



Structures & Architecture . 21-23 July 2010 . Guimarães - Portugal

Better than Steel?

The use of timber for large and tall buildings from Ancient Times until the Present.

Randolph Langenbach,

Conservationtech Consulting, Oakland, California, USA

ABSTRACT: In many countries in the present day, timber is considered to be suitable only for finishes rather than the structure of permanent multi-storey buildings, and yet, before the advent of steel and concrete, timber was used either exclusively or together with masonry for buildings of great size and height. This paper describes examples of tall timber buildings, including some that are unusual in size and others extant after hundreds or even a thousand years – long after steel would have rusted away. Many of these examples stand as evidence that present-day code height limits, which in some countries are as low as two storeys, are drastically over conservative. Timber grown and harvested using sustainable practices provides a ‘green’ alternative to steel and reinforced concrete even for large buildings. This can contribute significantly to a reduction in fossil fuel resource depletion and greenhouse gas emissions.

1 INTRODUCTION

In November 2006, when giving a lecture for UN-HABITAT to a group of government officials and structural engineers gathered to discuss the 2005 Kashmir earthquake, I asked if they would be surprised to learn that approximately 95% of the population of the United States lived in houses constructed almost entirely of wood. This drew a response of affirming nods across the audience. This example illustrates an important cultural as well as informational gap that exists between these widely separate parts of the globe. Timber construction is often seen in a very different context in Pakistan and many other countries than in the United States. This is more than just the question of availability of the raw material and the knowledge of how to use of it. It also goes to the heart of cultural perceptions of permanence and modernity. While a new wood-framed-and-clad single-family house meets the aspirations of the vast majority of American homeowners, in many societies across the globe from Europe to Asia it is viewed as insubstantial, impermanent, low-class, and – worse – un-modern.

One can find this cultural attitude reflected in the building codes that often restrict timber frame houses to one or two storeys in height. The Indian Standard Code IS 4326, for example states: “*timber construction shall generally be restricted to two storeys with or without the attic floor.*” Surprisingly, in the same code, this restriction follows the observation: “*timber has a higher strength per unit weight and is, therefore, very suitable for earthquake resistant construction.*” The inevitable question is, why then is it allowed for only two storeys in the earthquake areas subject to the code?

In India, a house considered by society and government as solid and permanent is called a “*pucca*” house. When a *pucca* house is described by people or referenced in newspapers or government reports, it is always described or assumed to be constructed of reinforced concrete, concrete block, and/or fired brick. When timber is found in *pucca* houses, its use is limited to joists and rafters to support the floors and roofs, for which, of course, it is particularly well suited.



Figure 1: Seven-story timber frame Himeji Castle, Japan, 1608AD, overlaid with photo of model of interior timber frame structure. *Photos and overlay © Randolph Langenbach.*

An earthquake, however, can turn this vision of the strength of a masonry or reinforced concrete *pucca* house on its head. The lighter and seemingly weaker wood houses, even when their frames are infilled with masonry, have often demonstrated a greater resistance to collapse in earthquakes than those of masonry, and concrete. This is especially found to be true near the epicenters of particularly large earthquakes. For example, In the 1999 earthquakes in Turkey, the 2001 earthquake in Gujarat, India, and the 2005 earthquake affecting both Pakistan and Indian Administered Kashmir, the seemingly weaker timber and masonry infill frame houses generally performed far better as a class than did those constructed of reinforced concrete.

“Better than steel?” Of course this question presumes also the question “better for what?” There are two aspects of the use of these materials for building construction where wood is indisputably better. One is responsive to the more recent concern over resource depletion and global warming – which is that, with proper forest protection and stewardship, wood is a renewable resource that has negligible impact on the use of fossil fuels in its processing compared to concrete and steel. It also sequesters CO₂ so long as it is protected from fire and decay. The other is that woodworking is a craft that is widely accessible to people in all walks of life. This second aspect is particularly significant. As we focus on the lives and livelihoods of people in rural areas and marginal economies, it is important to recognize that requirements to use industrially produced products such as steel or steel reinforced concrete can cause further impoverishment, rather than an improvement in the quality of life. First, however, some of the cultural attitudes that affect the acceptance of wood construction, particularly for large multi-story buildings, must be addressed.

