CONCRETE IN PASSIVE HOUSES - A HOLISTIC APPROACH TO RESIDENTIAL LIVING

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INTRODUCTION

Since the oil crisis of the 1970s interest in progressing energy efficient residential building design and construction has grown around the world. One specific outcome has been the Passive House Standard, certified by the Passive House Institute. Today Passivhaus is one of the most recognised and well respected ‘marks’ of energy efficiency across the global construction industry. It therefore comes as no surprise that interest in the Passive House Standard is growing here in New Zealand.

There is however, a widely held misconception that Passive Houses have to be constructed using timber frame systems, and that they are incompatible with concrete and concrete masonry construction. This paper seeks to correct this misconception and outline the benefits afforded Passivhaus designs through the use of concrete.

BACKGROUND

Before the development of the Passive House Standard there have been many examples of energy efficient driven design and construction. For instance, an understanding of passive solar design (and the importance of thermal mass) is evident in many ancient Greek buildings, while the Romans understood the benefits of heat capture and reuse.

However, with the disappearance of ‘cement’ with the fall of the Roman Empire around 1,600 years ago, the use of passive solar design also declined. Its re-emergence through German and American architecture just over a century ago is in part related to Joseph Aspdin securing the patent for Portland Cement and then François Coignet’s development of reinforced concrete construction.

Iconic architect Frank Lloyd Wright’s first passive solar house, built in the 1940s, featured a large roof overhang to provide shade in hot summer months, and large sun facing glazing to maximise heat capture during winter. These features were complemented by the thermal mass of the concrete floor that helped balance the interior climate, and in turn enhance energy efficiency.

Active solar design has enjoyed uptake over the past few decades, and involves the use of solar energy to generate either 1) hot water or 2) electricity.
1. Infrared light heats water in darkened glass tubes fixed to the roof; this generates hot water that is stored in a thermally insulated tank from where it is distributed to appliances throughout the house.

2. Ultra violet light and visible light charge photovoltaic arrays. The captured energy is transformed into electricity and sent to an inverter where it is converted into electricity for use throughout the house. Any surplus is either fed to the ‘grid’ or stored in batteries such as lithium ion or zinc bromine gel batteries. These batteries are becoming increasingly powerful, and are anticipated to soon enable off-grid living.

In many instances, active and passive solar design are utilised in combination.

THE PASSIVE HOUSE

The Passive House Standard sets out the criteria for quality, comfortable and energy efficient homes. The Standard is overseen by the Passive House Institute, which was established in Germany during the 1990s by Wolfgang Feist.

Today the Standard is the world’s most recognised label for energy efficient buildings, and will play a significant role in helping to achieve the European Union’s directive that by 2021 all new buildings are to be nearly zero energy buildings.

According to the Passive House Institute, the ship of arctic explorer Fritjof Nansen would have been the first ‘house’ to be eligible for Passive House certification. The ship was fully insulated with tarred felt over a cork filling, the roof had 400 mm of insulation and an early form of triple glazing was installed throughout. In addition, it was completely airtight.

Nansen wrote:

  Whether the thermometer shows 5 ° or 30 ° below zero, we do not have a fire in the stove. I therefore order with the idea to let the oven away completely - it is only in the way.

Similar to Nansen’s ship, Passive Houses are super thick, thermally insulated, airtight buildings.

PASSIVE HOUSE REQUIREMENTS

A Passive House shall not use more than 15 KWh/m² per year for space heating, and total energy consumption shall not exceed 120 kwh/m² per year. To achieve these levels the house must be airtight, with an infiltration rate that does not exceed 0.6 air change units per hour. For comparison, a well designed modern house in Germany has about 3 air changes (ACs) per hour, while a typical New Zealand home ranges between 15-20 ACs per hour.

The strict airtightness regime is not to be confused with required ventilation. Every house should be ventilated to remove stale air and moisture. However, a Passive House addresses this need in a controlled manner, either through managed window opening or sophisticated HRV systems. The 0.6 ACs is simply envelope performance measure to ensure heating and cooling energy is controlled.

