Timber Towers of Tomorrow

Explore the science and engineering of supertall timber from cells to skyscrapers

Trees, and their derivative products, have been used by societies around the world for thousands of years. Contemporary construction of tall buildings from timber, in whole or in part, suggests a growing interest in the potential for building with wood at a scale not previously attainable.

At the smallest scale our research group is exploring how the molecular structure of wood contributes to its macro-scale attributes.

At the mega scale, we are developing our understanding of the engineering innovations required to realise super tall timber construction.

By bridging the two scales, we are taking a holistic approach to increasing the already significant potential for using plant material at a large scale in the built environment.

SELECTED FOR
THE ROYAL SOCIETY SUMMER SCIENCE EXHIBITION 2019

Based at the Centre for Natural Material Innovation, University of Cambridge, our highly interdisciplinary research group comprises experts from architecture, engineering, biochemistry, materials science, polymer chemistry and fluid dynamics.

Bibliography and further reading

Ramage, M., et al., The wood from the trees - The use of timber in construction. Renewable and Sustainable Energy Reviews, 2017. 68(1): 333-359.

Foster, R., et al,. Proposal for Defining a Tall Timber Building. Journal of Structural Engineering, 2016.

Simmons, T.J., et al., Folding of xylan onto cellulose fibrils in plant cell walls revealed by solid-state NMR. Nature Communications, 2016. 7:13902.

Thomas Peter A. Trees: their natural history. London: Cambridge University Press; 2014.

SOM. Timber Tower Research Project. Technical report, Skidmore, Owings and Merrill LLP. 2013.

TRADA Technology. Wood: The UK mass balance and efficiency of use: summary report. Technical report, TRADA Technology. 2005.

Thompson Henrietta. A process revealed/Auf dem Howlzweg. first edition. Stadthaus. FUEL, London; 2009.

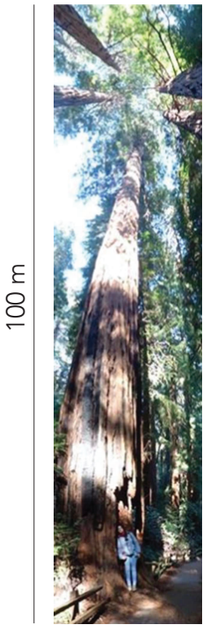
SELECTED FOR
THE ROYAL SOCIETY SUMMER SCIENCE EXHIBITION 2019

TEACHER RESOURCE 1

Timber Towers of Tomorrow:
Explore the science and engineering of super tall timber from cells to skyscrapers

Humankind has built with timber for centuries.

Why then have we not yet constructed a timber building taller than the tallest tree in the world?

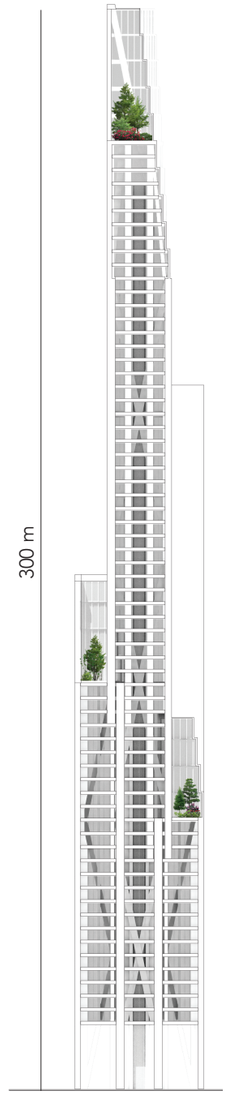


Hyperion, California Redwood National Park

The tallest tree in the world was recorded in Australia at 143 m. The tallest residential timber building today is the Treet in Norway which stands at 51 m.

Together with PLP Architecture, we have proposed the Oakwood Timber Tower which at 300 m will be the second tallest building in Europe after the Shard.

