Building Tall with Timber: A Paean to Wood Construction

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Summary

It may seem strange at first to propose that timber be used for the structural system of mid-rise buildings. Steel and concrete have held that position so long that the question of wood as an alternative for large-scale multi-storey construction would strike many people as archaic and impractical, but until the modern age, this was the case. The following essay highlights some interesting examples in history, concluding with the 17 blimp hangers constructed in the USA during World War II when steel was in short supply. Each of these structures was a third of a kilometer in length and equivalent in height to a 17 storey building, containing a single, column-free room.

Keywords: tall wood building; tall timber building; blimp hangar; airdock; Claremont Hotel; Todaiji; fire.

Introduction

This section provides a brief history of tall wood structures and buildings. The 190 m high Mühlacker Radio Transmission Tower in Germany has been identified as the tallest wooden structure ever. It was demolished in 1945, to avoid being used by the Allies at the end of World War II, leaving the Gliwice Radio Tower in Poland, which at 118 m is the tallest extant wooden structure.[1] For buildings, it is more complicated to say what was or is the tallest, as many stone buildings over the centuries have internal timber structures in their towers and spires. For centuries, Christian churches with their tall spires have most likely been the world's tallest buildings overall, most of which had wooden spires and floors. The 160 m height of the spire of Lincoln Cathedral in England that was constructed in the 14th century and blew off in 1549, was never exceeded by another building until the Washington Monument in the USA was completed in 1884.[2]

Among religious structures made *entirely* of wood, those in China were easily the tallest from at least 1056 until 2003. In 1056, the Yingxian Pagoda (also called Sakyamuni Pagoda) was constructed as part of the Fogong Temple in Yingxian County of Shanxi Province. The pagoda is 67,13 m high, and is today both the tallest and oldest fully wooden pagoda in China.[3] Tall churches built *entirely* of wood and still extant, include the 43,5 m high St. Georges Anglican Cathedral in Georgetown, Guyana, completed in 1890. This Anglican Cathedral was reported by its congregation to be the tallest wooden church in the world[4] until it as well as the Yingxian Pagoda were overtopped in 2003 by a new church in Romania. However, until a fire destroyed the Cathedral in 1995, San Francisco's St. Paulus Lutheran Church, which was modelled on Chartres Cathedral in France when it was constructed entirely of timber in 1893 by German Shipwrights, was of similar overall height (*Fig. 1*). Today, the newly constructed Sapanta-Peri Monastery in Romania is indisputably the tallest church, with a central spire that soars to 75 m (*Fig. 2*).[5]

It is one thing to measure spires and towers of religious structures, but that gives no sense of possible heights of timber buildings in general. In Hackney, a suburb of London, a British housing developer is currently constructing a nine-storey block of flats (apartments) to be called the Murray Grove Tower, built entirely out of massive wood cross-laminated panels manufactured in Austria that *"are like giant pieces of plywood."* In an article in the Timber Building magazine, it is claimed that the Tower will be the world's tallest residential timber building. Its size was not reported, but nine storeys will approximate 30 m.[6]

Fig. 1: St. Paulus Lutheran Church (1893), San Francisco (destroyed by fire in 1995)

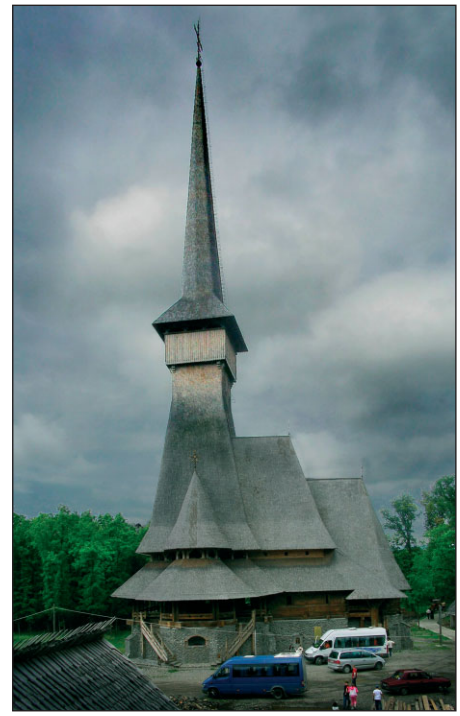

Fig. 2: The new Sapanta-Peri Monastery in Romania, completed in 2003 (Photocredit: Luca Florin Gheorghe, www.poze-romania.ro; two photos combined into one by Randolph Langenbach)

