Six storey commercial building – Is uniform diameter radiata roundwood suitable for the main structural elements?

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Paper Aim
To extend the ways of utilising NZ grown exotic timber in multi-storey building

Introduction

A current research project at the School of Architecture, University of Auckland, is investigating the feasibility of a 6 storey commercial building that uses uniform diameter roundwood as the main structural elements. This paper summarises the concept of the proposed building system and the factors which support it. In the conclusions of this paper, the probable future directions of this line of research are outlined.

Round Timbers, in building, are tree stems that have had their bark removed by peeling or shaving processes. Virtually all round timber utilised in New Zealand is pinus radiata. However, Corsican pine logs are available. (Reelick, Reelick, 2003)

Over the last 40 years pinus radiata poles have been used extensively as foundation piles, power poles, and as the members of retaining walls. They exist under a continual and often a reasonably high state of compressive or bending stress. Due to a minimum of in-service problems radiata poles have gained the reputation as a competent structural product.

Round timbers are a relatively stable form of wood, with typically higher characteristic failure stresses and modulus of elasticity than sawn lumber (Timber Design guide,1999). They require the minimum amount of machining and are available, in the shaved form, at less cost than sawn lumber. The paper discusses the recent development of 'uniform diameter roundwood' where the radiata stems are shaved to form a consistent and uniform diameter that, to a large extent, overcomes the problem of lack of surface regularity. Uniform diameter roundwood, with its consistent dimensions, means that member jointing cleats can be mass produced. This has led to uniform diameter poles being used as the structural members in portal frame buildings and 30m high tele-communication towers for cyclonic conditions (Reelick, Reelick, 2004)

1. Strength of Tapered Poles

Poles are regarded in the New Zealand Timber Structures Standard (NZS3603:1993) as being typically stronger for bending and axial stresses than sawn lumber. This can be seen in table 1 which lists the characteristic stresses for dry radiata as round timber and as framing. Table 1 also compares the modulus of elasticity. The characteristic stresses and modulus of elasticity for the round timbers have been modified for the effects of dry use (for the built environment), machine shaving, and steaming to make them more comparable to those of framing timber.

Modified Characteristic Stresses (MPa) & MoE (GPa) for dry Natural Round Radiata and Characteristic Stresses (MPa) & MoE (GPa) for dry Radiata Framing
Table 1

Category	*bending*	*tension*	*compression*	*shear*	*perpendicular*	*Modulus of elasticity*
High density poles	47.0	28.0	28.1	3.3	7.7	12.2
Medium density poles	34.3	20.8	18.0	3.0	7.2	8.8
Engineering grade Framing	24.5	14.8	24.2	3.8	8.9	10.0
No 1 Framing	17.7	10.6	20.9	3.8	8.9	8.0

2. Cost of Radiata‘Because there is less processing, less waste, and higher strength material, roundwood offers more load carrying capacity for the same cost than sawn timber’ (Timber Design Guide, 1999). Table 2 shows the relative costs of poles and lumber per cubic meter.

Table 2	**Approximate Costs of H5 tanalised Timber**		
Tapered Poles	Uniform Diameter Poles	No. 1 Rough Sawn Framing	No 1 Gauged Framing
NZ$400/cu.m	NZ$500/cu.m	NZ$900/cu.m	NZ$1000/cu.m

