How Do Builders Rate Wood In Intensive Residential Developments?

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In conjunction with the Auckland Regional Council ***Forest Research*** recently conducted a study on builders' perceptions of high-density housing and the adequacy of existing building systems to meet the needs of intensive residential construction. While the interview sample was relatively small it was representative of the different roles of people involved in this type of construction and the process provided valuable insights into the future placement of wood in the construction of intensive housing. Builders suggest that the ideal timber-based wall system needs to incorporate the following characteristics:

- Easy and quick to erect;
- Excellent/improved acoustic and thermal insulation performance;
- Durable;
- Stable, thus minimising movement within the building;
- Fire-rating credibility.

Fourteen people were interviewed. These people were selected because they had been involved in at least one of nine intensive residential developments in Auckland that are currently being studied by the Auckland Regional Council. The interviewees included building overseers, builders, site managers, site engineers and project managers. Our interview process was designed to elicit their views on the advantages and disadvantages of using wood products in comparison to non-wood products in intensive residential construction and thus areas where wood products could be improved for this type of development.

In terms of the scale of development, our interviewees were generally comfortable with the scale of medium intensity residential developments. Those with a background in the building trades were, however, more likely to prefer working on the smaller projects while one of the company directors preferred larger scale projects because of the profits that could be made. The study developments did not seem to create excessive problems that were not found in other types of developments. Traffic was an issue in the developments in already built-up areas while there was general recognition of the need to carefully plan the building schedule to avoid causing logistical problems - such as getting blocked in a small area with no room to move.

Timber movement, particularly in kiln dried timber due to changes in moisture content (either up or down) was mentioned in many cases as a problem on these developments and in others – especially by the builders and site managers. Timber movement affected the finish of buildings causing problems with nail peaking and popping in plasterboard, wall straightness, squeaky floors and playing a role in cracking of the exterior plasterwork etc. Rotting of timber framing due to water ingress behind plaster exteriors was also been found to be a problem. There was general recognition that problems with timber rotting and plaster cracking were more related to the design of the buildings, particularly the lack of eaves, tricky roofline detailing and on occasions poor workmanship.

Timber-frame was found to have been used predominantly in all developments for interior and exterior wall framing and for roof structures. Concrete had a monopoly on ground floors and, while timber and particleboard were mainly used for suspended floors, there was some application of concrete slab technologies. For party walls, where sound insulation was important, the use of blockwork was almost equal to the use of timber framing

Examples of intensive residential development

When we asked what sorts of materials the interviewees would prefer to use for a hypothetical typical intensive residential development we found that timber was still the overall favoured material for wall framing and roofing. The interviewees generally preferred timber because it was "what they know" and is straightforward to work with. However a number of interviewees expressed interest in using tilt slab or lightweight concrete technologies for suspended floors, party walls and load bearing walls. This was due to it's perceived better performance than timber systems for sound insulation, the fact that it was perceived to be easier to achieve acoustic performance standards, as well as being durable, stable and fireproof. As could be expected, once familiar with a product builders were reluctant to change products. The risk for timber here is that if timber performs poorly resulting in some loss of market share it would be difficult to regain the market.

When ranking different materials for their performance in wall framing, timber frame was the overall preferred material. In fact 10 out of the 13 people interviewed ranked timber as their most preferred material. Timber was ranked highly for being a safe, flexible and easy to use material. Surprisingly, blockwork and tilt slab were rated better for thermal insulation, in addition to acoustic insulation and the quality of finish. For suspended floor structures tilt slab rated highly for thermal and acoustic insulation performance and it was ranked as the overall most preferred material.

Not surprisingly a significant number of our interviewees thought that concrete and tilt slab pose the biggest threat to timber while the moisture related problem of kiln dried timber was a major issue that needed to be addressed. On a positive note, timber is still the most preferred building material and a large proportion of the interviewees felt that there were no viable alternatives. This does not mean that the timber industry can afford to be complacent about the position of wood. Failure to address these key performance issues facing timber products would be detrimental to the timber industry. Many of the interviewees prefer timber because it is the product that they are most familiar with, while concrete based products are increasingly being used in intensive housing as they are perceived to be superior for durability, fire-resistance, and thermal and acoustic insulation.