2 TIMBER CONSTRUCTION AS AN ACADEMIC DISCIPLINE

For those who live in North America, carpentry and wood construction may seem as common as breakfast cereal. In the United States, manual arts classes, often called “shop class” in the United States, at least used to be ubiquitous in middle and high schools nationwide. (Sadly, it has increasingly been eliminated in favor of computer classes, a remarkably short-sighted change in educational priorities.) This educational interest in woodworking, or what is left of it, is mostly limited to younger students. Only a small minority of those entering graduate programs in structural engineering and materials science choose to specialize in timber. This has been true even in the United States and Canada, where over 95% of the population lives in wood houses. For example, at the University of California, Berkeley, the woodworking shop originally included in the Graduate School of Environmental Design building is no longer used, and the renowned Forest Products Laboratory that had been connected to the engineering and building science departments was unceremoniously shuttered in July 2003 in a cost-cutting move.

In most of the rest of the world, this situation is even more extreme. In Germany for example, only 14% of all single family houses and negligible numbers of other buildings are constructed of timber (Betz 2006). Finding students who are studying more than the introductory basics in wood construction technology or engineering is extremely rare, as reinforced concrete rules the day. Those students who do have an interest in timber construction are often forced to pursue their interests on the side – more as a hobby than as a course of study. In large parts of China, timber used to be in common use for buildings, and for more than a thousand years timber pagodas were constructed so tall that one of which has survived to this day for almost one thousand years is still the world’s tallest multi-story timber building (see below). (Frank Lam, 2008) Today, wood construction has been almost entirely displaced by concrete and masonry, even in smaller settlements because of a ten-year logging moratorium which began in 1998 because of the rapid depletion of timber resources. This radical action was precipitated by a series of massive floods exacerbated by destructive logging throughout the nation's forests in the previous decades. (pulpmillwatch.org, n/d) With the disappearance of timber from the marketplace, engineering education shifted to masonry, steel and concrete, never to return to wood, which has increasingly given the public an impression that wood is an inferior and obsolete structural material. (Frank Lam, 2008)

3 FIRE!

The question is often raised: “Does not the risk of fire make wooden houses impractical?” Urban history in many cities has been shaped by conflagrations, but the death toll for all except the war-induced firestorms has been significantly less than that suffered from the earthquake-collapse of reinforced concrete buildings – even over the last decade in India, Pakistan, Turkey and other countries.¹ Of course, fire risks do demand our attention. But consider, for example, the irony that the fire that was started by the 1906 earthquake in San Francisco destroyed or burned out almost all of the brick, stone, and steel “fireproof” buildings in the city center, while most of the residential neighborhoods which consisting of 100% wooden Victorian houses survived intact. The city is now famous for these rows upon rows of wood frame Victorians.

This is not to say that the wooden houses somehow suddenly became fire-resistant; only that in the lottery of luck that surrounds every major disaster, the best efforts at both earthquake and fire protection can come to naught if all vulnerabilities are not addressed, such as disaster proofing of the water mains, the availability of fire-fighting equipment, and the proper training of the firefighters including the volunteers and military personnel who would be called upon in the event of a conflagration. In 1906, this was notably lacking. For example, when gun powder was used in lieu of dynamite to blow up buildings to create a firebreak, it only caused the fire to spread faster.

¹ The author has himself experienced loss from fire, having lost his home in the Oakland-Berkeley Firestorm of 1991 – an urban forest fire that destroyed over 3,400 residential structures and killed 25 people. His subsequent work for FEMA and in disaster recovery overseas is in part a consequence of this fire.



Figure 2&3: *Left:* Himeji Castle, Japan. A small fire extinguisher is visible in this all-timber structure. *Right:* Interior of the top floor of a ca. 1835 textile mill with “slow-burning” construction and brick walls, Amoskeag Mills, Manchester, N.H., USA photographed in 1968. *Photos © Randolph Langenbach.*

Fire? Earthquakes? Does one risk tend to be increased when the other is reduced? Why continue to build in wood in San Francisco when the city has burned down once already? Can timber construction once again find a role to play in the Istanbul where now millions of people live in very vulnerable concrete buildings? In the world to come – with the depletion of non-renewable resources including fossil fuels, timber may actually assume an ever increasing importance – even for urban multi-story buildings. Over past millennia, stone, timber and unfired earth have been our principal building materials. They all share two important features – they are abundant and require very little energy to be processed into building materials. Timber is also renewable and kilogram for kilogram, it is one of the strongest building materials available.

Like steel, wood is strong in compression, tension and bending. During the early Industrial Revolution in the United States, for example, the earliest great textile factories in New England were constructed with heavy timber beams and planks for the floors behind exterior masonry walls, rather than cast and wrought iron beams with masonry jack arches, as was common in 19th century Britain. The tallest of these pre-Civil War textile mills rose as high as 9 storeys, and many were seven storeys. In fact, the factory owners in the USA, in establishing the Factory Mutual Insurance Company in the first decades of the 19th century, developed and promulgated a fire-resistant form of heavy timber construction that eliminated joists and voids between the ceiling and floors by using heavy planks on beams. This form of construction at the time was called “slow-burning” construction, and it is the origin of what is now recognized in the current US and Canada based “International Building Code” as “Type IV, Heavy Timber.” It is considered to have a lower risk of collapse from fire than unprotected steel.