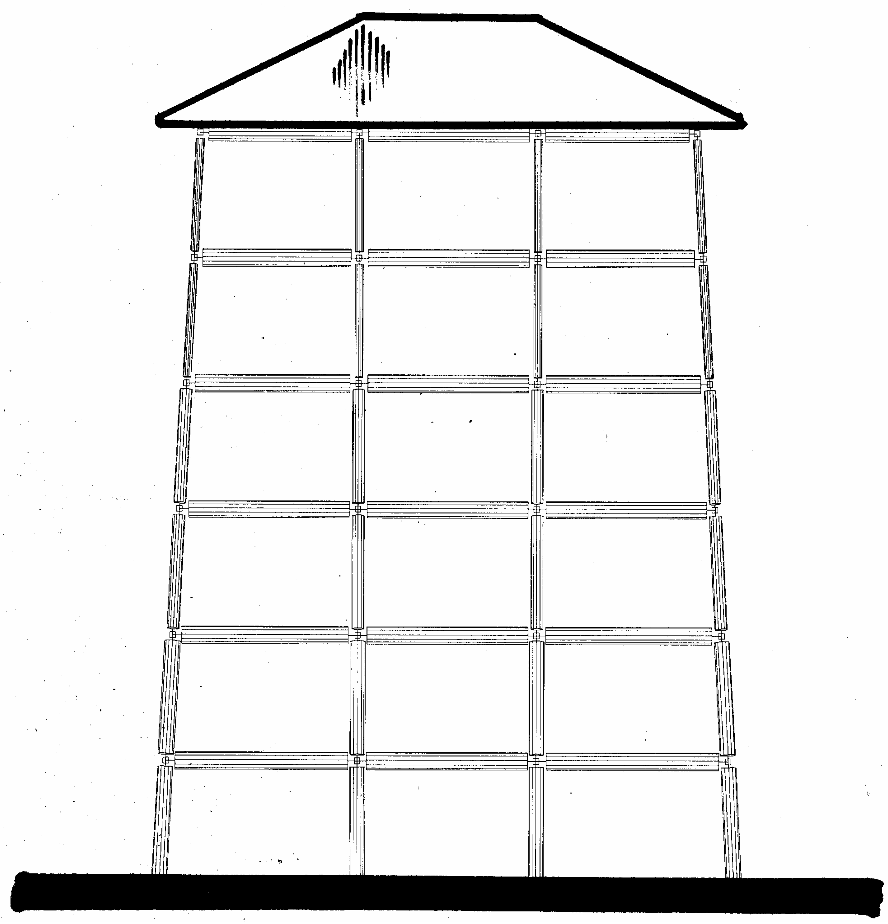
3. Uniform Diameter Roundwood
A recent trend, in New Zealand, is the peeling of poles to achieve an element with a uniform diameter. Uniform diameter roundwood overcomes the problem of the uneven surface of a typical tapered pole. This enables predictable thickness of member for assembly, standardised connection cleats, and a smoother appearance.
A significant manufacturer of uniform diameter roundwood is Tuakau Timber Treatment Ltd. Their web site advertises ‘unilogs’ for various diameters and for up to 12m lengths. Croft Pole Distributors Ltd makes a similar product which is marketed as ‘lazerlog’.
With uniform diameter roundwood there is loss of outer sapwood which is denser, stronger, and stiffer than the inner heartwood. I do not know of any research which has studied the significance of this loss with respect to strength and stiffness of a pole element.
Jayanetti and Follett comment on rounding poles:

> ‘Rounding can facilitate detailing, jointing, and construction and, depending on end use, improve the appearance of poles. However, these advantages can be offset by a considerable reduction in strength and wastage of material. For rounded and non-rounded poles of equal diameter there is a 30% loss of strength. Taking into account the 30% material wastage, this strength loss in respect of the original diameter increases to 40%.’

If we follow this comment by Jayanetti and Follett and reduce tapered pole strengths by 30% for uniform diameter poles, then for high density radiata poles, the characteristic stresses as found in NZS3603:1993 reduce from 52 MPa to 36 MPa for bending, and from 25 MPa to 17.5 MPa for compression.

4. Aims for Proposed 6 storey roundwood commercial building
The aims for the building are:

1) Maximized prefabrication
2) Building recyclable
3) Structural elements of uniform diameter roundwood
4) Simple jointing system and easy to erect
5) No shear walls or cross bracing
6) Explore Architectural opportunities of roundwood



6 STOREY ROUNDWOOD COMMERCIAL BUILDING ELEVATION
diagrammatic ***Figure 1***

4.1 Maximized prefabrication.
By maximizing prefabrication, there is better quality control, no fabrication time lost due to weather, and there are cost advantages.

