Timber framed Passive House Multi-Unit Homes

Acoustic, Fire and Structural Design Considerations

Most players in the NZ construction industry now understand that the best path to affordable urban housing, and better urban environments, is medium density terraced and multi-unit housing.

Fortunately, for those passionate about building better quality housing, the surface to volume ratios of these kinds of developments are perfectly suited to Passive House. From a simple PHPP point of view, it is frequently possible to upgrade the windows and airtightness, add a heat recovery ventilation system, and you are almost there.

This shift in thinking, from subdivisions to multi-unit housing, presents Passive House practitioners with numerous opportunities, but also with new technical challenges which must be overcome in order to deliver cost effective Passive House standard apartments and townhouses.

In Europe, the birth place of the passive house movement, many multi-unit passive house buildings are constructed in masonry (reinforced and unreinforced) and externally insulated using EPS or some alternative rigid insulation. This approach to construction makes for relatively simple fire and acoustic separations as the entire building structure is sheathed in a continuous thermal envelope.

While this approach is also possible in NZ and Australia there are various reasons why this is not always desirable.

For Maori and early European settlers timber was the natural choice for construction. It was in plentiful supply and easy to work with using simple tools. However, as towns and cities developed many settlers sought to replicate the masonry and stone buildings which they were familiar with in Europe and the UK. Masonry and stone were seen as durable, respectable materials. Unfortunately it wasn’t long before they discovered that Aotearoa was not like their homelands and that these islands have a tendency to move, and move violently, from time to time. Following the devastating 1931 Napier earthquake that killed 256 people, unreinforced masonry buildings rapidly fell out of favour with architects, and while reinforced concrete was still widely used for large commercial and public projects NZ largely became a land of timber framed construction.

Not surprisingly the result is that we still have a building industry which is geared toward working with timber. There are huge numbers of local suppliers and builders who can cheaply and efficiently create prefabricated timber frames and trusses anywhere in the country. This availability and competition means that lightweight timber construction is more often than not more economical than building in reinforced concrete.

In the age of the Anthropocene timber has other properties that make it attractive to developers and designers from an environmental point of view. Timber is a renewable resource. It is also the only building material which absorbs and sequesters carbon from the atmosphere. The manufacture of concrete contributes almost 5% of the world’s greenhouse gas emissions. Internationally construction sand for concrete construction is becoming harder to come by. These considerations generally carry more weight for clients and designers who are considering a passive house build.

Increasingly prefabrication and offsite construction are playing a greater role in the NZ construction industry. While precast concrete elements are regularly used in commercial construction they are less widely used in residential construction as timber alternatives frequently have cost advantages. Prefabricated elements based on timber structure are lighter, cleaner and more accurate than concrete alternatives as is borne out by the rise of Cross Laminated Timber (CLT) construction in Australia and NZ.

In addition, lest we require more reasons for favouring timber, light weight timber construction also has advantages in terms of the size and expense of foundations. Heavier buildings require heavier more costly foundations.

Due to these considerations it is not surprising that many developers and designers of passive house multi-unit projects favour timber as a construction material over EPS and concrete. However, as mentioned, building economical, Passive House certified, multi-unit buildings in timber is not without its challenges.

Timber has obvious issues in terms of fire resistance. Wood, after all, is flammable.

Timber also has issues in terms of acoustics. Concrete is far better at containing sound than timber.

In NZ, the traditional approach to this conflict is simply to use reinforced concrete for the jobs that is was good at (i.e. acoustic and fire separation) and timber for those jobs which it was good at (i.e. the thermal envelope). Hence the common combination of concrete inter-tenancy partitions and timber framed thermal envelopes. On the surface this sounds like a sensible approach, however, for fire and acoustic separations to perform their function they need to pass right through the thermal envelope all the way to the back face of the cladding and frequently extend for some distance past the edge of the thermal envelope, not only creating energy leaking thermal bridges, but also internal moisture and mould issues.

Clearly this is unacceptable from a passive house point of view. So what’s the solution? No doubt there are numerous solutions but I would like to discuss a number of different solutions that we have adopted on our multi-unit PH projects and flesh out some of the fire and acoustic implications which are not always obvious at first glance.

Case Study 1 - High Street Cohousing

Our first multi-unit PH project was the High Street Cohousing project. This was a steep learning curve for us. The project has a combination of both simple two storey terraced houses (requiring only horizontal fire and acoustic separation) and vertically stacked apartments (requiring both horizontal and vertical separation). From a fire safety perspective the objective, as with most medium density housing projects, was to avoid the use of sprinkler systems which would increase the cost and complexity of the project.