An additional interesting piece of this history of the use of wood in the USA for the internal structure of massive tall factory buildings is that wood replaced the earlier use of cast iron for the columns. The precipitating event occurred in 1852, when a miscast cast iron column cracked and broke in the Pemberton Mill in Lawrence, Massachusetts, leading to the sudden progressive collapse of the fully occupied building. Timber, rather than cast iron, became favored for the columns as well as the floors after this event, and complete timber slow burning construction remained common for the interiors of factory buildings in the United States well into the 20th century.

4 TYPOLOGIES OF TIMBER CONSTRUCTION

A survey of both contemporary and historical timber building typologies can be divided into two basic classifications: (1) those where the entire above ground structure and enclosure system of a building consists of wood products except for plaster, nails and fasteners, and (2) those where the timber is used in combination with other materials such as masonry for the structure and enclosure of the buildings. This compilation can also be subdivided into buildings where timber is used for both the horizontal and vertical load bearing structural system, or only for the horizontal spanning members, with other materials such as masonry, cast iron, or steel used for the vertical walls and columns.

4.1 All-wood Construction:

At least in non-tropical areas, the oldest form of timber construction, quite possibly, was not a timber frame structure, but rather, a log cabin. Such solid wall structures, where undressed logs are laid up like masonry, avoid the need for sawing technology to cut the tree trunks into boards. Although profligate in the use of wood, log structures required no nails or other metal hardware and tools other than an ax to fell the tree and notch the logs. Nor was it necessary to know much about engineering or timber craftsmanship, such as that found in the ancient Chinese and Japanese pagodas which were constructed to great heights without nails.

Improvements in the technology for sawing and the making of nails allowed for the propagation of timber frames with smaller timber sizes. Frames, of course, are much less wasteful in the use of wood than log structures. Timber frames may be braced for lateral forces or designed to rely on masonry walls for horizontal stability. In Chinese and Japanese temples and pagodas, for example, lateral bracing was also accomplished using the bending strength of the timber beams slotted through the columns or the use of elaborate systems of brackets, thus avoiding the diagonals - while at the same time increasing the flexibility and resilience of the structure over that of most conventionally braced frames.

The development of timber stud frame construction known originally as the “balloon frame,” originated in the United States around Chicago shortly before the middle of the 19th century. This has now evolved into what is known as the “platform frame.” Its invention came at a time when saw mill technology had been refined sufficiently to easily convert logs into boards and beams of consistent dimension and small cross-section. In balloon frame construction, all of the timber structural parts of a building except for the horizontal spanning members (beams, joists, and rafters) are framed with nothing larger than 2 inches x 4 inches (5cm x 10 cm) in cross-section. Also influential on the proliferation of balloon frame construction was the invention of the wire-cut nail, which greatly increased the availability of nails at lower prices. Machine-made steel wire-cut nails were invented in about 1850, rapidly replacing the blacksmith’s hand-forged iron nails. Prior to wire-cut nails, people would often light older houses on fire simply to recover the precious nails. Now machines can produce 700 nails a minute.

This semi-industrialization of timber building materials and the efficient cutting of wood into timber members of radically smaller cross-sections vastly increased the efficiency and economy of building in timber. Counter-intuitively, stud frame timber buildings have proved to be more resilient against lateral forces than the traditional braced heavy timber frames that preceded them. There are examples of stud-frame houses that have survived a roll down a hillside after having been undermined, or even remained intact when swept downstream in floods. In contrast, in Japan, where heavy timber braced frame construction has continued to be used, timber houses collapsed by the hundreds in the 1995 Kobe earthquake.



Figure 4&5: *Left:* Hand sawing of log into boards, 2006, a still common practice in rural Kashmir, India. Photo by ©Abbid Hussain Khan for INTACH. *Right:* Balloon frame house washed downstream but remained intact when dam burst in Jonestown, Pennsylvania, 1889 killing 2209 people.

4.2 Mixed Construction with Wood

Timber construction continues to be common only in timber-abundant areas like North America, parts of Switzerland, Scandinavia and parts of Asia. When looked at worldwide, the construction of permanent buildings completely out of timber is quite rare. Historically, prior to the invention of power saws to mill whole trees into boards as well as beams, the task of working each piece with hand tools discouraged builders from using timber for cladding. Masonry thus more easily served for the construction of walls, while timber was eminently suitable for beams and rafters. Over the centuries, many a tall structure such as towers for military purposes or bell-towers on churches, or minarets on mosques have stormed the heavens with their height – and timber for the internal structure was often an essential component in their construction. In addition to masonry bearing-wall construction with timber floors, it became common in many areas of Europe and parts of Asia to build complete frames out of timber and use the masonry as an infill, as in what in England came to be called “half-timber” construction.

