The true cost and performance of multi-unit residential housing

New Zealand cities, particularly the main centres of Auckland, Wellington and Christchurch, in recent years have experienced a previously unseen demand for multi-unit residential accommodation. To cope with this growing call for medium density urban living, developers are looking towards the benefits offered by multi-unit apartment construction.

Despite the growth in multi-unit construction there seems to be no sign of consensus amongst key decision makers as to an ideal construction material - with steel, concrete and (on occasions) timber being preferred in isolation or combination.

“This article seeks to inform the debate around which construction material offers the optimum return for multi-unit buildings in terms of initial expenditure, on going maintenance costs and overall performance,” says Ralf Kessel, Concrete NZ (formerly CCANZ).

Apartment Developments

While initial building capital expenditure is an important factor for any construction project, maintenance and repair costs can potentially be more significant over a building’s lifetime.

New Zealand buildings are subject to a range of harsh, predominantly coastal, environmental conditions that include extreme winds, high temperature variations and heavy rain. As such, the *durability* and *service life* of our built environment are critical considerations, and place a premium on the appropriate selection of building materials.

In recent years New Zealand has experienced significant growth in the construction of multi-unit apartment buildings, particularly in the main centres. CBRE figures indicate that Auckland currently has approximately 32,250 apartments in in 480 buildings.

“Some would argue that much of New Zealand’s current multi-unit stock lacks overall *quality*, offering poor acoustic separation, low fire protection as well as being prone to moisture ingress,” says Ralf. “Here is a case study to help clarify true costs over the life time of a building.”

Case Study

A comparison of initial building costs, using concrete, steel and timber as the structural material, was undertaken using a multi-unit apartment building case study model. The design was based on the CCANZ entry in the 2012 *Breathe* international competition that challenged entrants to develop a concept for medium density mixed-use living for a site on Latimer Square in Christchurch.

The Concrete NZ design consists of five 4 -5-storey blocks totaling 8000m^2 for apartments (95 one, two and three bedroom units), 2000m^2 for retail / office space, 3000m^2 or underground car parking and storage. One 'block' typically contains eight apartments and ground floor retail / office space.

The case study model considers a building consisting of three blocks having three access cores.

Case study model area: 2500m^2 apartment area and 825m^{2}retail / office space

Case Study – Structural Design

Three different structural design options underwent analysis. For all three design options the following dimensions were consistent:

- 55m Building length
- 15m Building width
- 3.5m Overall storey height
- 14m Building height
- 205mm Ground floor concrete slab

Three structural materials were applied to the design options:

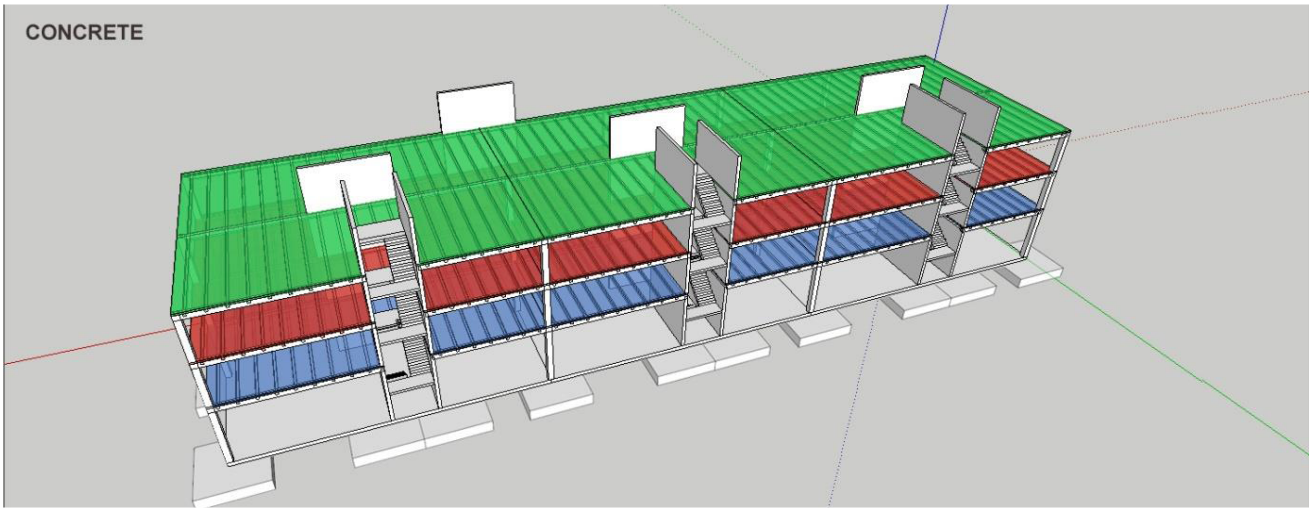
1. **Concrete Bracing core, circular columns and timber infill (TI) span slabs**
2. **Steel Eccentric framing and ComFlor slabs**
3. **Timber Ply bracing walls, LVL columns, GL8 beams, structure flooring**