Treet, Norway 2018

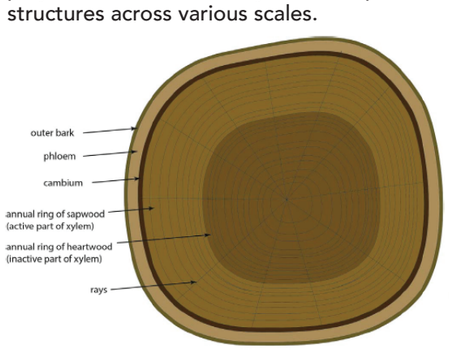


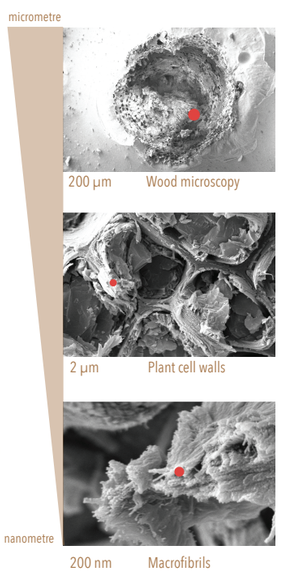
Oakwood Timber Tower, London *(proposed)*

Cells to Skyscrapers

In order to understand this we must first look at what makes a tree so strong. Our research therefore starts at its molecular structure.

Trees (and plants) are made up of polysaccharides. We study their complex structures across various scales.





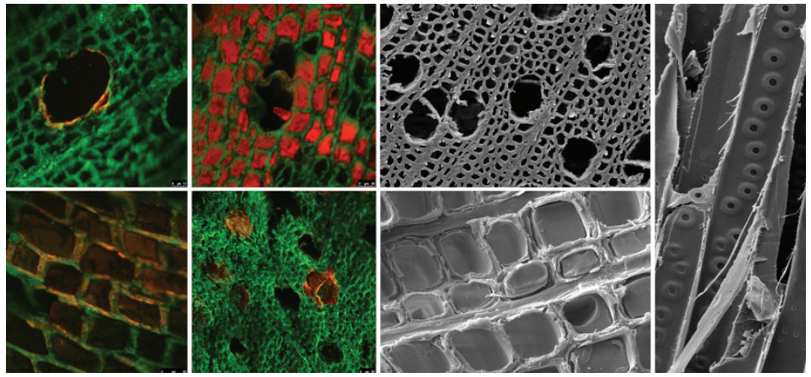
Property changes and counter measures

Timber is biological products and respond to different environmental conditions. Moisture content above 20% makes wood susceptible to attack by fungi and bacteria.

Degradation leads to unacceptable loss of mechanical properties.

Our group studies chemical and thermal properties of wood and its response to water flow and polymer impregnation.

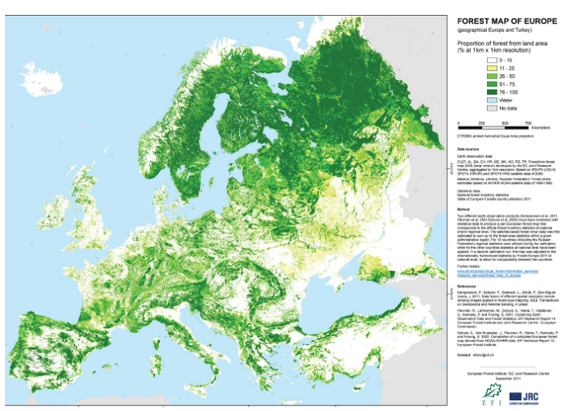
Microscopic details of vessels within wood structures. *Image: CNMI*



But is the promotion of timber in times of climate change a wise idea?

Unlike conventional building materials such as steel, concrete and brick, the supply chain for timber is quite distinct.

Forests outlive human timescales and if recommended rotations (ranging from 35 to 70 years) are followed, they can serve as excellent renewable resources.



Moderate increases in timber demand from construction may be met, at least in part, by more efficient management of existing forests.

