Precast Concrete Panels as a Sustainable Cladding in New Zealand

Morten GJERDE
Senior Lecturer
Victoria University
Wellington, New Zealand

Summary

Indigenous timber and concrete have been the main influences on the development of New Zealand's built environment. However, recent times have seen an increase in the use of imported methods and materials. The poor performance of some of these, coupled with the need to build in a sustainable manner have led to renewed consideration of precast concrete as a cladding. The paper comments on the performance of concrete cladding systems in several areas: embodied energy, thermal performance, acoustic performance and deconstruction or recycling. A case study evaluation of a building constructed in the 1980s highlights the real benefits of a concrete cladding system.

Keywords: precast concrete cladding, sustainability, New Zealand

1. Introduction

The built environment of New Zealand is relatively young as the nation has largely been established and settled in the period since the Industrial Revolution. The forms and materials of construction have been mainly adapted from those found elsewhere; ideas brought with settlers who worked with the available materials to fashion solutions that were affordable and would perform in the unique environment. The principal influences on this pattern of development have been the remoteness of the island nation, the unique natural materials found locally and the changeable marine climate [1]. The strategy of developing materials and methods from within has proven to be very successful over time.

The world continues to become smaller and many of the restrictive influences that led to the successful development of local materials and methods have been erased. In recent times material transport to New Zealand has been relatively low in cost. Restrictions on importation, long a feature of the political landscape in New Zealand, have been set aside in favour of free trade principles. In addition to barriers being lowered, recent times have seen added pressures generated from within to import and use building materials and methods from elsewhere. As a nation, New Zealanders now appear to be less comfortable with having a unique culture than previous generations have been. The popular and architectural media have been quick to play on and influence the desire to be like others. In a residential context, images of Mediterranean and American colonial architecture abound. The design and construction of commercial buildings have been influenced by architectural fashion generated offshore and by pressures for rapid completion times. In this environment, purpose made and proprietary lightweight cladding systems, most of which are sourced complete from outside New Zealand, have become very popular.

The use of such lightweight systems has in recent times been blamed for problems with weathertightness [2]. Poor results from lightweight systems have seen many in the building industry look for alternatives. After a strong period of development and use of precast concrete cladding in the 1970s and 80s [3], its use waned in favour of those methods based on lightweight materials. As the New Zealand building industry searches for improved cladding solutions and as pressures to increase the sustainability of our built environment, precast concrete cladding systems once again deserve serious consideration.

2. Environmental Performance

2.1. Embodied Energy

Human activity generally has indelible effect on the planet. Among others, building activity consumes energy that in many circumstances is generated from non-renewable resources. Quantifying the energy embodied in a product of construction activity allows comparison between products, a useful decision-making tool. Embodied energy values for any one building material, component or completed building are unique to the country or region in which the building is built. These values are affected by the form of energy used and the transport distances involved as well as the energy used in manufacture.

Given that concrete is produced throughout New Zealand and the materials are all locally available, the embodied energy of concrete compares very favourably to that of many other common building materials in New Zealand. A very basic comparison of the embodied energy values for three common cladding systems is shown in Table 1.

Cladding system	Embodied Energy (Mega joules) per **m**^{2} wall area [4]
150 mm steel reinforced concrete (30 MPa) with exposed aggregate finish	680.4 MJ
7.5 Fibre cement sheet on steel framing	719.2 MJ
High performance aluminium curtainwall	1,806.8 MJ
1. 1kWh = 3.6 MJ or 1MJ = 0.277kWh	

Table 1: Comparison of the embodied energy values for three common cladding materials in New Zealand

The comparison considers only the exterior cladding and any necessary support framework. See Figure 1 for the concrete example. These values will be put into context as a comparison in the case study that follows.

2.2. Thermal Performance

Not only is the initial energy cost of the construction an aspect of consideration, but the ongoing energy costs as well as the health and comfort aspects related to thermal performance should also be considered when specifying the exterior envelope. The greatest thermal quality that concrete cladding systems offer is that of mass. Thermal mass is most effective in moderating temperature changes when it is directly exposed to the internal environment. However, the most common methods of construction create a layer of insulation between the mass and the interior space. Many advantages derive from this construction method, including the opportunity to conceal fixings, space in which to run services and the opportunity to create a continuous insulation layer. Even when isolated in this manner the concrete does help to minimise temperature changes by the thermal inertia that derives from its mass [5]. Most of the energy demand in large buildings is for cooling, mainly due to heat that is generated within by people and machines. Solar gain through the exterior envelope compounds the situation, a factor that has influenced the development of performance glazing systems. With lightweight construction, heat from the sun passes more easily through, whereas the heat transfer is delayed through heavier weight materials such as concrete (Figure 1). A similar delay due to thermal inertia can be seen in situations where heat travels out of the building. The effect is ideally suited to New Zealand conditions. The climate is highly variable and does not feature the extremes seen in continental areas. The thermal mass of concrete coupled with the relatively narrow temperature band and dependable diurnal swings can reduce heating and cooling demands within a building.