4.2 Building recyclable
Building recyclability adds to its sustainable value. If the building stops being useful, then it can be unbolted and re-erected in a new location. This is a big improvement on reinforced concrete buildings which are impossible to recycle and require a large amount of time and energy to remove.

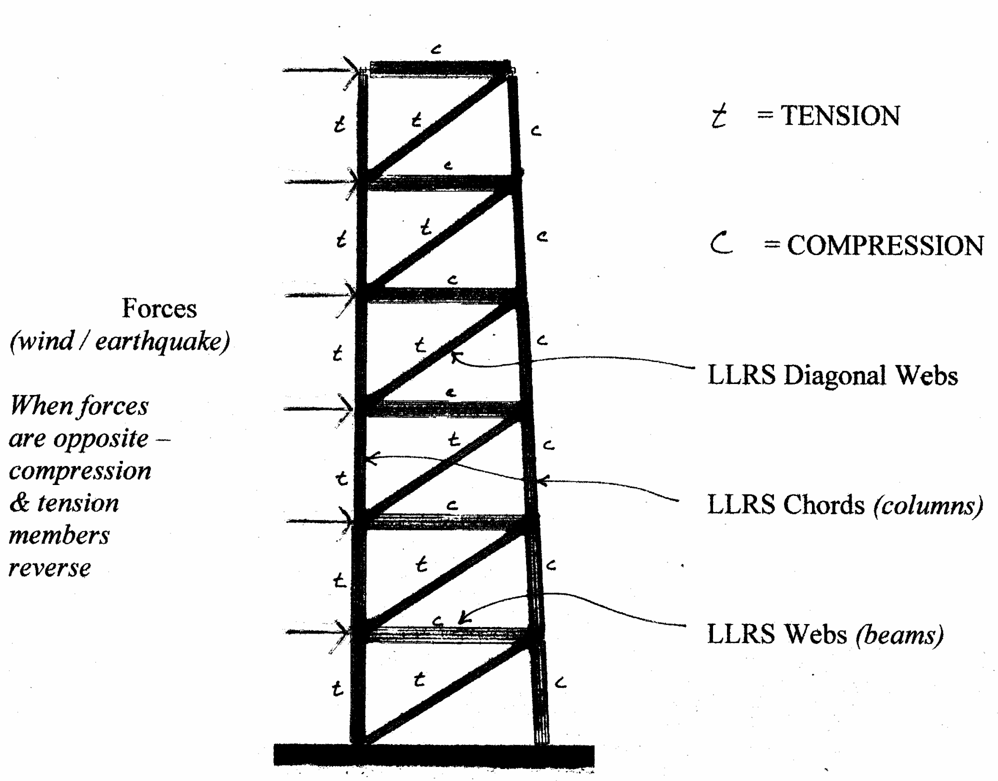
4.3 Uniform diameter roundwood for structural elements.
The advantages of uniform round timber, compared to tapered poles, include standardisation of joint connection brackets, predictable member thicknesses for assembly, and a smoother appearance.
The reasons why the roundwood is preferred over sawn lumber are as follows:

- Less timber wasted. Sawn lumbers can only utilize 50% of the log. Uniform roundwood has 25% log loss.
- More economic. Uniform roundwood cost around NZ$500 /cu.m. compared to NZ$1000/cu.m for selected sawn lumber.
- Less handling and energy for manufacture
- Higher strength and stiffness
- More stable in service
- Available in longer lengths

4.4 Simple jointing system and easy to erect
Ease of building erection means that a wider range of construction workers is available to assist on site. Also, site costs are reduced. These advantages help the export potential of the building. Ease of erection depends on simple jointing systems. It is expected that the first jointing system to be considered will be an adaption of that used by Tuakau Timber Treatment Ltd on their portal frame buildings and tele-communication towers. (Reelick, Reelick, 2004). The jointers are interconnected mild steel 'sleeves' which the ends of the round members slot into.