Whether in 16th century Elizabethan England, or early 20th century Turkey and Kashmir, the use of masonry or wattle and daub as an infill in a complete timber frame has demonstrated a practical way of combining the assets of both materials by allowing the timber frame to serve not only as the internal structure, but also support the exterior masonry walls, thereby reducing the thickness and weight of the masonry to the short dimension of a single brick, usually about 10 cm for fired bricks, and somewhat more for adobe bricks. Infill wall timber buildings thus have much lighter and thinner walls than masonry bearing-wall structures, and are thus more economical and easily constructed than masonry bearing-wall buildings. Also, a not often recognized fact is that this form of construction was as the precursor to the first generation of wrought iron, and, later, the steel, skeleton frame skyscrapers. Until well into the 20th century, the skeleton frames were infilled with masonry. This infill not only served as the walls and partitions, but it also braced the frame against lateral loads. (Langenbach 2006)



Figure 6&7: *Left*: Houses of traditional timber with mixture of timber-laced masonry (known locally as *taq*) and timber frame with infill masonry construction, (known locally as *dhajji dewari* or “patchquilt wall” in old Persian) in Srinagar, Kashmir. *Right*: Partial demolition of *dhajji dewari* house reveals the timber frame and thin masonry wall construction. Photos © Randolph Langenbach.

5 TALL TIMBER BUILDINGS IN HISTORY

Older examples of tall timber buildings include a variant of half-timber construction unearthed from the volcanic debris in Herculaneum, revealing that this construction may have been common in Roman times. When archeologist Amedeo Maiuri of Herculaneum dug up a house with an infilled timber frame in the 1930's, he identified it as the ancient masonry construction typology described by Vitruvius as “Craticii” or “Opus Craticium.” While the house in Herculaneum is only two storeys, it may hold a clue as to how much of Rome may have been constructed in the classical era where tenements, known as *insulae*, rose to seven or eight storeys to house a population that grew to a million in an area much smaller than modern Rome because it was confined to the area protected by the ancient city walls. Masonry bearing-walls on what are known today to have been the footprints of some of these ancient buildings would have been too thick at the base to fit with sufficient space left over for habitable rooms. It is thus likely that the Romans constructed many of these tall buildings with infill masonry on timber frames to heights which exceeded what is allowed by any standard building code in any country today. (Langenbach, 2007)

Moving forward in time by approximately thousand years and around the globe to China, one can find an ancient structure completely made of wood referred to earlier that is still extant after almost a millennium of earthquakes, wars and exposure to the elements: the Sakyamuni Pagoda of the Fogong Temple in Ying County. More commonly referred to as the Yingxian Wooden Pagoda, it was constructed in 1056. The pagoda is nine storeys in height, including four storeys that are hidden behind the pagoda roof structures, but this number of storeys hides its most astonishing metric: including its 10 meter high top spire, it is 67.31 meters (221 feet) high. This means that it may be the second tallest extant wooden building in the world today, exceeded only by the Sapanta-Peri Monastery Church in Romania, a building constructed 944 years later. It appears that this 2003 church itself took over the honor of Europe's tallest wooden structure from another Romanian church, the Bârsana Monastery Church, constructed almost 300 years earlier in 1720.



Figure 8&9: Left: The 67 meter high Sakyamuni Pagoda, constructed in 1056, China. Photo by Gisling (Wikipedia GFDL) Right: The 75 meter high Săpânța-Peri Monastery, Romania, constructed in 2003. Photos ©Luca Florin Gheorghe, www.poze-romania.ro; combined into one by Randolph Langenbach.

Incredibly, if one were to limit one's comparison to multi-story wooden structures, and not include the thin spires on either the Săpâna-Peri Church or the Sakyamuni Pagoda, the Pagoda under this simple criteria is most probably the tallest multi-story building in the world either entirely out of wood or with its entire interior and exterior weight-bearing structure out of timber.