The airtightness of existing or new buildings can be measured via a blower door test, during which a fan device fully covers the house entrance and under-pressurises the interior by extracting air. The amount of air streaming into the building through gaps to balance the loss
provides a leakage intensity figure in ACs. Visible gas and infrared images can assist in identifying the location of the gaps.

**THE BENEFITS OF CONCRETE**

One of the many benefits of concrete in Passive House design and construction is its inherent airtightness.

Lightweight construction requires an internal membrane (air/vapour stop) to be installed between the internal plaster boards and the structure to prevent air-leakage. An external barrier (‘weather stop’) is also needed between the exterior weatherboards and the structure to protect against wind and rain ingress. A rain-screen or masonry veneer with ventilated cavity could potentially increase the wall’s overall performance, but may still not achieve an adequate level of airtightness.

Concrete and concrete masonry walls do not require the installation of any membranes. They are inherently airtight and also provide a natural vapour barrier. Other benefits afforded by concrete and concrete masonry walls in a Passive House include:

- **Moisture Absorption** - Concrete is able to absorb a certain amount of moisture from the ambient air, and release it back into the room once cooking or bathing has occurred. This helps to balance internal humidity levels.

- **Thermal Mass** - Concrete’s mass is able to capture, store and release the sun’s heat to off-set internal temperature fluctuations. This helps to create a comfortable living environment, as well as reduce costs associated with heating and cooling.

It must be noted however, that concrete’s high thermal conductivity, does pose a ‘heat loss’ challenge for Passive House design, but one which can be addressed through appropriate levels of thermal insulation.

- **Acoustic Separation** – As the move toward medium density residential construction grows so too does the importance of insulating against noise disturbance from external sources of sound. The conventional rule for airborne sound attenuation is the ‘mass law’ - the higher the mass the greater the noise reduction. A 150 mm concrete wall provides compliance with *New Zealand Building Code (NZBC) Clause G6 Airborne and Impact Sound*, offering a Sound Transmission Class (STC) of 55.

- **Fire Protection** – In terms of fire performance concrete offers greater peace of mind, particularly with the aforementioned growth in medium density living. A 100 mm concrete or concrete masonry wall provides 90 minutes fire protection, which exceeds *NZBC Clause C Protection From Fire Acceptable Solution for Buildings with Sleeping (non institutional) (Risk Group SM)*, which requires only 60 minutes for apartment partitions.

- **Durability** – Concrete’s most vaunted attribute helps it resist damage from impact, water and fire.

The leaky building crisis is never far from the headlines; a situation that will remain for many decades to come. At the core of this national catastrophe is lightweight construction’s susceptibility to damage from moisture ingress - the consequences of which are not as devastating for concrete or concrete masonry construction.
DETAILING TO PASSIVE HOUSE STANDARD WITH CONCRETE

There are many hot spots, or rather ‘cold spots’, in standard residential design where heat energy can escape and condensation form. Typical spots for cold bridging are at junctions such as wall-to-roof and wall-to-floor, as well as balconies and penetrations.

A concrete roof, for example, offers great protection against fire and sound and is very robust; however it requires thermal insulation and waterproofing. One option is for first water defence measure to be installed beneath the insulation to prevent moisture from the curing concrete compromising the insulation. A second water membrane is then applied on top of the insulation to take up any wind driven water or water potentially leaking through the cladding. This protection layer also resists condensation moisture which collects under the roof cladding on cold and humid days.

The roof is ventilated to protect the underside of the cladding from condensation. Should condensation form, any water will fall onto the upper (second) membrane from where it either drains towards the gutter or is carried away by the air coming in through the vermin mesh on the side of the gutter and through the roof top’s ventilated capping profile. Any roofing could be applied to this detail, be it corrugated metal or concrete tiles.