4.5 No shear walls or cross braces.
For domestic apartments, the consistent party walls can be utilized as shear walls. However, shear walls and cross bracing constrain the use and architecture of commercial buildings. They inhibit windows on external elevations and reduce flexibility of floor spaces. Also, shear walls require experienced carpenters during erection.

4.6 Architectural opportunities of roundwood.
Typically, the result when the sides of sawn timber are butt jointed is a right angle joint. However, with round sections, the butt joints on longitudinal surfaces is the same at any place around the peripheries of the members. Thus, members which are inclined are easier to construct. The proposed prototype commercial building (figure 1) has the external walls at 3 degrees to the vertical. It would also be easy to make the external walls as a gentle curve – like the sides of many 19th century lighthouses.



6 STOREY ROUNDWOOD COMMERCIAL BUILDING - LATERAL LOAD RESISTING SYSTEM (LLRS)
diagrammatic ***Figure 2***

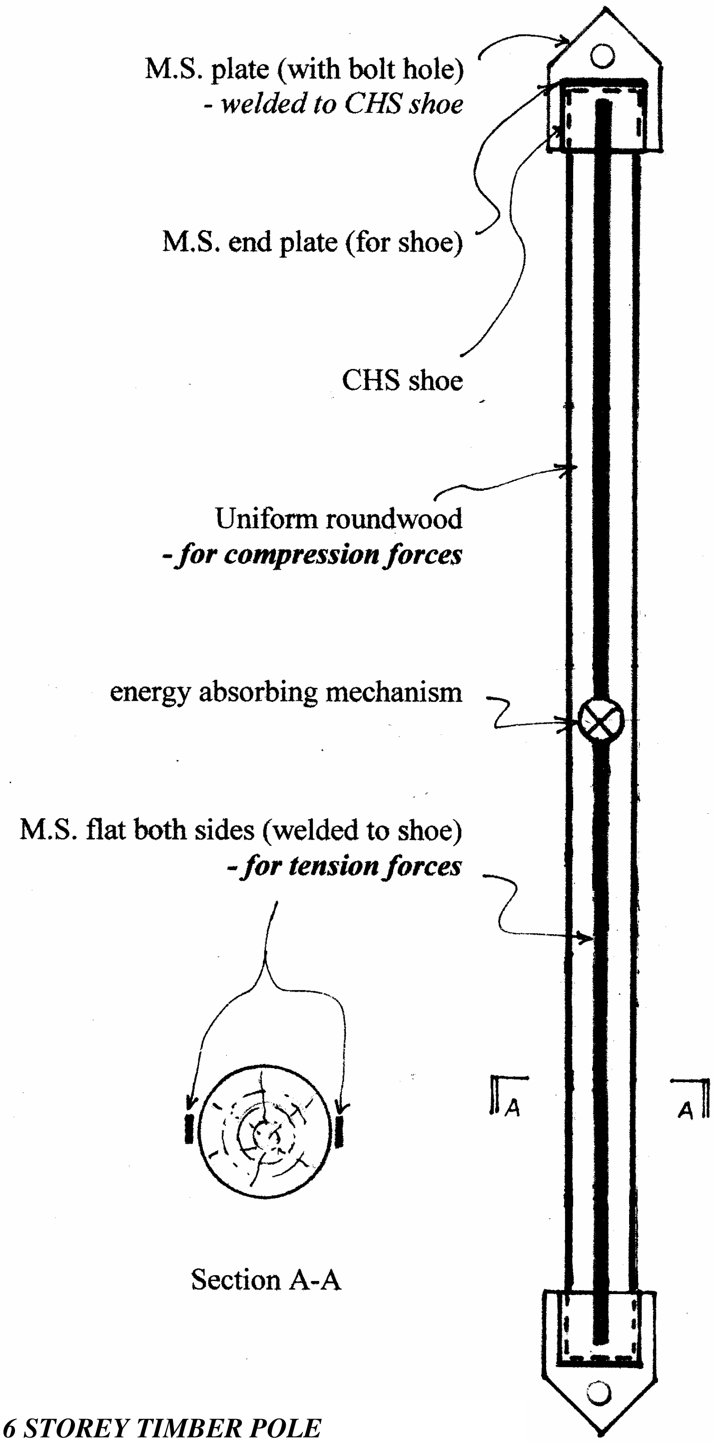
5. Proposed lateral load resisting system.