The two storey townhouses were actually pretty straight forward. We worked with Ehaus to decide on the external envelope and party wall specification. We looked pretty carefully at a number of different building systems including traditional timber framing, structural insulated panels and insulated concrete forms. After further investigation and pricing we settled on structural insulated panels as the preferred external wall system.

Architype had already designed and built a number of SIP homes and we were fairly confident designing standalone homes with structural insulated panels but a little unclear of how they would work with the additional fire and acoustic requirements.

Different party wall systems were also investigated including concrete block, precast concrete panels, speedwall and a number of Gib intertenancy systems. In the end the recommendation was that we adopt a timber framed acoustic and fire wall system called Gib Barrierline. The benefits from a design point of view was superior acoustic performance, the ability to locate services within the timber framed walls on either side of the core, economy and (we hope) relative airtightness between units though this is yet to be tested on site. The only challenge with this system is that the central plasterboard fire barrier still passes through the thermal envelope. Even though plaster board does have a lower thermal conductivity than concrete and dimensionally the thermal bridge is smaller than say a precast wall, there was concern that we could have condensation forming on the plaster board. Our solution was the set the edge of the Barrierline 20mm back from the outside wall and pack around the end of the barrier with fire resistant rockwool. This is how GIB specifies that the roof junction is to be constructed. So while there is still a thermal bridge here we were able to satisfy the hygiene requirement of PH.

The other complicating factor for the townhouses was that we did have a number of areas where the thermal envelope itself needed to be fire rated to prevent the spread of fire between units. We had designed a number of recessed entrances to the homes to provide shelter and create a sense of threshold. However this meant that the structural insulated panel walls beside the doors were required to have a 60min two-way fire rating. Because the structural insulated panel industry is still fairly new here in NZ there are a number of areas where details have yet to be developed and this is one of them. Typically we would expect to be able to open up the design manual and select a 60min fire rated version of the system with the knowledge that the solution had passed through various physical tests to ensure that it performed as designed. Unfortunately for our structural insulated panel system no such solution existed. So after a fair amount of back and forth between us, the suppliers and fire engineers we decided that we would have to treat these sections of the SIP wall as timber framed and simply add studs at 600 crs and clad the panels in the appropriate number of layers of fire resistant plasterboard essentially ignoring the fact that they were SIP walls and treating them as stick framing. This was not without its toll in terms of additional thermal bridges however as a workaround for small areas of envelope it was ok.

By comparison, the High Street block was far more complicated. Here we had a mix of 3 level town houses and combination-ground floor one bedroom homes with three bedroom, 2 level homes above. This configuration introduced a level of complexity far in excess of what we faced with the townhouses.

One consequence was that we were required to install a Type 2 alarm system with manual call points for the entire development.

Again the thermal envelop of these homes was to be structural insulated panels with Gib Barrierline partitions. The real challenge was achieving vertical separation between the vertically stacked units.

Access to these units was achieved using an external freestanding stair and walkway. This walkway needed to be fire rated for 60min both so occupants could have time to escape and to prevent the vertical spread of fire out of the ground floor windows and up to the unit above. Our solution was a steel frame treated with intumescent paint. For the deck we selected a hybond concrete deck which would achieve our fire requirements and also be weatherproof with a minimum build up.

For the floors between units we were limited in that we needed a solution that would closely match the thickness of the neighbouring non fire rated floors as our roof height was fixed. Concrete makes great intertenancy floors as it is inherently fire proof and acoustically very good. However a concrete midfloor requires concrete lower floor walls and we couldn't go here.

Our decision was to adopt a light timber framed Gib acoustic and fire rated floor system. This floor has 26mm thick plaster board lining to the underside through which only fire rated penetrations are permitted. The floor structure is timber joists with acoustic batts between. The system is completed with a 20mm timber or fibre cement floor structure and a selected acoustic floor finish. In our case we specified 8mm Regupol acoustic mat and engineered timber flooring. The compromise being that we really only just meet the building code minimums for airborne noise and impact noise.

In addition the floor is only one part of the fire separation between floors. The other essential element is the prevention of the spread of flames between floors. I.e. in the event of a fire what is to prevent the flames exiting through the windows and climbing up the side of the building into the next unit.