The Sakyamuni Pagoda is reported to have survived as many as 40 earthquakes in its long life. These records indicate these may have included two above a Richter magnitude 7 and six between a magnitude 6 to 6.9. *Yingzhou zhi* records show a total of seven earthquakes between the years of 1056AD and 1103AD. It even managed to survive the over two hundred rounds shot into the temple during the 1937-45 Second Sino-Japanese War (Frank Lam, 2008)

The structure of this temple shares with other wooden Buddhist Pagodas throughout Asia a system timber framing braced with layers of brackets, all notched and mortised together without the use of any nails or bolts, which has proven to be very resistant to earthquakes because of its flexibility and redundancy, and also the friction damping from the cribbage-like system of timber layers. In fact, its longevity may be partly a result of its lack of iron or steel nails and other hardware, which would have been subject to corrosion.

Moving forward to 1709, one finds yet another still extant iconic wooden structure of giant proportions: the Daibutsu-den or Great Buddha Hall of the Todaiji Temple in Nara, Japan. In this case, the still extant structure is 57 m long by 50,4 m wide by 48,6 m high, is actually 30% shorter than its short-lived predecessor constructed in 1692 that reportedly was 88 m by 51 m, by 48,5 m high. Although not taller than the Sakyamuni Pagoda, the Todaiji Buddha Hall, which in 2009 is exactly 300 years old, is frequently cited even by the Encyclopedia Britannica as the "largest wooden building in the world."

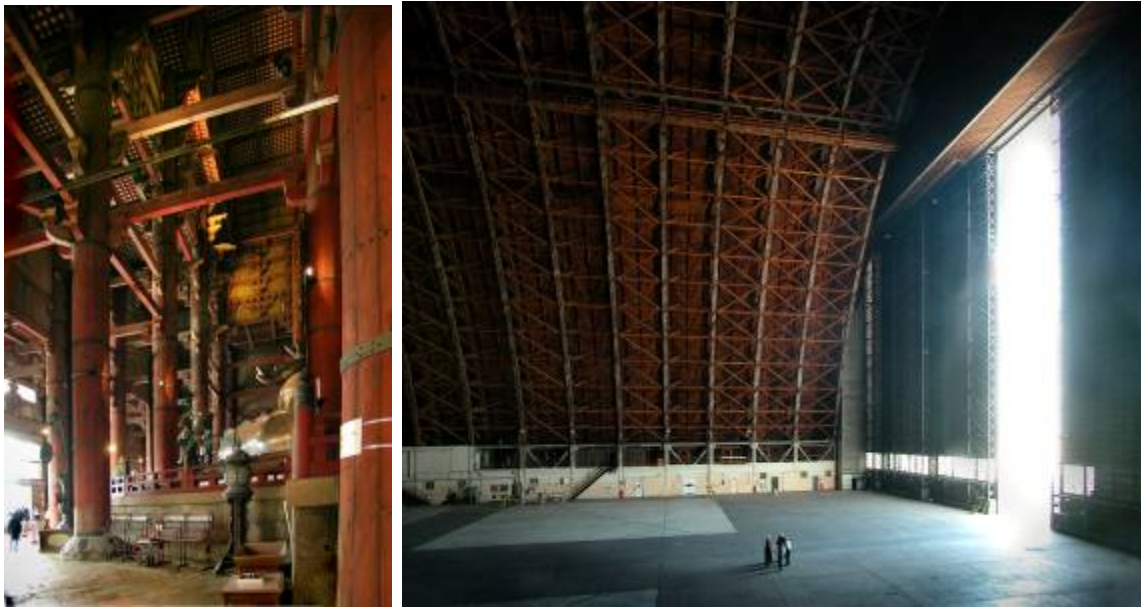


Figure 10&11: *Left*: Daibutsu-den, Todaiji Temple, constructed in 1709, Nara, Japan. *Right*: Hanger 2, Moffet Field, near San Jose, California. Photos © Randolph Langenbach.

Despite this claim, the Todaiji Temple has long been eclipsed, not by one, but by 17 timber structures. Not only that, each of these structures had only a single room entirely without any interior columns! During World War II, when steel was in short supply, seventeen "airdocks," were constructed on both coasts of the United States for helium filled blimps that were used to observe submarines in shipping lanes during the war. Nothing on this order of magnitude had been constructed in timber before, but a number of steel airdocks with a similar configuration had been constructed before the US entered the war. Each wooden one had a total of fifty-one Douglas Fir heavy-timber trusses resting on concrete foundations.