A flat concrete roof is traditionally installed with a vapour barrier on top of the concrete slab, followed by rigid insulation, waterproofing membranes and finally membrane protection via pebbles, pavers on chairs or any other decking options. Recently, the ‘reversed roof’ design has become popular. Here the waterproofing membrane is directly applied to the concrete slab, and then covered with rigid, moisture resistant insulation, with a secondary waterproofing on top. While this secondary waterproofing could easily be damaged, any failure only means that water will travel through the insulation and be captured above the slab’s waterproofing layer from where it is guided into gullies.

The parapet also needs thermal insulation wrapping, while a timber wedge on top of the parapet ensures water will drain to the inside of the roof, preventing water running down the façade and creating stains. Balustrades must be fixed onto a vertical surface, never horizontally, as remaining pooling water could potentially leak through the envelope.

A deck access threshold is another detail typically prone to cold bridging. One necessity is installing thermally broken window and door frames. Insulation and roof membranes have to be fixed to a concrete upstand beneath the threshold. While the deck can end level with the threshold, there needs to be a 5 - 10 mm gap to allow for drainage in between.

A deck or balcony cantilevering with no habitable space beneath also requires a thermal break. Systems specifically made for concrete construction have been available since the 1970s, and typically involve stainless steel reinforcing (which offers low conductivity and high durability) connecting the balcony to the structural slab through a rigid thermal insulation layer (such as XPS) which forms a thermal break.

Window to wall joints have to be protected against infiltration and moisture ingress. An external vapour barrier is required to protect from wind and rain, and a further internal barrier should protect from any vapour or moisture carried into the wall from the inside. The insulation should wrap into the opening where the window is fixed in recessed fashion. The lintel detail should also include a drip section or chase, while the sill details should allow 30 mm projection over the face of the wall in order for rain water to easily drop off without running down the façade.

Basement walls for Passive Houses need to be fully insulated. In addition a waterproofing system is required, rather than simply a weathertightness system, as is the case for above ground walls. The typical detail shows the basement insulation and waterproofing coming
above ground for ca 300 mm where it joins with the weathertightness system of the wall. Many available systems have proprietary connection details, such as compression seals, drip edges and cappings.

The waterproofing membrane, whether bituminous, butyl, bentonite or polyolefin, is adhered directly against the concrete to minimise risk of failure. Thermal insulation, which is then applied in front of the membrane, has to be water resistant and cannot soak up or store moisture as the performing R value would drastically decline. Insulation made from foamglass or XPS is deemed suitable as moisture will not penetrate, meaning the R value is unaffected. The insulation wraps fully around the basement, including under the slab.

A drain dimple sheet is applied in front of the wall insulation to provide additional protection and to enhance downwards drainage. A ring drainage should be placed below the finished floor level; protected against blockage from mud and roots by a woven textile fabric. The trench between soil and basement should contain a back fill with drainable material to prevent wet soil being in contact with the basement wall.

More information about basement waterproofing can be found with the Cement & Concrete Association of New Zealand’s (CCANZ) Concrete and Concrete Masonry Basement Design Guide (BG 01:2016).

SUMMARY

The number of Passive Houses is increasing across New Zealand particularly in the residential sector, but also in the commercial sector, and multi unit and retrofit areas.

The attributes of concrete and concrete masonry can be enjoyed across all Passive House applications, with medium density construction currently offering the most high-profile example.

Architects are, and must continue to play a leading role in advocating for Passive House through appropriate design decisions. Software, such as the PHPP (Passive House Planning Package) is available to assist the design process, and also forms part of the current verification method for the Passive House Standard.

Passive House is a voluntary Standard, with clear performance requirements, a design methodology and accessible design tools. It does not prescribe which materials and methods should be used, and at the same time it does not restrict architectural expression or aesthetics. It is simply about enhancing architectural performance through energy efficiency.

In 2014 the first large scale Passive House office tower, built using concrete as the primary structural material, opened to a positive response (that continues) in the Austrian capital of Vienna. Such significant investment and feedback indicates the legitimacy of the Passive House Standard, and the key role concrete (and concrete masonry) construction can play in realising its potential.

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