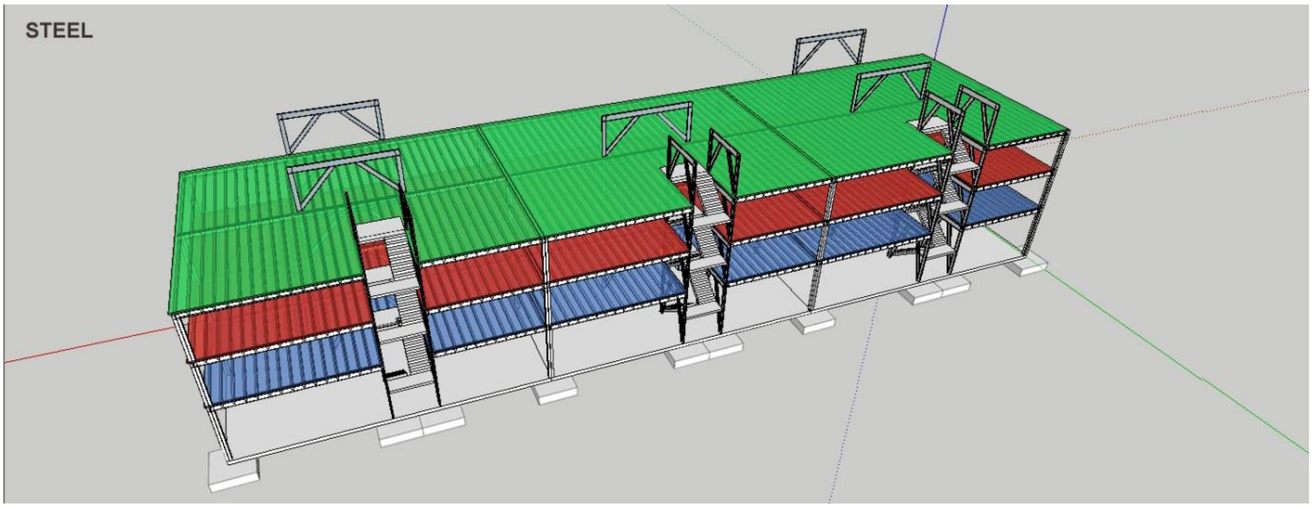
The design solutions were as follows:

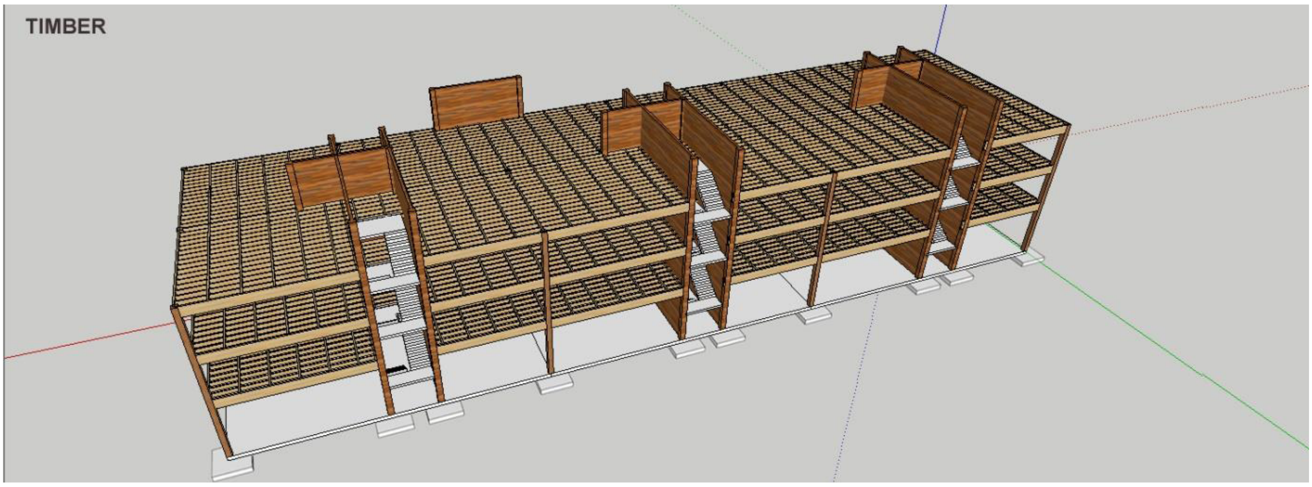
Concrete	Steel	Timber
· Foundation 33 pads of 3.9 x 3.9m x 760mm thick · Columns 450mm square · Floors TI 250 concrete, 600mm x 40 mm beams along 8.5m span · Bracing walls 200mm concrete, 10 of 5m length · External walls Insulated concrete sandwich panels	· Foundation 35 pads of 2.4 x 2.4m x 620 mm thick · Columns 250 UC 89 · Floors ComFlor 210/90, 460UB67 beams along the 8.5 m span · Bracing walls Eccentric steel frames, 250 UC 89/ 360 UB 57, diagonals 360 UB 57+ 460UB67 beams towards the 8.5m span · External walls light frame, metal studs with insulation and weatherboards	· Foundation 34 pads of 2.0 x 2.0m x 330mm thick · Columns 300mm square, LVL · Floors GL8 540 x 90 by 1.7m, 250 x 50 by 400mm, 30 mm GL structural flooring, GL8 630 x 90 beams towards 8.5m span · Bracing walls 25mm ply, 2 sides, 300mm width, end columns 300 x 50mm · External walls Light frame, timber studs with insulation and ply cladding

One particularly noticeable difference between these design solutions is the foundation. The concrete solution required about three times the reinforced concrete compared to the steel solution and almost eight times when compared to the amount of the timber solution.

Illustrations







Case study - Cost Estimates

Cost estimates for the three material solutions were developed using the 2014 edition of the *Rawlinson Handbook*. The largest up front cost for the foundation element of the designs applied to the concrete solution, which demanded 380m^3 reinforced concrete, at an estimated cost of $570,000. The steel solution's foundation was estimated to be $190,000, approximately 33% of the concrete solution. The timber solution was deemed to only require 45m^3 of reinforced concrete, at an estimated cost of $70,000 - equivalent to 12% of the concrete solution.

However, the cost outlay is proportioned very differently between the materials in relation to bracing. The ten concrete bracing walls of 200mm structural concrete totaled $ 265,000, the steel solution's eccentric bracing frames were the most expensive at $520,000, while the timber bracing walls came in at $395,000.

The study also estimates the timber flooring cost to be around twice that of the TI 250 concrete solution, while the steel ComFlor system (including beams) is deemed 18% higher.
Table 1: Percentage summary of the total structural building costs based on the *2014 Rawlinson Handbook*

	Concrete	Steel	Timber
Foundation	100%	33%	12%
Columns	100%	146%	92%
Floors	100%	118%	192%
Bracing	100%	198%	149%
Total	100%	103%	114%

Maintenance + Perception

Costs incurred following a building's completion for maintenance, operation and repair must be an important consideration during the project's initial decision making stages. This has traditionally not been the case, as up-front costs tend to be given greater weight by the developer over ongoing-costs.