As of 2009, only seven of these airdocks remain, two of which are at Moffet Field near San Jose, California. Each of these is 340 meters long by 115 meters wide by 52 meters high (1,114 ft. by 378 ft. and 171 ft.). As many as six Todaiji Buddha Halls could fit in each of these when

placed end-to-end. The only thing that would prevent a double row of 12 of them from fitting would be the constraints of the extruded parabolic shape of the airdocks, and the depth of the wood trusses. These airdocks are the largest clear-span wooden buildings ever built. If spires and steeples are not included, The Tillamook Hanger in Oregon is probably also the tallest wooden building in the world. Over 2.5 million board feet of Oregon Douglas fir were used, which saved over four thousand tons of steel. The cords were built up out of multiple sawn boards held together with steel split rings and bolts. All timbers were treated with fire-retardant salts. After the building of a prototype under the direction of the principal engineer of the Navy's Bureau of Yards and Docks, Arsham Amirikian, it took only a year to complete all 17 hangers. With over 2 million cubic meters (70 million cubic feet) of volume and more than nearly 40 thousand square meters (4.2 million square feet) of floor space, it is doubtful if any other wood structure in the world of any type is larger.

The airdocks bring us into the modern era, but these examples are monumental structures – first for religious devotion, and second, for military combat. What about multi-story residential structures? Certainly here height was for practical rather than for symbolic reasons, and restraints on height often had less to do with the limitations in the structural capacity of wood than on practicality. Until the invention in the 19th century of the elevator, residential buildings exceeding five storeys push the limit of tolerance. This makes the height of the ancient Roman *insulae* particularly interesting, as some of these are believed to have exceeded that threshold.



Figure 12&13: *Left:* Five and six storey Medieval houses in the Marais District of Paris, France, constructed beginning in the 14th century, redone to their present form by the turn of the 16th century, and restored in 1967, revealing the timber that had been plastered over. *Right:* The Claremont Hotel, constructed in 1906 in Oakland, California, USA has 11 storeys of occupancy in its tallest portion, including assembly spaces. The stone at the base is veneer onto the timber structure. *Photos* © Langenbach

In any case, these thresholds were again known to have been exceeded in some congested Medieval towns, where again, as in Rome, the need for city walls drew a fixed perimeter around the town leaving the only direction for expansion to be up. As in Rome, the timber frame with masonry infill known in French as *colombage*, or in German as *Fachwerk*, proved to be suitable for tall construction because it eliminated the need for thick masonry walls at the base of the structures where often the shop fronts demanded more openness. It was also more economical to build, and allowed for larger room sizes upstairs as well. In the earthquake hazard areas in Eastern Europe, Greece, Turkey, and Kashmir, this form of construction continued to be used up

well into the 20th century. In Portugal and Italy, a variant of it was “invented” and promulgated after the devastating Lisbon earthquake of 1755 and Calabria earthquake of 1783 specifically because of its earthquake resistance. (Langenbach, 2007 & 2009)

In the competition for the tallest and largest residential buildings, moving forward in time, but again looking at 100% wood frame construction, one must acknowledge the contribution made by the larger examples of late nineteenth and early twentieth century timber frame hotels constructed in the United States and Canada. Before it was dismantled and burned in 1962, the Canyon Hotel in Yellowstone National Park, which was nearly a mile around its perimeter, was claimed to be the world’s largest wooden building (again ignoring the airlocks). The still extant Claremont Hotel in Oakland, California, constructed in 1906, has 279 rooms plus conference facilities on 10 occupied floors that rise approximately 36.6 meters (120 feet) from the foundation to the roof on its downhill side, with a central tower that is approximately 160 feet (49 meters) from foundation to top, equal to the height of the Great Buddha Hall of the Todaiji temple and nearly the height of the World War II airlocks.

6 TALL TIMBER BUILDINGS IN THE PRESENT DAY

Moving ahead to the present, just as the war-time shortage of steel was the stimulus for the use of wood for the vast parabolic arched trusses of the airlocks, the now the growing depletion of fossil fuels provides a stimulus to reexamine the potential of using wood for multistory urban buildings. In Hackney, a suburb of London, British housing developer Telford Homes constructed in 2008 a nine storey block of flats called the Stadthaus Tower (previously called Murray Hill Tower) entirely out of timber. The building was designed by Waugh Thistleton Architects with structural engineer Techniker Ltd. Rather than having a timber frame, its structure is of a solid wood wall system of cross-laminated wood panels pioneered by manufacturers KLH of Austria that “*are like giant pieces of plywood.*” It is claimed that “*this will be the first building in the world of this height to construct not only load-bearing-walls and floor slabs but also stair and lift cores entirely from timber.*” (Timber Building) KLH, the Austria-based manufacturer of the panels also did the erection. “*It took the four-man KLH construction crew just 27 days to erect the nine-story structure...[which] helped to compress the overall project schedule to just 46 weeks—40% shorter than if the team used traditional concrete frame construction,*” according to the architect. The wood embodied in this structure “*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.*” (David Barista, 2009)

In an article in Timber Building magazine, it is claimed that the 30 meter (100 ft) high, 9 storey Hackney building will be the world’s tallest residential timber building, but as shown before with the Todaiji Buddha Hall, such claims are always risky. It is not as tall as the 103-year old Claremont Hotel described above, and there are likely to be other examples in North America built before modern building code restrictions.

