure surrounding it, reaching a height of 29,5 meters. Currently, a 18 storey building of mass timber panels, designed by Acton Ostry Architects is being built in Vancouver reaching 53 meters in height.

Evolution in regulations allows increasingly higher wood buildings and, obviously, architects are designing taller wood buildings. However, wood buildings were built around the world centuries before the existence of regulations. As an example, Horyu-ji Temple, a five storey pagoda in Nara, Japan, was built fourteen centuries ago reaching 57 meters in height. It is believed to be the oldest wood building in the world and it is still standing even being placed in a high risk earthquake region. There is still a path to follow in terms of improvement of the actual regulations in order to make the design and building of high-rise wood buildings possible.

The Wood Innovation and Design Centre was created following a system called FFTT (Green, 2011) that we had created, which is a solution based in a flexible system that uses a combination of CLT panels and glulam elements that allow to tilt up six storeys at a time if needed. Initially engineered to work in the Vancouver context with a structural capacity to reach 35 storeys tall (Figure 5), the system is now available globally for a variety of different architectural styles and characters in order for us to build safely.

To reach such heights with a wooden structure involves solving a variety of technical issues. One of them is related to fire safety. Fire is perhaps one of the most relevant worries that people might have when discussing high-rise architecture. However, there are two concepts that have to be taken into account in relation to wood and fire. For example, when taking a match to a log and try to start a fire, the log won't burn. To build a fire, small pieces of wood have to be used to start it, then it has to be worked out with bigger pieces of wood and eventually a log can be added to the fire to have it burn. Then, the log burns, but it burns slowly. Mass timber panels are much like the log: it's hard to set them on fire and when they do catch fire they burn in an extraordinarily predictable manner. These two behaviours are referred to as 'reaction' and 'resistance'. While wood reacts to fire burning, it does so in a very slow and predictable way and thus, resistance can be calculated and applied to design under the actual building regulations (Figure 6). We can use fire science in order to predict and make these buildings at least as safe as concrete and as safe as steel, if not safer.

18 per cent of our contribution to greenhouse gas emissions worldwide is the result of deforestation. The last thing we want to do is cut down the wrong trees. There are models for sustainable *forestry that allow us to cut down trees properly and these are the trees that are appropriate to use for construction. This use of young wood for high technological engineered wood products will change the economics of deforestation. Countries with deforestation need to find a way to provide better value for the forest. Policies will have to be set to actually encourage people to make money through very fast growing cycles, 10, 12 and 15 year old trees. Those trees can be used in the fabrication of new products like mass timber panels that allow us to build at a taller scale.*

The growth rates of the North American forests supply enough wood to build a 20 storey building every 3 minutes (ReThink Wood, 2015). If we build a 20 storey building out of concrete, the process of manufacturing will result in the emission of 1,215 tonnes of carbon (Green, 2011). If we build it in wood with this solution (Figure 7) we will sequester about 3,150 tonnes for a net difference of 4,360 tonnes which is equivalent to 900 cars removed from the roads in a year(3). These figures reflect the construction of a single building. We can easily imagine the effect that progressive adoption of wood construction to build houses to those 3 billion people might have in the reduction of the emissions and the control of global warming.

We are at the beginning of a revolution in the way we build because this is the first new way to build a skyscraper in probably a hundred years. The challenge is to change society's perception on the adequacy of wood for building high rises. Quality of wood, performance of newly derived wood products and new digital tools for design and fabrication facilitate the engineering part of the process.

The first 10 storey high skyscraper was built in Chicago in 1885 by William Le Baron Jenney (Turak, 1986) and people were terrified to walk underneath this building. It was the first tall building to use steel framing. Only four years later Gustave Eiffel completed building the Eiffel Tower in Paris, a 324 m high steel structure. As he built the Eiffel Tower he started to change the skylines of cities around the world. He created competition between places like New York City and Chicago where developers started building bigger and bigger buildings and pushing the envelope up higher and higher with better and better engineering.

Today, wood is one of the most technologically advanced materials to build with. Wood construction leaves nature's fingerprints in the built environment. We're starting to push the height of wood buildings (Figure 8) and eventually, in the very near future, a wood skyscraper will be built that will break the arbitrary ceiling and allow wood buildings to join the competition. The race is on. m

NOTES

(1) Carbon stored in wood is about half of its dry weight. In the case of a cubic metre of Douglas Fir that weights 490 kg (Canadian Wood Council, 2017), carbon content is approx. 245 kg. As a consequence, the weight of carbon dioxide sequestrated from the atmosphere is 245 x 3,67 = 899 kg. 3,67 is a ratio that can be easily calculated using the periodic table of elements and the atomic weight of Carbon and Carbon Dioxide.

(2) A site-specific building regulation was created for the Wood Innovation and Design Centre in Prince George, British Columbia, (Wood Innovation and Design Centre Regulation, B.C. Reg. 271/2012) that limited the height of the building to 30 m. A second site-specific regulation was created for the UBC Brock Commons building in Vancouver (UBC Tall Wood Building Regulation, B.C. Reg. 182/2015), that allowed a maximum height of 18 storeys.

(3) The average annual carbon dioxide (CO_2) emissions of a typical passenger vehicle is about 4.7 metric tons (US Environmental Protection Agency, 2016).

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