RAIN SCREEN TECHNOLOGY

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THE PROBLEM

The system of exterior cladding for timber frame buildings that uses stucco is being used very widely in New Zealand – sometimes with disastrous results. Likewise with stucco or sprayed-on textured coating over polystyrene foam – called "chillybin" construction. In the Northwest United States and in Western Canada similar construction has led to losses running to billions of dollars. That part of the world has high rainfall, like much of New Zealand. The problem lies not with the materials so much as with the system. What has happened is that water has penetrated the exterior cladding and has been unable to drain away, or to evaporate. Untreated timber in contact with moisture and warmth is bound to decay and it will do unnoticed, provided the interior lining does not collapse first. Boric treated timber will stand occasional but not continuous wetting. Typical construction uses building wrap over the timber frame and fibre-cement sheet, followed by stucco. The use of reinforced plastic TYVEK building wrap is an improvement over building paper but not the complete answer because it is inevitably punctured by nails and staples. BRANZ (2001) has also just published an article on this, pointing out that "there has been little research done as yet in New Zealand…..the following is the best advice we can give at the present".

THE SOLUTION

It did not take much thinking to work out what was wrong, and to come up with a solution. This is described by Hazleden and Morris (1999). The solution relies on good design and can best be expressed as "Rain Screen Technology" or "The 4 D's". These four lines of defence are illustrated in Figure 1 and are listed in order of importance.

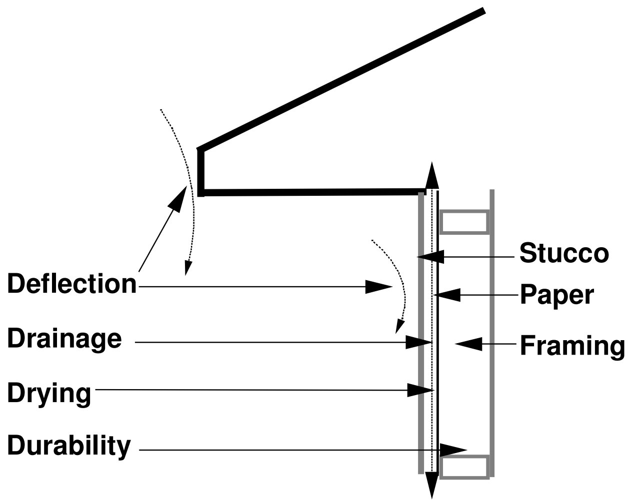

Figure 1. Illustration of the 4 Ds

- **Deflection** means the use of wide eaves to deflect rain off the walls. This is fine for a single storey building but wide eaves are not a popular architectural fashion. Besides, there are still the gable ends of a house to contend with. Nevertheless deflection is the first line of defence and this is estimated to be capable of dealing with perhaps 90% of rain incidence on a building. I see the draft Standard for earth housing requires eaves to half the wall height. That does limit its design but the thinking is the same.
- **Drainage** means that there is a cavity between the exterior cladding and the building paper or wrap. It also means that there are adequate flashings. Some disasters have occurred where builders thought that modern spray-on exterior thick film coatings did not need flashings but that is another story. Hazleden and Morris (1999) say "There is considerable discussion as to whether drainage is possible between stucco and the building paper, using one or two layers of paper. Due to doubts as to the effectiveness of this system, the City of Vancouver has mandated a 19 mm cavity using battens behind stucco." Here stucco means reinforced plaster rendering possibly with fibre-cement sheet support.
- **Drying** means that there is an air flow through the cavity and no opportunity for water to be trapped or ponded. A gap to allow air flow through the cavity behind the exterior cladding is essential. At the top of the wall some kind of overhang or flashing is needed to cover the gap. At the bottom care needs to be taken to ensure that the gap remains open and that creeping plants or vermin do not enter.
- **Durability** means that if water gets to the timber it will not decay. Untreated timber will tolerate occasional wetting provided it dries quickly. How quickly is a matter of some debate, but it is generally thought that if the moisture content stays above 25%, decay fungi may become established in as little as three months. The battens creating the cavity behind the exterior cladding must be H3 treated because moisture will wick into the crevice between the batten and the building paper. With a drainage cavity the studs are unlikely to need treatment but as a fourth line of defence or insurance, H1 treatment can be specified. Boron salts (H1) are a very effective fungicide

and do not leach out unless there is running water on the timber. H3 treatment would be overkill for framing but necessary for the battens.

Figure 2 shows the exterior cladding arrangement used on multistorey apartment buildings in Vancouver, BC, Canada.

1. Plywood Sheathing
2. Building wrap - 2 layers
3. Battens
4. Separation board
5. Flashing
6.
7. Gap above flashing
8. Vinyl siding
9. Ventilation gap

Apart from the use of vinyl siding, this detail is notable for the cavity created behind the siding, and the drainage/ventilation created at each floor level. Make a few changes and you have the answer for the New Zealand situation:

- Replace the plywood sheathing with fibre-cement sheet or use Gib Braceline® for the interior lining.
- Use treated timber battens over the building wrap along the line of each stud.
- Replace the vinyl siding with stucco or whatever.