In Norway, an even taller wooden structure, the “Barents House,” is in the planning stage in the town of Kirkenes near Norway’s border with Russia which is billed by the Barents Secretariat as “*a signature building for the Arctic border town of Kirkenes. [which] will be the highest wooden building ever constructed, and made in line with the best possible environmental standards.*” (Barents Observer, 2009) It is planned to be 16-17 storeys high, but no measurement is given. Figuring 12 foot floor to floor storeys, this will be about 57-60 meters or 188 -200 feet in height. While environmentally sustainable, again the claim to be the tallest is not credible since the thousand-year-old Sakyamuni Pagoda, the seven-year-old Sapanta-Peri Monastery Church, and possibly the Tillamook Hanger will remain taller.

Interestingly, the publicity for the yet-to-be-built Barents House mentions as the current record holder for the tallest wooden residential structure the 13 storey, 44 meter (144 feet) owner-built house constructed by an eccentric post-Soviet era contractor, Nikolai Sutyagin. This house rose over the rural village (to the chagrin of his neighbors) like a mine shaft elevator head. Much of it was constructed of sawn logs notched and assembled like a log cabin. Sutyagin began the project in 1992, but then, having lost his money and been subjected to jail time, was never able to finish it, and it was demolished in 2008-09 by order of the authorities. (A. Blomfield, 2007)

| DATE | TALLEST TIMBER BUILDINGS (tallest at top) | Story height | height (meters) |
|-------------------|---|--------------|-----------------|
| 1935 | <i>Gliwice Radio Tower, Poland (not a building)</i> | N/A | 118 |
| 2003 | Săpânța-Peri Church, Romania | N/A | 75 |
| 1056 | Sakyamuni Pagoda, Yingzian, China | 9 | 67 |
| 1720 (moved 1802) | Bârsana Monastery, Romania | N/A | 62 |
| proposal | Barents House, Kirkenes, Norway | 17 | 60 |
| 1942-3 | Tillamook Hanger, Oregon, USA | N/A | 58.5 |
| 1942-3 | Hanger 2&3, Moffit Field, California, USA | N/A | 52 |
| 1942-4 | Four other extant timber Airdocks of similar dimensions | N/A | |
| 1906 | Claremont Hotel, Oakland, Ca. USA (Tower) | 10+Cupola | 49 |
| 1709 | Daibutsu-den, Todaiji Temple, Japan | N/A | 48.6 |
| 1992-d.2008 | Sutyagin House, Russia (demolished) | 13 | 44 |
| 1890 | St. Georges Anglican Catholic Church, Guyana | N/A | 43.5 |
| 1893-d.1995 | St. Paulus Church, San Francisco, USA (burned) | N/A | 43.5 |
| 2008 | Stadthaus, London, U.K. | 9 | 30 |
| started 1992 | Tennessee Tree House, USA | 10 | 29.5 |

Table 1: Tallest Timber Buildings. (NOTE: The research possible for this paper may miss a number of buildings that belong in the list. If any reader knows of other examples, please send them by email to ran@conservationtech.com.)



Figure 14: The 13 storey, 44 meter high single-family house constructed by Nikolai Sutyagin for himself and his wife in Arkhangelsk, Russia. It was never completed before it was demolished in 2009. Photo taken in 2004 by © Yury Kiselev, Panoramio.com



Figure 15&16: This dirt poor Pakistan Kashmir farmer who is rebuilding his house in the traditional *dhajji dewari* construction after the 2005 earthquake destroyed his rubble stone house. Not only is he doing the construction, but he is milling his own timber on the large old band saw visible in the photo of the interior on the right. Photos © Randolph Langenbach

7 CONCLUSION

The question of whether new residential structures are the tallest or largest on record is not so significant as the fact that they are new – as they have broken through the psychological and legally imposed barriers that have come with the concerns over fire safety combined with the perception that wood is inferior to steel or reinforced concrete. It is, in a way, emblematic that the Stadthaus Tower is not a frame, but a solid wall structure (the structural system for the Barents House is not yet described in their publicity). The use of cross-laminated boards for the structural system of mid-rise buildings is as radical a change in timber construction as was the invention of the balloon frame in the mid-19th century. In one move, timber construction is been both made more fire resistant and produced by a highly industrialized building delivery system – not unlike tunnel-form multi-story concrete construction. Better than that, wood construction continues to be lighter in weight while strong, flexible and resilient - all attributes that have distinguished it long before the modern era.