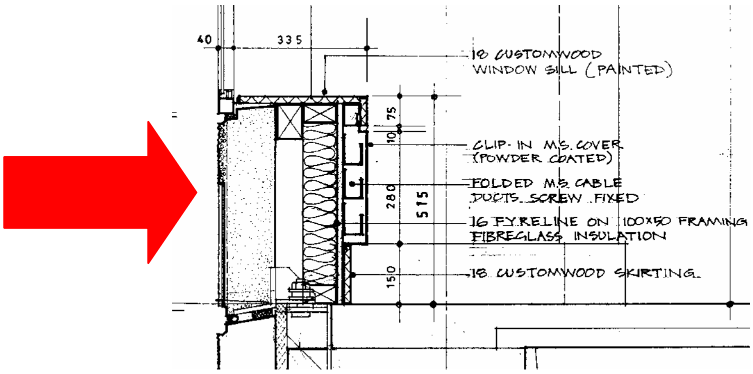

Fig. 1 Thermal mass slows transfer of heat

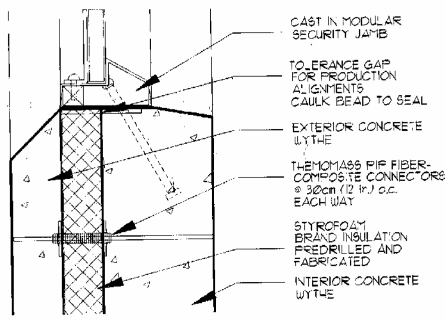

Fig. 2 Sandwich panel construction allows full thermal mass benefits to accrue

Of course the greatest benefit can be derived from mass within the building. The development of sandwich panel construction techniques (Figure 2), where an insulation layer is bound between two layers of concrete, will see the full thermal benefits of concrete cladding realised.

2.3. Acoustic Performance

Increasing environmental noise leads to consequential increases of unwanted noise inside buildings. Wellington, like many other territorial authorities in New Zealand, has recognised the negative impact noise has on building occupants and has recently legislated that the exterior envelopes of buildings used for residential purposes in the urban centre achieve a minimum sound insulation level [6]. It is likely that this requirement will follow on to other building types as users become more sensitive to noise pollution. The legislation background notes the poor performance of lightweight building claddings and detailing around openings as areas of the greatest concern.

150 mm thick concrete panels provide a noise insulation value of STC 55, easily complying with the requirements. This compares with STC rating of 15 - 20 for common metal curtainwall systems, a performance level that requires additional mass, often by way of multiple layers of interior lining. Composite systems can be designed to effectively insulate against higher range frequencies, however in the lower frequencies the only effective method of insulating is by way of mass.

Of paramount importance in any system designed to provide effective acoustic performance is the detailing around openings and changes between materials. As concrete is a mass material there are fewer such junctions that are potential sources for sound leakage.

3. Economic Sustainability

Along with timber, concrete can claim to be a truly indigenous building material to New Zealand. The concrete industry is mature and is well suited to cater for the widely dispersed settlement of New Zealand. All the raw materials exist in abundance, as do supplies of the energy necessary to produce cement. Not only are they abundant, but the raw materials can be found in virtually every corner of the country. As is reflected in the comparison of embodied energy values, the local availability of concrete helps to minimise the initial construction costs and improves certainty of supply.

3.1. Life Cycle Costs

Development models have tended to be guided by the initial cost of the project, largely disregarding the ongoing costs. Often it is not the developer of a building who is liable for the ongoing costs, yet it is decisions made at the time of building that will have greatest influence on the full economic cost. Sustainable practice requires a project to be specified in consideration of the full costs, which include the initial cost but also the ongoing maintenance costs and value of a building at the end of its economic life.

Concrete materials, especially those without applied architectural coatings, provide a durable and relatively maintenance free surface [7].

3.2. Deconstruction

At the end of the economic life of any building it is important to capture and use the embodied energy and resources in the building rather allow these to go to waste. To that end, recycling and deconstruction of buildings is seen as an important phase in the lfe cycle of a structure. Unfortunately, the majority of buildings that are now and will in the foreseeable future be at the end of their economic lives have not been designed to facilitate deconstruction. The result is that buildings are more often demolished and put to landfill in New Zealand rather than recycled.