Despite this anticipated claim to fame, another yet-to-be finished structure already exceeds the height of the Murray Grove Tower and is a single family dwelling! It is a 13 storey, 44 m tall house constructed by a post-Soviet era contractor, in Arkhangelsk, Russia. Like Murray Grove, this building has massive wood walls but they consist of sawn logs notched and assembled like log cabins. Reportedly the contractor began the project in 1992, but now, having lost his money and served time in prison, he lives in the structure but may never finish it.[7] (To see a photo of this structure, see Ref. [7]).

The late-nineteenth and early-twentieth century timber frame hotels in

Fig. 3: Claremont Hotel under construction in 1906 (Source: University of California Berkeley Library)

North America are likely to be the largest residential wood buildings ever constructed. Before it was torn down, the Yellowstone Canyon Hotel was claimed to be the world's largest wooden hotel. The still extant Claremont Hotel in Oakland, California has 279 rooms plus conference facilities on ten occupied floors that rise approximately 36 m from the foundation to the roof, with a central tower that is approximately 48 m from the foundation to the top (*Fig. 3*).

What About Fire?

The question asked most often about such structures is "what about fires". In fact, the 1981 Oakland Firestorm, which consumed over 3400 homes (including this author's) and killed 25 people, came within 100 meters of the Claremont Hotel. Urban history in many cities has been shaped by conflagrations, but the death toll for all but the war-induced firestorms has been significantly less than that resulting from the earthquake-collapses of reinforced concrete buildings, especially if one looks at the record of the last decade in India, Pakistan, Turkey, and elsewhere. This is not to minimise the concern over fire, but rather to contextualise that risk. Consider the irony of the fact that when much of San Francisco was destroyed by the fire started by the 1906 earthquake, all of the brick, stone, and steel "fireproof" buildings in the downtown business district were completely burned out, while many neighborhoods consisting of wooden Victorian era houses, for which the city is now famous, survived intact (*Fig. 4*).

It is also interesting to notice that both San Francisco and Istanbul, Turkey, share a common heritage of closely spaced timber buildings in their urban

Fig. 4: Typical nineteenth century wooden houses in San Francisco

cores. Even the architecture in Istanbul (*Fig. 5*), with its horizontal parapets and square bay windows, resembles San Francisco's ship-lap clad timber framed Victorian buildings. However, in the twenty-first century, the situation could not be more different. Wooden buildings, as always, continue to be constructed in San Francisco and the surrounding Bay Area, but Istanbul is now filled with thousands of four- to six-storey apartment blocks of reinforced concrete.

In North America, catastrophic fires destroyed large sections of New York in 1835, Montreal in 1852, Chicago in 1871, Boston in 1872, Seattle in 1892, and both Baltimore and Toronto in 1904. Of all of these fires, the one spawned by the earthquake in San Francisco in 1906 was arguably the most devastating, yet unprotected wooden buildings, now banned in almost every other city, continue to be allowed to be constructed in close proximity to each other. Why?

Istanbul was also famous for frequent fires. In fact, Turkish author Orhan Pamuk has said that there was a *"tradition of watching fires,"* and that French author Théophile Gautier (1811–1872) had written *"In four months I have seen six great fires."* In his own life growing up in Istanbul, he reported that he saw *"wooden buildings burned by greedy owners who wanted to live in larger modern concrete apartment blocks."*[8] However, the recent 1999 Marmara earthquakes and 2003 Bingöl earthquake have made it clear that most of the reinforced concrete buildings that now fill the city are extremely vulnerable to pancake collapse.

Earthquakes are the one natural disaster, which can strike at any time without warning, adding a level of fear like no other natural hazard. The identified problem is so large in Istanbul that the World Bank determined that the costs and difficulty of fixing the problems

Fig. 5: A typical nineteenth century wooden house in Istanbul

city-wide are so great that there is no way they can even begin to finance such an undertaking.