Short cuts taken during the design and construction phases will inevitably lead to high maintenance costs during occupancy; giving rise to the often used phrase 'build cheap, repair expensive'.

Building materials play a crucial role in limiting maintenance costs and helping retain property value. Materials prone to rot, rust and colour fade require significant investment in terms of up-keep, as well as impacting of the living experience of occupants who have to endure the noise and general disruption associated with maintenance activity.

Data collected from building surveyors in Auckland illustrates the maintenance costs of different cladding materials.

Total maintenance costs over a period of 10 years:

- **Concrete panels Annual inspection & wash down 113 $/m2 100 %**
- **Weatherboards Annual inspection, wash down & 7 yr repaint 160 $/ m2 142 %**
- **Ply Wood Annual inspection, wash down & 7 yr repaint 140 $/ m2 124 %**

Looking at these figures that over decades the maintenance costs for a solid façade will be significantly less compared to lightweight cladding.

Anecdotally, building surveyors across Auckland anticipate that at least 70% percent of all existing apartment buildings have, or will experience, some form of 'leaky building' issue. This observation should have decision makers in the construction industry and their clients placing a premium on durable structures, internal partitions and floors.

In one particular high-profile case a 13 year old multi-storey development in Auckland was plagued by 'leaky building' issues from day one. As a result, approximately 80 % of its timber structure has been replaced as its load bearing capacity became compromised. It is reasonable to assume that had the same building utilised concrete or concrete masonry in a structural capacity, any moisture ingress could easily have been mitigated.

Fire and Sound Performance

Sound Performance

A survey undertaken by Wellington City Council in 2009 identified that noise generated from the urban environment, including neighbours, is the largest nuisance for apartment dwellers.

A later study, commissioned by CCANZ and BRANZ, analysed post-occupancy survey data from apartment dwellers in Auckland. While the survey did not specifically target noise and how people value a quiet environment, it was able to create two statistically relevant comparison groups of people who were living in buildings constructed of high and low-mass materials.

Results showed to a statistically significant level that high-mass construction materials protected occupants from noise generated by traffic and neighbours to a greater degree than low-mass materials. It was also noted that 12 % of those surveyed had moved away from an inner city apartment due to noise disturbance.

Disruption from noise can be a serious threat to apartment inhabitants' health and well-being. The New Zealand Building Code (NZBC) *Clause G6 Airborne and Impact Sound* takes care to protect residents with the following requirements:

- **Inter-tenancy walls shall provide at least STC 55 db sound attenuation.**
- **Inter-tenancy floors shall provide at least IIC 55 db sound attenuation.**

Fire Performance

As the move toward medium, and in some cases high-density, living gathers pace, the importance of robust fire protection measures will increase significantly to align with the potentially catastrophic outcomes from a fire. Fire protection in apartment buildings must be addressed carefully as it is a serious threat to lives and property.

The requirements for building performance in a fire are detailed in NZBC *Clause C Protection from Fire*. One mechanism for apartment design to comply with this Clause C is to follow the compliance document *C/AS2: Acceptable Solution for Buildings with Sleeping (Non-Institutional) (Risk Group SM)*. The fire rating required is 60 minutes for inter-tenancy partitions and floors, and for protection of escape routes.

Fire and Sound Partitions

The following wall build ups provide STC 55 db and F 60 fire ratings to comply with the NZBC:

- The concrete solutions suggest either a 150 mm in-situ or precast wall or a 200 mm solid filled masonry wall.
- The timber solution requires 100 x 50mm double studs, or staggered studs, with 20mm airspace in between, 100mm sound insulation and two 10mm gypsum boards either side.
- The steel solution is very similar to the timber design just that timber studs are replaced by metal studs.

Cost proportions for ready installed 55 db sound walls with F 60 minutes fire protection:

- **Concrete 150mm** **100%**
- **Masonry 200mm** **94%**
- **Double Timber stud wall** **90%**
- **Double Steel Stud wall** **85%**

Using the 2014 edition of the *Rawlinson Handbook* the metal stud solution works out less expensive than the timber equivalent, while both are slightly cheaper when compared to the two concrete solutions.