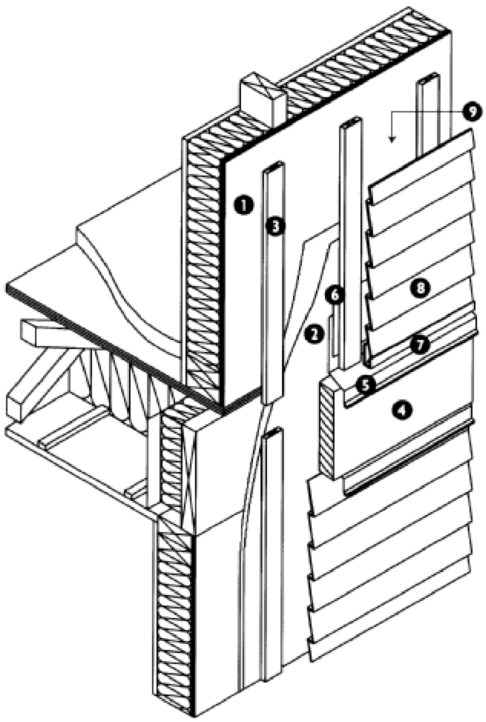

Figure 2. Vancouver example

PROS AND CONS

What are the fish hooks in this solution?
The ventilation gaps create a haven for spiders. A fine mesh at the bottom should stop that.
The painted timber separation board at each floor level would require painting so omit that. Just make sure that there is a continuous line of flashing and an air gap at each floor level to ventilate the cavity. It may be that a line of flashing and a gap is not required at each floor level. If that was omitted then the appearance would be exactly the same as is being achieved now. The ventilation gap at the top and the bottom of the wall would not be visible.
Another consideration might be fire. Although small, the ventilation gap could act as a chimney and carry fire between apartments. A separation with appropriate flashing is necessary at each floor to ensure fire separation.

REFERENCE

D G Hazleden, PI Morris, 1999; Designing for durable wood construction: The 4 Ds. 8th International conference on durability of building materials and components, Vancouver, Canada.
Tony Condor, 2001; Drained and ventilated cavities for wall claddings. Build, July/August

WHAT TIMBER, WHAT GRADE, WHAT SIZE, WHAT STRESSES?

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The sometime designer of timber structures can be easily confused by the options of what timber, what size, what grade and what moisture condition to specify, and what stresses to use with that choice. Simply asking local suppliers what is available might reduce the number of choices considerably so that is often the best starting point, since market demand determines what is stocked. An invaluable reference is the "Timber Design Guide", published by the NZ Timber Industry Federation. You will probably find that the choices are:

- NZ sizes in No. 1 Framing, green or dry, or
- Australian sizes in one grade, dry only, or
- Laminated Veneer Lumber (LVL), dry only.

What species?

Radiata pine is almost the only option in New Zealand. Douglas fir (sometimes called Oregon or Oregon pine) is the second option. Its strength and stiffness are practically the same as radiata. The major differences are that Douglas fir is more stable than radiata, it cannot effectively be treated with CCA, and its non-uniform texture makes it difficult to nail by hand. It is favoured for roof trusses because of these attributes. There are numerous minor species for which ***Forest Research*** can provide design data. Then there is Laminated Veneer Lumber (LVL), with highly reliable properties. This is made from radiata pine veneers.

What size?

- Nominal or call dimensions, e.g. 4x2 (inches) or 100x50 (millimeters). Rough sawn timber will have these dimensions with a tolerance of –1 to +3 mm. Timber treated to H4 for ground contact use is often available rough sawn, and unseasoned.
- Green gauged. When houses were commonly built with unseasoned framing, these were the common sizes, e.g. 100x50 is actually 94x47. NZ grades only. The arrises are rounded for nice handling. It can be assumed that these dimensions will reduce by 2.5% due to drying shrinkage.
- Dry dressed. Dry framing is produced in these dimensions. 100x50 is actually 90x45. NZ visual grades only.
- LVL. This is available in thicknesses of 36, 45 and 63 mm. It is intended to produce thicknesses of 90, 105 and 120 mm from the CHH plant at Marsden Point. Widths can be anything up to 1200 mm.
- Australian sizes. Pine is produced in the dry condition only, and the sizes are called by their actual dimensions. F-grades and MGP-grades are produced in the same dimensions.

What grade?