Precast concrete claddings are in most circumstances recyclable [8]. The construction process requires that cladding components be modular, easy to handle and readily transportable. In moderate to large scale buildings it is not common for the concrete cladding components to be designed as load bearing and in these circumstances it is likely that the are accessible and reversible. Precast concrete components are therefore readily recyclable. Consequently, the investment of material and energy resources does not have to be lost when a building or the cladding reaches the end of its economic life in one format. In this light, the use of precast concrete claddings can be seen to be truly sustainable.

4. Case Study

The Clarendon Towers project was undertaken by the architects Warren & Mahoney in Christchurch in 1985. The project was built during a buoyant period of commercial real estate development in New Zealand, and was, at 17 floors, the tallest building in the city at the time it was constructed. The building shell is largely concrete. The structure consists of a perimeter moment resistant frame with internal concrete columns and beams supporting a precast concrete floor system. The exterior cladding panels are also concrete and an important factor in the success of the project, both as a building project and as an ongoing investment.

The architects developed the design with modular precast concrete panels of approximately 3.4 m height x 2.9 m width. One of the prime requirements of the developer, who also acted as the builder, was to minimise the construction time. The floor to floor turnaround time for the structural frame was refined to 7 days. While the frame was being built on site, the concrete cladding panels were being constructed off site. Two basic panel designs were used for the building, one being flat and the other with a recessed window opening. A dark greywacke aggregate from one of the several braided rivers that cross the Canterbury Plains was used in the concrete mix, which was then exposed on the surface. The design of the panels was further articulated with the introduction of a grid pattern of recessed grooves at a spacing module related to the panel dimensions in an effort to downplay the joints between panels. Each panel was then 'dressed up' with a single row of ceramic tiles below the windows. The upper floors were different in design to give the building a distinctive top. Although more open at these levels, the architects maintained the use precast concrete for the solid portions.

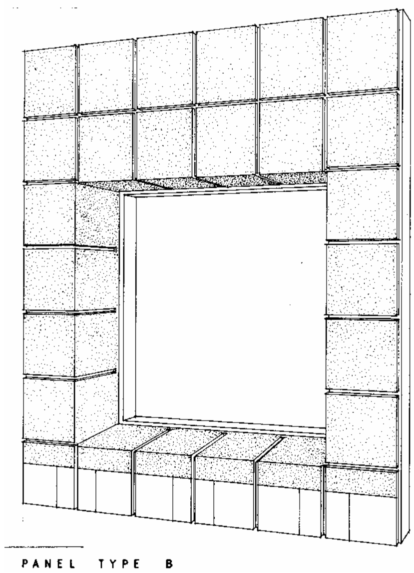

Figure 4: One of the two main panel configurations. The concrete has an exposed aggregate surface

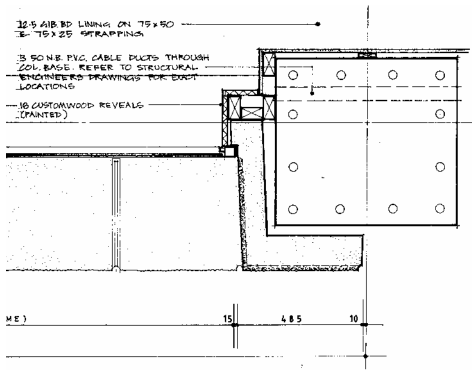

Figure 3: View of the Clarendon Tower project from the northwest

Figure 5: Plan detail of the concrete panel at a structural column

The design for construction was developed with experience gained by the architects on several earlier projects in which they experimented with precast concrete as a cladding. Precasting allowed the concrete work to be done in controlled conditions and the architects worked with the builder to maximise opportunities for a high quality result. Several prototypes of the cladding were manufactured and evaluated. The tile band was installed in the factory and the panels were delivered to the site complete with aluminium window frame. The window frame was installed with the inside face to the outside. This allowed all glazing work to be done from inside the building, reducing safety risks and the cost of working. Attaching the panels to the structure was also done from inside. Although it was not considered at the time, the design of the fixings will allow for the ease of removal of the complete panels at some point in the future, when the building reaches the end of its useful life and is a candidate for recycling.

The building is of a moderate scale in the New Zealand context. Table 2 compares the embodied energy values for fibre cement sheet cladding and a high performance aluminium curtainwall system against the concrete panels that were used. Refer to Table 1 for a description of the systems.

