Wood! - You believe it

by Peter Standring

Figure 1 Artists impression of the W350 Sumitomo Forestry Tower.

Last summer during a few pleasant lunchtime walks along a canal from my workplace into town, I watched with the curiosity of a bystander as a five story building was erected on the opposite bank and between a main road. The footprint for the new building seemed like a long and very thin wedge with a footprint hardly justifying the work involved. As construction continued I was even more surprised to see that it was entirely made from wood and as such, shot upward in what seemed to be an inordinately short time.

This somewhat mundane observation was dumped in my memory no doubt to be forgotten had it not been for an article I read on April Fools Day (1st April). The article stated that Sumitomo Forestry were intending to build a 350 metre, 70 storey skyscraper in Tokyo where 90% of the material used would be wood, the rest steel. Titled W350, the Tower is planned to open 2041 as a celebration of the Company's 350th anniversary of its foundation.

Naturally, this happening to be the day when tricks and pranks are played, I checked the web and found the announcement by Sumitomo Forestry had originally been made in February. This was no April Fool's joke - as can be seen in **Figure 1**. Moreover, looking further into the modern use of wood for buildings it transpires there is indeed a rapidly growing movement amongst architects seeking to be environmentally friendly. In doing so, they are breaking into the one hundred year plus domination of steel and concrete used for construction. One compelling reason for this is that every cubic metre of wood used in a building stores one tonne of CO2. So, what might the implications of large scale construction in wood have for the fastener industry?

Building in Wood

Very surprisingly, until March 2019, the tallest multi storey wooden building in the world at 67 metres was the 963 year old Sakyamuni Pagoda of Forgong Temple in China. This year, the Mjosa Tower in the Norwegian town of Brumunddal topped it by 13 metres. Of more importance however, in the last decade, 48 new buildings constructed from wood have been proposed, are being built or have been completed all between 26 to 305 metres in height.

We may consider this to be a small and insignificant matter of concern only those who have a strong environmental point of view. But it is very interesting to note that the first steel and concrete buildings constructed around the turn of the 20th Century were new and many so called 'informed' experts of the day, fully expected they would collapse. Of course problems were encountered but the benefits steel and concrete construction brought ensured their long term success.

Wood has 'anisotropic' properties which means it is strong in the direction of its grains (in tension and compression) but weak across them (hence it can be split). Ply wood consists of thin strips of wood bonded together. The grains of each strip are placed at right angles thus creating a 'composite' structure where the properties are the same in the plane of the product. Depending on the number of bonded strips, the finished ply is either flexible (with thin products) or stiff when many strips are bonded to make it thick. The glue used to bring the strips together determine the suitability of the ply for different applications namely: interior, exterior or marine.

In modern building construction, three types of 'ply' structures are used and most importantly, can be made from unwanted wood. This means that trees which are at the edges of a plantation and deemed unsuitable for the primary applications can be commercially viable.

- Glulam is a Glued Laminated timber which has been manufactured for over 50 years and is used for straight beams and columns.
- LVL is Laminated Veneer Lumber which has the same strength properties as concrete.
- CLT is Cross Laminated Timber which when bonded using fire resistant glue is claimed to be as strong as structural steel.

Enclosing the ply in a weather tight envelope makes it impervious to rot. Currently, panels up to 6 metres square and 0.5 metres thick are used as walls, floors or for roofs. These have been demonstrated to survive intense heat better than steel or concrete. Besides their environmental credentials, it is highly significant that prefabricated wooden buildings can take half the time to construct compared with those using cast-in-situ concrete. They also have only 25% of the mass and reduce the carbon footprint by 60-75%.

It is perhaps worth noting how quickly 'stock turns' take place in the modern technological age. Two You Tube videos serve to illustrate this point. One showing the growth/spread of the human population through the ages (You Tube – Growth of human population by the American Museum of Natural History), the other plotting the performance of the world's top 15 branded companies between 2000 and 2018 (You Tube – Top 15 best global brands ranking 2000 – 2018). Watching these is informative and gives a fundamental focus on how quickly the world is changing.

By its 2041 target date official opening, the Sumitomo Forestry W350 Tower could simply be one amongst a great many equal timber built skyscrapers spreading like wooden forests in cities around the world?

Fasteners for Wooden Buildings

As stated in a previous article, the intellectual concept of using a third item to fasten together two other dissimilar things must have been the most significant leap forward ever made by humans (A Fascination with Fasteners – Published in Fastener World Issue 173, Nov/Dec 2018 pp 288 – 291). Move on to the problem of attaching wood together to produce a tall building and as yet there isn't an easy solution.

At great heights, nails and screws are not appropriate to be used as fasteners because the buildings are so light they risk being blown over.

The constructional methodology used in residential structures is not too problematic because the smaller internal unit elements provide a honey comb of adjoining rooms which can be used to achieve structural stiffness. The design of open plan commercial space requires heavy duty anchoring which effectively means placing tie rods through the entire building to secure the top to the ground.