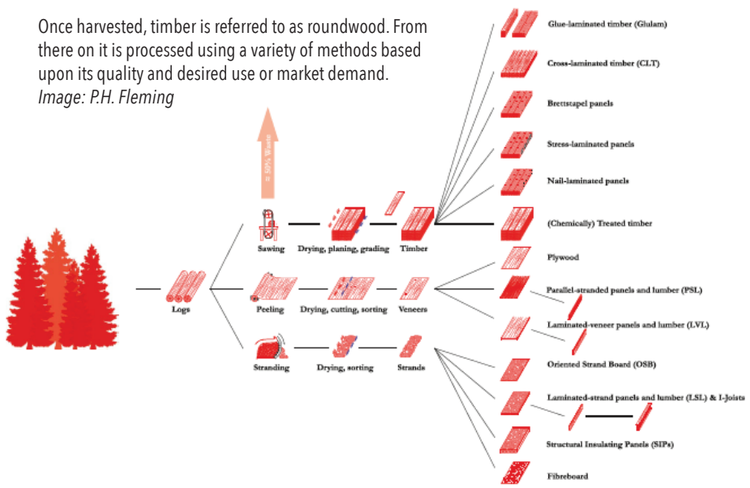
Much of Europe's forests lie predominately in the northern latitudes or on the periphery of the mountainous regions of central and southern Europe.

The life of a well-maintained timber building is comparable to that made in reinforced concrete or brick. This allows for time to replenish the harvested timber.

When thinking in terms of geological timescales, these cycles are only a blink.

So how does timber from the forest come to a construction site?

Once harvested, timber is referred to as roundwood. From there on it is processed using a variety of methods based upon its quality and desired use or market demand.
Image: P.H. Fleming



Wood treatment is a process that is used to improve the material properties of wood but produces a material that can be disposed off at the end of a product life cycle without environmental hazards

Structural use of timber

20% of new houses in the UK and up to 70% in Scotland are timber frame.

Besides being a renewable resource, timber has a strength parallel to that of reinforced concrete.

Comparing compression properties

Timber has low density and therefore superb structural efficiency for long-span and tall structures that typically need to carry their own weight. While timber has traditionally been successfully employed for the former, our group's research advances contemporary understanding for building super tall with timber.

TEACHER RESOURCE 2

Timber Towers of Tomorrow:
Explore the science and engineering of super tall timber from cells to skyscrapers

SELECTED FOR THE ROYAL SOCIETY SUMMER SCIENCE EXHIBITION 2019

Complex Engineering

In an earthquake, the force imposed on the structure by shaking depends strongly on its mass. A tall timber skyscraper will be much lighter than an equally tall one made out of reinforced concrete or steel. Similarly, it is possible to strengthen a lighter timber building through tectonic configurations not required in steel or reinforced concrete.

Working with timber in this unprecedented manner requires innovative solutions in structural engineering and architectural design.

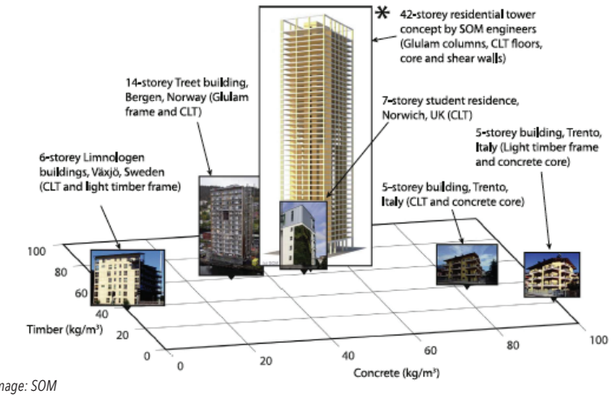
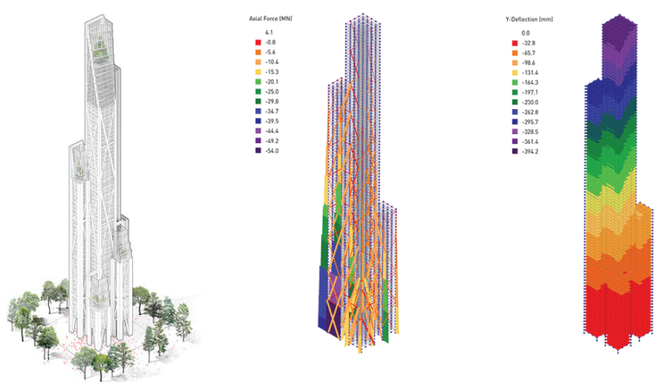


Image: SOM

Cross-laminated Timber

The recent development in timber processing has made the use of cross-laminated timber (CLT) a lot more feasible. CLT enables designers to not only revisit timber but also explore new structural configurations with it.