- NZS 3631 describes the visual grades of Engineering, No. 1 Framing and No. 2 Framing. Engineering is practically unobtainable and NZS 3603 does not list stresses for No. 2 Framing. Therefore for green gauged and dry dressed sizes consider No. 1 Framing only. NZS 3631 also lists stresses for the machine grades of F6 and F11. These are no longer available.
- Australia has a system of stress grades; F4, F5, F7, F8, F11, F14 etc. Their multitude of species are fitted into this system. Timber to meet a given stress grade can be visually graded to AS 2858 or machine graded to AS/NZS 1748. Because the F-grade system is based on the properties of visually graded hardwoods, it does not represent accurately the properties of machine-graded pine, so machine-graded F5, F8 and F11 pine was evaluated and renamed MGP 10, MGP 12 and MGP 15 respectively. F-grades and MGP-grades are not widely marketed in New Zealand but visually graded F7 and machine graded MGP 12 may be available locally.
- The two major corporates in NZ, Carter Holt Harvey Timber and Fletcher Challenge Forests, produce MGP 10 for Australia and put it on the NZ market as Laserframe™ and Origin Timeframe™.
- LVL comes in one grade only, Hyspan™.

To summarise, the possible combinations of size, grade and moisture condition are:

Table 1. Grade/size combinations available in New Zealand

New Zealand grades: Engineering (perhaps), and No. 1 Framing									
	Thickness	Widths							
Call size:	40, 50, 75, 100	75	100	125	150	200	225	250	300
Green gauged:	37, 47, 69, 94	69	94	119	144	194	219	244	294
Dry dressed:	35, 45, 65, 90	65	90	115	140	180	205	230	280
Dry framing: Laserframe™, Origin Timeframe™									
Actual size:	35 or 45	70	90	120	140	170	190	240	290
LVL: Hyspan™									
Actual size:	36, 45, 63, 120	150	200	240	300	360	400	450	600

What stresses?

The design stresses in Table 2 are extracted from NZS 3603 and trade literature. Note that the tension parallel stresses have been set to 50% of bending rather than 60% as in NZS 3603. This is in line with recent research results and the Australian code AS 1720.2:1999.

Table 2. Characteristic stresses for grades readily available in New Zealand (MPa)

Species	Grade	**Bending Strength**	**Tension Strength**	**Compression Strength parallel**	**Shear Strength**	**Compression Strength perpendicular**	**Bending MoE**
		f_b	f_t	f_c	f_s	f_p	E
Moisture condition: green							
Radiata	No. 1 Framing	14.8	7.4	12.7	2.4	5.3	6500
Douglas fir	No. 1 Framing	14.8	7.4	14.5	2.4	4.7	6500
Moisture condition: dry							
Radiata	No. 1 Framing	17.7	8.8	20.9	3.8	8.9	8000
Douglas fir	No. 1 Framing	17.7	8.8	22.1	3.0	8.9	8000
Radiata	Laserframe™, Origin Time frame™	16*	8.9	24	5.0	12	10000
LVL	Hyspan™	42	27	34	4.5	12	13200

*19 MPa for 45 mm thick timber.

Furthermore, shear can be the limiting factor in beam design but from experience in testing, it is very rare for radiata to fail in shear, even in beams with a span/depth ratio of 6:1. The shear stresses for No. 1 Framing are not based on in-grade tests (as are the other stresses) and are therefore too conservative. Adjustments will be made in the next amendment of NZS 3603.

Finally, for treated timber, only No. 1 Framing is treated although the other grades could be but are not normally supplied as such.

Where to from here?

Forest Research has proposed, and has developed a system to back up, two more MGP grades to better represent the New Zealand resource. They are MGP8, as equivalent to the present No. 1 Framing, and MGP6, as a replacement for No. 2 Framing. These would be produced dry, in Australian sizes and by means of some mechanical sorting device. The proposed stresses are given in Table 3 and are compared to suggested values for dry No. 2 Framing grade. Stresses for the scarcer MGP grades and F7 are also given.

Table 3. Proposed grade stresses (MPa)

Grade	Bending Strength	Tension Strength	Shear Strength	Compression Strength	Bending MoE
MGP 12	28.0	15.0	6.5	29.0	12700
MGP 10	16.0	8.9	5.0	24.0	10000
MGP 8	14.0	6.3	4.0	20.0	8000
MGP 6	10.0	4.0	2.5	16.0	6000
No 2Framing*	13.0	7.7	3.8	9.7	6100
F7	20.0	10.0	2.1	15.0	7900

* Assumed equal to F4 grade except shear equal to No. 1 Framing

Whether the proposed grades are ever produced, or some other grade/stress combination is introduced, depends on the timber industry. They need to determine the optimum balance between what can be obtained from the resource both here and in Australia, how a new grade might fit in with or replace existing grades, what remanufacturing can be done with lower or reject material, and how well the performance of any new grade can be guaranteed.

Another consideration for engineers designing members that are not load-sharing is the variability in MoE. While visual grading is reasonably efficient at sorting for strength, it is very poor at sorting for stiffness. To address this problem it has been proposed that values for a minimum (or lower 5 percentile) MoE be published. For visually graded timber this would be 50% of the currently-published (average) MoE. For machine graded timber it would be 80%, while for LVL it would be more than 90%.