The proposed lateral load resisting system is shown in figure 2. It is a vertical cantilever truss with singly braced bays. This arrangement is better than shear walls or cross bracing because more area is available for windows on external walls; and for internal vertical trusses doors can be located under the braces. In the proposed lateral load resisting system, the horizontal and inclined web members need to act both in tension and compression depending on the direction of the horizontal load.

The main problem with timber tension members is achieving the end connections. e.g. a timber member with an axial tension force of 200kN will require approximately 200no. 3.15, dia. Nails. These joints are awkward, expensive and time consuming.

The proposed web members are illustrated in figure 3. They have a round timber element for supporting axial compression load, and axial tension load is transferred by 2 no. mild steel flats, which are located opposite each other. As a consequence, only a few locating bolts or nails are required at the joints. Using steel for supporting tensile axial loads was used extensively for bridges that were built in the late 19^{th} and early 20^{th} centuries (Thornton,2001).

The proposed lateral load resisting system, due to the steel tension members, could be considered to have a ductile response. The response of the steel members could be refined by introducing an ‘energy absorbing mechanism’ or a ‘mild steel fuse’ where ductility would take place. By sizing the chords and webs members of the lateral load resisting system to ensure that the steel reaches yield, brittle timber failure can be avoided.



6 STOREY TIMBER POLE COMMERCIAL BUILDING- LATERAL LOAD RESISTING FRAME – WEB MEMBER
Diagrammatic Figure 3

6. Timber Poles and Architecture

Round timber elements are being used more and more by Architects. This is evident when looking through recent NZ Architecture magazines or similar journals. The appearance of round timbers is organic and is unobtrusive. It is particularly reflective of a 'pacific' style. Pole columns and roof beams are used extensively in Auckland in Pacific Island churches which are affectionately known as 'coral cathedrals'.

Round timbers are presently being used with significant architectural effect in contemporary European buildings. Examples of these have been published by Andrew Charleson in NZ Timber Design Journals (Charleson, 2002) & (Charleson, 2002)

7. Conclusions

Factors which support the proposal to use roundwood for multi-storey commercial building include its time proven competence as a structural product; the advantages for the environment; physical properties which are superior to sawn lumber; and lower material and manufacturing costs.

The paper briefly reports on how uniform diameter roundwood overcomes the problems due to the natural taper of poles to ensure predictable dimensions for assembly, and standardised joint cleats.

The aims for the 6 storey commercial building are outlined above and a prototype building to achieve these aims is diagrammatically proposed.

Future research directions for this line of study include:

- proposing column locations in plan (perhaps at 4.8m centres in both directions)
- choosing a floor system to achieve suitable sound and fire insulation
- analysing a 6 storey building to check the ability of commonly available uniform diameter roundwood to provide the required strength
- assessing the economic viability of this type of building
- Investigating further the above lateral load resisting system.

Because the axial forces in the lateral load resisting system are relatively large for timber elements, it will probably be necessary to carry out racking tests on a full scale model. Testing would ensure that the members and joints performed as expected.

This paper outlines a possible new direction for utilising pinus radiata. In some ways the proposed 6 storey commercial building is being informed by the designs of the large span timber road and rail bridges of the early 20^{th} century whose structural members had internal actions of a similar magnitude.

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