Cladding type	Surface area[1]	Embodied energy / m^2	Total embodied energy
Precast concrete	3784 m^2	680 MJ	2,574,634 MJ
Fibre cement sheet	3784 m^2	719 MJ	2,721,453 MJ
Aluminium	3784 m^2	1,807 MJ	6,837,688 MJ

[1] Net area of cladding only. Windows and other elements common to all three systems not measured

Table 2: Embodied Energy Comparison

The comparison highlights the significant reduction of embodied energy realised in the decision to use precast concrete claddings in this project. The net reduction is in the order of 4,263,054 MJ or 62%. In economic terms this equates to a reduction of $NZ 142,101 at 2003 energy prices.

The building remains a landmark in the skyline of Christchurch. After close to twenty years the appearance of the building remains fresh. The cladding panels have performed very well and cost little to maintain. The majority of the building is unpainted, relying instead on the subtle colour variegation and textures of the exposed aggregate to add architectural interest. A nearby building of similar scale and constructed subsequent to the Clarendon Tower shows clear signs of fading and deterioration of the imported metal cladding. While there is no evidence that the deterioration is leading to leaks at this stage, the poor appearance has a negative effect on the image of the building.

Virtually no costs have been incurred to maintain the exterior cladding. In the near future it is likely that the sealants between panels will require routine maintenance to be carried out. After 20 years the strong UV light in New Zealand may have cause the two part polysulphide material to deteriorate. All areas of sealant are readily accessible from the building maintenance unit. The building managers have reported that overall, the precast concrete cladding has not incurred any unforeseen additional costs and has instead led to overall cost savings when compared to other lightweight buildings. A further study has been planned to quantify the lifecycle cost differences in the case of this building.

5. Conclusions

Changing global and local circumstances have affected the use of cladding materials for New Zealand buildings. While precast concrete enjoyed popularity during the 1970s and 1980s, over the past decade its use has reduced in favour of lightweight systems. However, it has become apparent that some lightweight systems have performed poorly in the unique environment. The paper has evaluated precast concrete claddings in several contexts.

A precast concrete cladding system embodies considerably less energy than a lightweight cladding system using aluminium components. A study has shown that the decision to use precast concrete cladding on the Clarendon Tower project in Christchurch resulted in a saving of some 4.2 million megajoules of energy. The cost savings at 2003 prices would be in the order of $NZ 142,000.

Precast concrete cladding systems have inherent better thermal performance in New Zealand conditions over lightweight systems in due to the thermal inertia created by the mass of the material. This has the effect of slowing temperature change inside a building as outside temperatures change.

Concrete provides superior sound insulation qualities over lightweight systems as a consequence of its mass. Even though composite systems can be detailed to provide similar insulation ratings in the high frequencies, concrete performs much better in the low frequency range. This is a particularly important consideration for buildings in urban settings, where environmental noise is ever increasing.

Precast concrete cladding components are readily able to be recycled at the end of the economic life of a building. Concrete components are very durable and likely to perform well in a new setting. The construction of precast concrete systems makes them ideally suited to disassembly.

A case study demonstrates the strong performance of precast concrete cladding over an 18 year period. The construction process was very efficient and led to a timely completion of the project, in part owing to the efficiency of offsite cladding manufacture. The cladding has retained its architectural qualities with very little maintenance and will continue to do so in the foreseeable suture. The use of an exposed aggregate has been instrumental in this. Finally, the manufacture and construction of the precast concrete cladding has saved in the order of 62% of the energy that would have been used in the construction of a performance aluminium cladding.

6. References

[1] GJERDE M., "*Why Stop Innovating? Recent Weathertightness Problems in New Zealand*", Innovative Developments in Architecture, Engineering and Construction – C J Anumba, Ed., Millpress, Rotterdam, 2003, pp. 227 – 236.

[2] BOND, I, HUNN, D & KERNOHAN, D. Report Of The Overview Group On The Weathertightness Of Buildings With Addendum, Building Industry Authority, Wellington, 2002, 58 p.

[3] CHISHOLM D., *Concrete Cladding Encourages Diversity*, New Zealand Concrete Construction, April/May 1992, pp. 14 – 17.

[4] ALCORN A., *Embodied Energy Coefficients of Building Materials*, Centre for Building Performance Research, Wellington, 1998 3 ed., 34 pp.

[5] ANON., *PCI Manual for Structural Design of Architectural Precast Concrete*, Prestressed Concrete Institute, 1977, 448 pp.

[6] KOS P., "Proposed District Plan Change 23 – Central Area Noise Insulation Rules", Wellington City District Plan

[7] ANON., *Architectural Concrete Cladding*, Cement & Concrete Association of New Zealand, August 1992, 33 pp.

[8] STOREY J, GJERDE M, CHARLESON A, & PEDERSEN M, *The State of Deconstruction in New Zealand*, Centre for Building Performance Research, Wellington, May 2003, pp.