It is fascinating to learn that the Sakyamuni Pagoda previously mentioned uses no nails or screws in its construction and has incidentally survived many serious earthquakes in its almost 1000 years of existence along with the usual ravages of time. It, like so many ancient Chinese, Japanese and Korean wooden buildings uses 'Dougongs' (wood blocks 'dou' and short beams 'gong') in its construction.

As shown in **Figure 2**, in engineering beam theory, a 'redundancy' refers to an additional support (a prop) placed under a beam to reduce the bending moment. In ancient structures and buildings made from stone which is weak in tension, corbelling (the placing of one flat stone slightly further out into space from the one which it rests on) provided a common method to form roofs. Also, in antiquity, the use of columns to support roofs was widely used in formal structures but these seriously limited the free room inside. It was the total lack of columns inside the Pantheon Building in Rome which was truly sensational and which even after ~2000 years still makes it at 43 metres the largest unsupported dome in the world.

Some 1500 years before the Sakyamuni Pagoda was constructed, artisan craftsmen in China developed the concept of a dougong. As shown in **Figure 3**, the block (dou), carved to accommodate the short beam (gong), was placed (free standing) on top of a column. The short beam was then placed centrally in the block extending axially in line with the intended roof beam and equally on both sides of the column as a simple double cantilever support. The symmetrical loading on either side of the column ensures equilibrium and therefore is secure. Over time and presumably with the confidence of previous success, dou's were added to the ends of the gong and a longer gong put in place above it thus extended the cantilever. With increasing knowledge, skill and confidence, this practice of 'flexible' support led to the richly decorated multi dougongs found at the many Imperial and religious buildings across China, Japan and Korea.

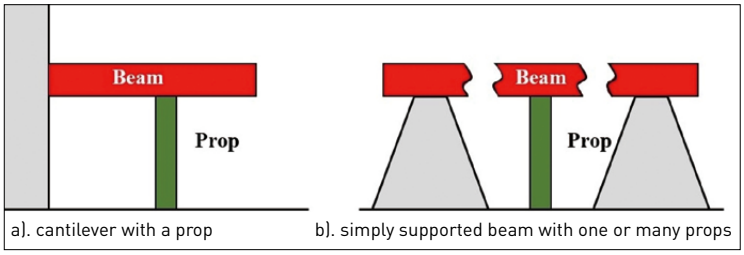

Figure 2 Examples of beams where redundancies (prop) is employed.

The dougongs are undoubtedly 'flexible' fasteners, secured only by the mass of the roof holding them in place. Yet scientific studies carried out on quarter scale replicas have shown that such structures can remain intact even after being subjected to an induced earthquake of 10 on the Richter Scale. However, such studies only serve to explain what has been common knowledge for centuries.

So, could the use of wood for high rise buildings largely replace steel and concrete for construction? As yet, only the dougong methodology is proven technology for holding high wooden buildings together. Therefore, the question must be asked, what implications does this have for the fastener industry?

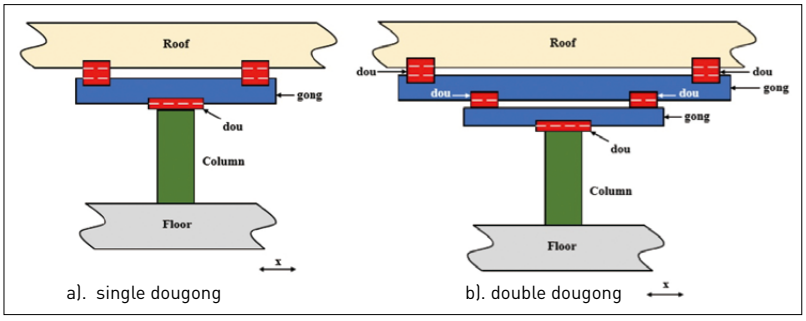

Figure 3 Simplified dougong construction showing redundancies.

(It should be noted that using complex carpentry for sophisticated seatings, multiple dougongs were constructed at various angles to each other in the horizontal plane and not simply in the x direction as shown in Figure 3 above).

What may Tomorrow Bring?

As pointed out in a previous Fastener World article, the construction industry represents 50% of the world use of steel (As you LIKE it – Published in Fastener World Issue 175, Mar/Apr 2019 pp 248 -252).

So, if we assume that by 2050, 50% of the world construction will be made from prefabricated wood, then what changes might this herald for fastener producers?

Clearly, modern wooden buildings will not be built using dougongs but they might be made using similar techniques in a different form. For example, if future building regulations insist the weather proofing envelope of ply materials must at no costs be penetrated to ensure their longevity, then supportive rather than securing methods may need to be invented?

Clearly, at present, fasteners and fixings must be employed in all the previously mentioned 48 new wooden builds. But, as with the initial development of steel and concrete structures, problems will be identified and solutions required to be found.

As we all know, change is everywhere continuous and each second, minute, hour, day etc.. brings new opportunities. For those engaged in the fastener industry, today, wooden building construction may be where steel and concrete construction was over 100 years ago. Perhaps now would be a good time to get in at the ground floor? Oh and this is definitely not an April Fool's joke!