While the Hackney block of flats in Britain and presumably the Barants House in Norway are examples of industrialized forms of construction dependent on modern manufacturing plants, as well as site based construction, this stands alongside rather than supersedes the attribute of timber construction mentioned in the beginning – that it is far more easily accessed and understood by ordinary people in rural environments building their own shelters. It is comparatively so easy to use and so forgiving that, more than any other material, it can enable relatively untrained people to construct their own homes and work places – itself a basis for bringing a certain kind of independence, well being, and self-respect for millions of people around the world.

Perhaps nothing can better demonstrate this than eccentric structures like the Sutyagin House in Russia, or also a 97 foot high “tree house” in Tennessee, USA, a 17 year and continuing project by Horace Burgess, a now 60 year old landscape architect. Burgess reports that a vision came to him in 1993 from God: “*If you build me a treehouse, I’ll see you never run out of material.*” Constructed entirely from recycled wood, (and presumably without engineering calcula-

tions), the project cost Burgess only about \$12,000 by July 2007 after being topped out by a bell tower. The bells? They were fashioned from ten oxygen acetylene tanks. In the July 29, 2007 issue of USA Today, news of this project was published in a column entitled “Religion.” (Ken Beck, 2007)

Timber is arguably the most versatile building material available on the planet. As the examples of the tallest and largest wood buildings described here demonstrate, building tall wooden buildings is not new, but rather the continuation of a long tradition. Two important issues, however, need to be addressed in the present. One is the deforestation and consequential high price of timber which can and must be reversed by reducing waste and encouraging and teaching the proper stewardship and regeneration of forests around the world. Second is the reintroduction into schools of both shop classes for the teaching of carpentry, and engineering classes that focus on the science and structural engineering of building with timber. Students also need support and encouragement to concentrate in these areas. The gradual adoption in many countries of performance-based design is opening new possibilities, but it is now time for the education of architecture and structural engineering students to embrace timber along with concrete and steel.

REFERENCES

- Barents Observer.com. 2009. *Sky High Barents House Plans*. 5 June 2009.
- Barista, David. 2009. World's tallest all-wood residential structure opens in London. London: *Building Design & Construction*, 14 June 2009.
- Beck, Ken. 2007. Divine Vision Inspired a 97-foot Treehouse. USA TODAY, 29 July 2007.
- Betz Jonathan. 2006. *Thick Cross-laminated Solid Wood Panels in Europe*, University of British Columbia, Faculty of Forestry Report, April 15, 2006.
- Blomfield A. 2007. Gangster Who Built World's Tallest Log Cabin. London Telegraph, 7 March, 2007 posted on www.telegraph.co.uk.
- Building Design and construction, 6/14/09, London, www.bdcnetwork.com.
- Ebeling CW. 2006. The blimp barns. *American Heritage* 22(1)
- Encyclopedia Britannica Online. 2007. <http://www.britannica.com>.
- Lam, Frank & He, Minjuan. 2008. Example of Traditional Tall Timber Buildings in China – the Yingxian Pagoda. In *Structural Engineering International* 18(2): 126-129.
- Langenbach, Randolph. 2006 "Saga Of The Half-Timbered Skyscraper: What Does Half-Timbered Construction have to do with the Chicago Frame," *Proceedings of the Second International Congress on Construction History*, Cambridge University, UK. (www.conservationtech.com)
- Langenbach, Randolph. 2007. From “Opus Craticium” to the “Chicago Frame,” Earthquake Resistant Traditional Construction. *International Journal of Architectural Heritage: Conservation, Analysis, and Restoration* 1(1) 29–59. London: Taylor & Francis. (www.conservationtech.com)
- Langenbach, Randolph. 2009. Don't Tear It Down! Preserving the Earthquake Resistant Vernacular Architecture of Kashmir. New Delhi: UNESCO & USA: Oinfroin Media. (www.traditional-is-modern.net)
- Nichi, Dan. 2006. *The Tallest Wooden Church in the World Consecrated in Sapânta, Romania*, on website: www.sapanta.ro, 10 July 2006.
- Page & Turnbull. 2006. *Re-Use Guidelines, Hanger 3. NASA Ames Research Center, Moffett Field: California*, August 30, 2006 (Technical report). San Francisco. USA
- Pulpmillwatch.org. n/d. www.pulpmillwatch.org/countries/china.

ACKNOWLEDGEMENTS

The author wishes to recognize the contribution that UNESCO, UN-HABITAT, The Swiss Agency for Development and Cooperation, FEMA, and the American Academy in Rome have made in providing the opportunities to gain information that have contributed to this paper.