While building up to 6 storeys with CLT may not be cost-appropriate, the economics of building super tall buildings with CLT (and light frame timber) make for a very persuasive case.

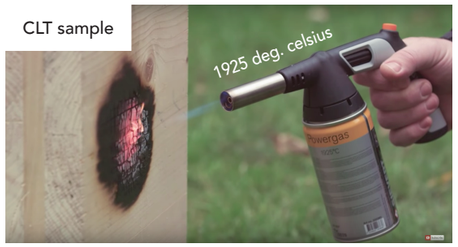


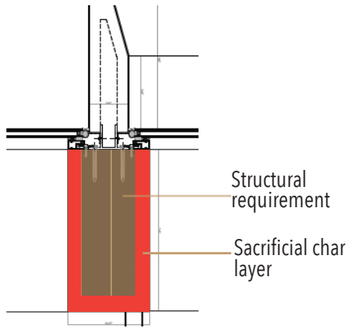
Architectural rendering of the Oakwood Timber Tower, London with structural calculations for axial forces and deflection. *Image: PLP*

FIRE

While exploring building tall with timber, we are mindful of the fire hazard involved.

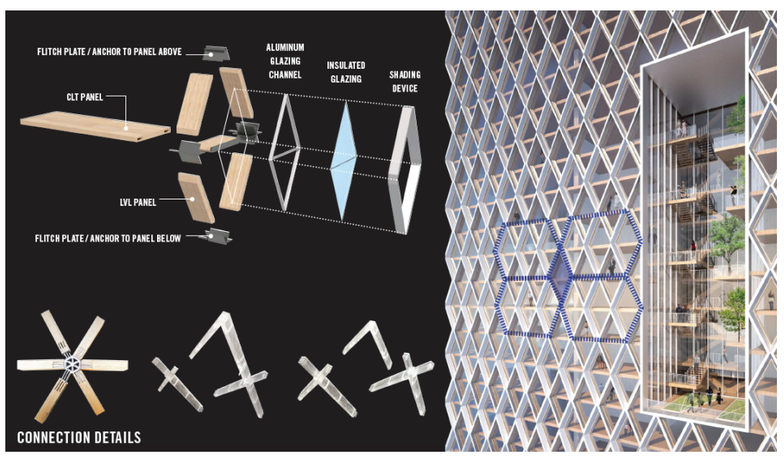
Our designs for timber buildings implement fire safety with the understanding that in the event of a fire, the building retains its structural integrity for fire extinguishing and evacuation.





As CLT is made up of laminated boards of timber, glued at 90 degrees to the preceding grain, it has superior strength to GluLam. Due to its laminated nature, it emerges as a strong choice for fire resistance too.

In the event of a fire, its outer layer chars and in turn protects the inner mass. The thickness of the outer layer is therefore factored in as sacrificial safety measure upon loss of which, the building's structural integrity is not compromised.



Special joints and structural assembly systems have been developed to optimise the deployment of timber in tall buildings.
Image: Perkins and Will / Michael Ramage

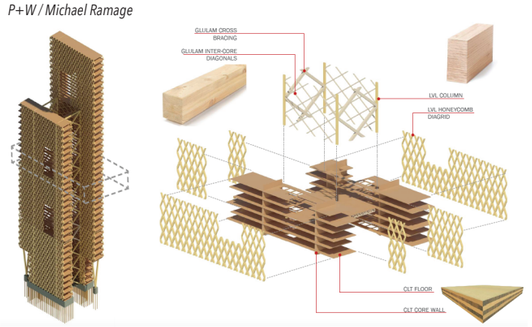
Synthesis

Synthesizing the group's research from cells to skyscrapers, the Centre for Natural Material Innovation at the University of Cambridge is collaborating with partners on the following super tall timber buildings around the world

PLP Architecture

Project:	**Oakwood Timber Tower, London**
Architects:	PLP Architecture, London
Sturctural Engineers:	Smith and Wallwork
Height:	300 m

P+W / Michael Ramage



Project:	**River Beech Tower, Chicago**
Architects:	Perkins and Will
Sturctural Engineer:	Thornton Tomasetti
Height:	243 m

PLP Architecture

Project:	**The Lodge, The Hague**
Architects:	PLP Architecture, London
Sturctural Engineers:	Smith and Wallwork
Height:	130 m