However, each material solution offers quite different levels of fire protection. While the steel and timber solutions are limited to F60 performance, the concrete walls provide inherent 180 minutes protection. This allows for greater guard against fire spread, as well as more time for fire fighting personnel to enter the building, retrieve trapped occupants and conduct fire fighting activities. The peace-of-mind offered by the concrete solutions, and enjoyed by building owners and residents, must also be accounted for.

To upgrade the timber or steel solutions to a 180 minute level of fire protection would require approximately 20% of their initial cost, which would render them more expensive than the concrete solutions.

Lightweight materials for internal walls do have advantages when allowing for easier space (re)configuration, as well as placing less load on the foundations. However, as discussed above, heavyweight alternatives usually perform better in terms of sound separation, fire performance and rot-resistance.

For instance, in the timber and steel 'build ups' the linings would soften or dissolve with moisture ingress, resulting in compromised sound separation and fire performance. The studs and acoustic infill would most likely also be damaged, more so if the leak remained undetected for a period of time. Replacement would be the only (but expensive) option.
Concrete walls also offer a higher degree of security compared to lightweight alternatives. This is particularly important as the population ages and the emphasis on community and personal safety increases. Concrete's virtual impenetrability can also withstand willful damage and resist arson.

Fire and Sound Floors

The following floor build-ups provide IIC 55 db and F 60 fire ratings to comply with the NZBC:

- **The concrete solution suggests TI 250 mm slabs.**
- **The steel solution suggests a ComFlor 210/90 system.**
  (Both solutions have underlay and carpet to separate the stepped on surface from the structure. This is required to avoid sound transmission and flanking via the floors and walls of the building.)
- **The timber solution requires GL8 540 x 90 mm beams each 1.7m plus 250 x 50 mm joists every 400 mm. A 30 mm structural flooring is applied to the top.**

To fire and sound proof the timber solution an additional substructure to carry the suspended fire / sound boards is required. The substructure must be separated from the main structure to avoid sound transmission and flanking via the floors and walls of the building. A sound insulation infill within the suspended part of the floor is also required to achieve the IIC 55 db rating.

Estimated cost proportions for ready installed IIC 55 db sound and F 60 fire floors

- **Concrete TI 250mm** **100 %**
- **ComFlor 210/90** **118 %**
- **GL8 timber system1** **192 %**

The TI concrete and the ComFlor systems are relatively competitive in regards to cost, durability, maintenance and long term sound and fire performance. However, the Glulam flooring is considerably more expensive.

It is mandatory to address fire and sound protection with floor designs but there are also differences in comfort and perception. Walking and living on a concrete floor provides a very solid and safe feel, while timber floors tend to be prone to shrinkage and eventually torsion, leading to creaking and cracking with pressure and changes in temperature.

Summary

As more apartment buildings rise to grace the skylines of New Zealand's three main centres it is important to consider their long term maintenance requirements, sound resistance and fire performance, as well as initial construction costs. The multi-unit apartment building case study model examined here was deemed to perform best, in terms of whole-of-life costs and living experience, if its primary structural and cladding material was concrete.

While lightweight materials offer advantages in terms of internal partition repositioning, the study found heavyweight inter-tenancy walls provide extended fire safety, superior airborne sound attenuation, as well as impact resistance and protection against moisture ingress.

Looking at floors, the study identifies concrete systems, such as TI (timber infill) or ComFlor slabs as ideal in terms of mitigating sound and fire related issues. Lightweight floors can achieve a similar performance, but come at a higher cost, and remain susceptible to impact damage while demanding increased maintenance.

Throughout the study the importance of the building's performance in terms of sound attenuation and fire resistance were considered paramount. However, the building's energy efficiency was not assessed as this can be dramatically influenced by factors other than building material. The issue of seismic performance was also not considered. All three materials considered here can be used to design buildings that offer protection during an earthquake.

Cost (short and long term), along with performance must always be considered in combination. Such an approach, as demonstrated by this study, sees a concrete solution offer a superior alternative over steel or timber solutions.