The concrete deck served as a fire apron protecting the north face of the building. Intumescent strips were located on the back edge of the steel deck which would close the gap between the house and the deck in the event of fire.

For the south side of the building two different solutions were used. In some areas we were able to use the folded steel entry canopies as eyebrows. These are treated with 60min rated intumescent paint. However for the remaining unprotected windows we needed to provide 60min fire rated spandrel panels below the upstairs windows. Again without a specifically designed fire rated detail we were obliged to add timber studs at 600 crs and line the panels inside and out in fire rated plaster board.

In addition we also needed to protect any ground floor structure which supported and upstairs unit for 60mins. More timber studs were required on the ends of the units and around the egress stairs. This had a substantial effect on the timber content of the SIP walls and brought into question whether they were really the sensible choice for the external thermal envelop. In the end we did persevere with SIPs as we felt that there were still sufficient large areas of SIP walls without additional timber framing that it was still the right choice.

Case Study 2 - Leith Street Passive House Apartments

The next multi-unit passive house project which we were asked to design was for a Dunedin developer who specialises in student accommodation. He had made the decision a few years ago to install Zehnder passive house certified ventilation systems into all his new student flats and having visited a number of our high performance residential projects he finally made the leap to go full PH for this project. The client owned a central city site which could be developed up to a density of 21 habitable rooms as of right. From the developer's point of view the best returns came from single bedroom apartments.

After considering a number of different configurations we developed a 3 storey, 18 unit apartment scheme. The initial timeline for the project was very tight so in order to minimise delays we utilised a number of the readymade solutions from the High Street project. We adopted a similar circulation strategy to the High Street one bedroom designs. External, fire rated, free standing steel framed balconies with stairways tucked back into the building block. By using external balconies we were able to keep the size of the thermal envelope as small as possible. It also allowed us to triple duty the balconies as private outdoor areas, entry and egress routes and fire aprons.

We had to deal with very tight recession plane constraints which meant that we needed a thin intertenancy floor build up. We also knew at this point that we wanted to do better than the High Street interfloor solution especially from an impact sound point of view. These requirements suggested that a CLT floor might be the right choice for this project. We knew we could span around 3.5m with a 105mm deep panel and we also knew that greater mass was helpful when it came to dissipating noise.

We had had a very positive experience using cross laminated flooring panels on a previous office project which allowed us to make substantial savings on the foundations, so we wanted develop a low profile, highly acoustically separated, fire rated floor system.

There has been a lot of work done recently on developing acoustic solutions for CLT floors. Xlam – NZ's biggest manufacturer of cross laminated timber has worked with PKA Acoustic Consulting to develop a tool which allows designers to estimate the STC and IIC rating of a number of different combinations of ceiling systems and linings, floor toppings and floor finishes. Frustratingly for architects it proves to be rather difficult to leave either the top or the bottom of the CLT visually exposed and still achieve the code minimum acoustic ratings. We are currently working on an acoustic topping system which would allow us to achieve this outcome but further work is required to confirm this.

Initially our client was very keen on using SIP panels for the thermal envelop. As the High Street block was also a three storey passive house building we assumed that this would be possible. However it soon became obvious to our structural engineers that due to the additional weight of the CLT floors the SIP wall panels weren't going to be suitable as load bearing elements. At this point in the design process it looks as though plywood clad 140mm timber framing will be adequate from a structural and thermal point of view but it is also possible that we will move to CLT external walls with an external insulation material.

The key take away points are:

1. Simple passive house townhouses are reasonably straight forward to achieve using lightweight timber construction as horizontal acoustic and fire separation can be readily achieved using standard intertenancy wall systems with only minor modifications to the standard details.

2. Vertically stacked apartments are significantly more challenging, mainly because lightweight materials are not good at controlling impact sound. Also because of the need to control vertical spread of flame which often requires parts of the external envelope to be 2-way fire rated.

3. Any attempt to deal with impact noise by increasing the mass of the floor system has implications on the structure of the building especially for buildings 3 storeys and over and will likely preclude the use of SIP walls and introduce additional structural thermal bridges.

4. It is possible to provide acoustic performance which is beyond the code minimums using lightweight timber midfloors, given a deep enough buildup 400-500mm.

5. Where the midfloor depth is limited, mass timber is probably the only way to achieve code compliant acoustic performance but designers should be aware that it is not easy to leave any of the CLT exposed without compromising the acoustic performance.