Thus, while fire can be a motivating factor in banning new construction with exterior wood cladding in central city areas, in the case of Istanbul it is clear that it had not been fully realised that the vaunted strong material, reinforced concrete, would actually perform *worse* in earthquakes than the seemingly flimsy wooden structures that were replaced. However, experience has shown that in the absence of extensive training of the builders and stringent quality control, they do. Istanbul finds itself, therefore, in a predicament that it did not expect, with whistles in handbags to enable one to be heard if sandwiched between slabs of concrete as the only mitigation device at hand.

Although what is discussed here is only one instance of questionable planning and building regulatory policies, it does point to a systemic irrationality concerning suitability of timber buildings in urban settings.

The Largest Wooden Buildings

The Daibutsu-den or Great Buddha Hall of the Todaiji Temple in Nara, Japan, is frequently cited as the largest wooden building in the world.[9] The current structure, constructed in 1709, is 57 m long by 50,4 m wide by 48,6 m high, which is actually 30% shorter

than its short-lived predecessor constructed in 1692 (reportedly 88 m by 51 m, by 48,5 m high) (*Fig. 6*).

Despite these claims, the Todaiji Temple has long since been eclipsed in size by 17 lesser known timber structures that are almost 12 times its volume! During World War II, when steel was in short supply, 17 "airdocks," or "blimp hangars", were constructed on both coasts of the USA for helium-filled blimps that were used to observe submarines in shipping lanes. Those airdocks are the largest clear-span timber buildings ever built.[10] A number of steel-supported airdocks with a similar configuration had been constructed before the USA entered the war. Each airdock had a total of 51 Douglas Fir heavy-timber trusses resting on concrete frames.

Hangars 2 and 3 at Moffet Field near San Jose, California, are two of seven remaining wooden airdocks, (*Figs. 7* and *8*). Each of these identical hangars is 340 m long by 115 m wide by 52 m high. With over 2×10^6 m^3 of volume and about 40×10^3 m^2 of floor space, it is doubtful that any other wood structures have ever been nearly as large.

The engineers considered several framing possibilities for the airdocks before deciding on an inverted catenary arch truss with a Pratt truss configuration. The cords were built of multiple sawn boards held together with steel split-ring connectors and bolts. All timbers were treated with fire-retardant salts. After the construction of a prototype, it took only a year to complete all 17 hangars.[11]

Thoughts on the Potential of Timber in Modern Construction

This brief survey reveals that throughout history, it has been religious devotion or the exigencies of war that have lead to the creation of most of the world's tallest and largest wooden structures. The war-time shortage of steel was the stimulus for the vast timber parabolic arched timber trusses of the airdocks, and now the growing depletion of fossil fuels is beginning to be a stimulus to reexamine the potential of using wood for multistorey urban buildings. For example, the wood embodied in the nine-storey residential Murray Grove Tower *"stores over 181 tons of carbon, and … by not using a reinforced concrete frame, a further 125 tons of carbon are saved from entering the atmosphere. This is equivalent to 21 years of carbon emissions from a building of this size."*[12]

Fig. 6: Daibutsu-den (Buddha Hall) of the Todaiji Temple in Nara, Japan

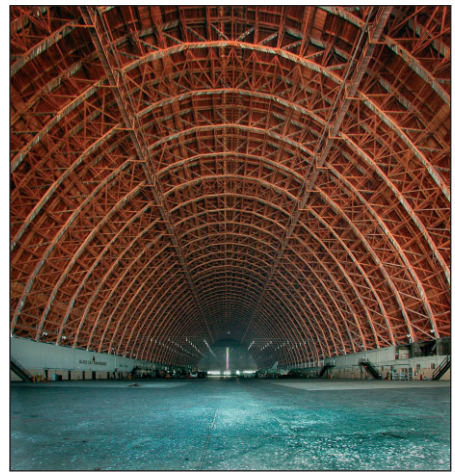

Fig. 7: Hangar 2 interior, Moffet Field, California, USA

Fig. 8: Hangar 2 exterior, Moffet Field, California, USA

Conclusion

Over the past millennia, stone, timber, and unfired earth have been the world's principal building materials. They all share the important features of abundance and require very little processing energy. Timber is also renewable, and kilogram for kilogram, it is one of the strongest building materials available. In much of the world, it has been displaced by reinforced concrete from historical niches like housing. The long-term potential of tree farming has been ignored in favour of strip mining for limestone and coal used to make cement. It now seems time for this practice to change, so that the true potential of a vastly under-appreciated resource can be more fully realised.

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