Briefing

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Concrete Panel Homes

- Walling Systems
- Performance Benefits
- Detailing and Construction Issues

A Concrete Panel Home is defined as a dwelling that is predominantly built out of concrete wall panel elements. That does not necessarily mean that the whole structure is of concrete, although this is certainly possible.

The main walls (external and possibly internal) are constructed from modular solid and/or insulated concrete panels produced either on or off the building site.

Concrete Panel Homes are finding increased use in Australia. In particular, they are being used on narrow inner-urban sites and for architecturally distinctive homes.

There are many advantages associated with the use of concrete panels within the housing market which include:

- Speed of construction (on- or off-site)
- Reduction of site congestion from trades, material storage and waste
- Performance benefits, eg thermal and acoustic efficiency, fire rating, etc
- Inherent strength capacity of the product, loadbearing walls
- High level of quality inherent in the product with reduced labour demands
- Variety of shapes and finishes that can be provided with the product.

CEMENT & CONCRETE ASSOCIATION OF AUSTRALIA

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Concrete Panel Homes

Front Cover: *Panels can be manufactured in any size or shape.*
Caption above: *Panels can be used for basement retaining walls (carpark under) and front fences as well as the building structure.*

WALLING SYSTEMS

GENERAL

There are various types of concrete walling systems in the current market place that could be used in building a Concrete Panel Home.

The two main concrete panel systems that are readily used both in Australia and internationally are:

- Cast off-site concrete panel walling (typically called precast concrete panels)
- Cast on-site concrete panel walling (typically called tilt-up concrete panels)

A variation of the above solid concrete panel systems is:

- Concrete Sandwich Panels. These have insulation 'sandwiched' in the centre of the panels and they can be manufactured both on- or off-site.

The main advantages of concrete panel walling are, but certainly not limited to the following:

- Speed of construction can be increased to minimise the overall time required to complete the structure. Progress is less dependent on the weather conditions.
- Reduced requirement for scaffolding and supporting structures during construction. Safety rails can also be fixed to concrete elements prior to erection.
- Solid construction such as concrete panel walling provides performance benefits in areas of acoustic, thermal, condensation, weatherproofing, fire rating properties, as well as the ability for the wall panels to be load bearing. Thus, the walls may be designed to physically support suspended floors, additional upper level wall panels and even the roof framing. The solid walls also provide a high level of security from vandalism or "break-ins". Safety in cyclonic areas is also increased by the demonstrated high performance for resistance to airborne debris.
- An engineered structure designed by qualified engineers to withstand the various loads (externally and internally) expected over the life of the structure for each individual home.
- Architectural design freedom is provided by being able to cast panels in an infinite variety of shapes and sizes to suit the particular design of the home. Panels can incorporate door and window openings of complex shapes without the need for separate lintels, and can even have them cast in or factory fitted off-site.
- Endless range of finishes are available in terms of colour, texture and surface form to enhance the appearance of the facade of the home.

CAST OFF-SITE CONCRETE PANEL WALLING

Cast off-site concrete panel walling (generally known as precast) is a form of construction that provides speed of construction, as well as the benefits of solid concrete walls at a competitive economical price.

The system involves the casting of solid concrete panels horizontally on level casting mould bases (generally steel) in

quality-controlled precast factories away from the building site. The panels are then left to cure until they have reached the designed strength for lifting, at which time they are stripped from the casting mould and lifted into storage areas until required for transport to the building site. Mobile cranes are generally used to install the panels on site, lifting them from transport trailers directly into the final position. The panels must be braced temporarily until a sufficient number are installed and connected to provide a self-supporting braced structure. Panel thicknesses generally range from 150 to 250 mm and may include a cast-in insulation layer for increased thermal performance (ie concrete sandwich panels).

The main advantages of precast concrete panel walling include those listed for concrete wall panels plus:

- Reduced congestion on site, as available space is maximised and the amount of labour and waste/mess on site is reduced.
- Controlled level of quality in the product due to casting in factory (normally under cover) conditions. Tolerances in panel size, placement of reinforcement and fitment inserts, level of finish and concrete mix quality can be better controlled.
- Preparation work on site can be performed uninterrupted while the concrete panels are being manufactured.

Precast concrete panel walling for housing provides a quality, high performance and economical alternative to traditional forms of construction. However, it should be stressed that to achieve an optimum result, thorough planning and practical design/detailing is required.

CAST ON-SITE CONCRETE PANEL WALLING

Cast on-site concrete panel walling (generally known as tilt-up) results in rapid construction of the building structure with benefits of solid construction at an economical rate.

Casting on site involves the manufacture of the concrete panels in a horizontal position on a suitable level casting base and then lifting, tilting and moving them into their final position. The manufacture of the panels requires only minimal equipment such as simple edge formwork, basic reinforcement and paving expertise. Lifting devices and suitable cranes are in common with panels manufactured off-site.

As the concrete placement is simply accomplished at or near ground level, traditional finishing techniques for pavement work can be employed. Panels can often be cast one on top of the other (stack cast) to maximise site usage and utilise panel surfaces as the casting bed.

Once the concrete reaches the required strength, formwork can be removed, and a mobile crane used to lift and move the wall panels into position. They are temporarily braced until permanently incorporated into the structure, or a sufficient number of panels are connected to each other to produce a self-supporting structure. Panel thicknesses generally range from 150 to 250 mm and they may include a cast-in insulation layer for additional thermal performance, (ie concrete sandwich panels).

The main advantages of tilt-up concrete panel walling include those listed for concrete wall panels plus:

- On-site manufacture of wall panels eliminates transport costs to site. In addition, because there are no transport size limitations, the panels can be made larger than precast concrete panels, thereby reducing the numbers of panels to be made.
- Speed of construction, can be increased as panels can be cast directly on the concrete floor slab of the house, often on top of each other (stack-casting) to optimise site space. Once they have gained the required strength, the panels can be lifted directly into their final position.

Concrete Panels allow architectural design freedom and loads such as floors and stairs to be supported.

Tilt-up concrete panel walling provides a quality high performance and economical housing option. However, it should be stressed that to achieve an optimum result, thorough planning and practical design/detailing is required.

Professional advice from architects, engineers and recognised tilt-up concrete panel contractors should be obtained for all concrete panel walling projects to ensure that the project runs as efficiently as possible.

CONCRETE SANDWICH PANEL WALLING

Concrete sandwich panel walling systems incorporate an insulation layer, generally 'sandwiched' in between two layers of concrete. While still providing the same advantages detailed above, concrete sandwich panels (whether precast or tilt-up) inherently provide a higher level of thermal efficiency by combining insulation with the high thermal mass of concrete. Panels generally range from 180 to 280 mm in thickness.

The process of manufacture and installation of the concrete sandwich panels is essentially the same as for conventional concrete panels. However, there are additional manufacturing steps that involve the following:

- The panels are cast in two stages (but generally in one operation) as opposed to a single stage for conventional concrete panels.
- The off-form or external face of the panel is cast first, then the insulation board (which may vary depending on the particular proprietary sandwich panel system being used) is installed onto the off-form concrete layer. Connection devices to join the two layers are inserted through the insulation material and a second internal concrete layer is cast on top of the insulation board to both enclose the insulation board and provide a finish to the panel.
- The external layer of concrete is non-loadbearing while the structural internal concrete layer provides the loadbearing capacity to the panel.
- There are now a number of manufacturers/suppliers of proprietary sandwich panel systems in Australia.

Simple features can produce an interesting facade

REPEATABILITY AND MODULARIZATION

A concrete panel home design that aims for repeatability of its panels will offer significant cost savings. Onsite construction using simple formwork (rather than the steel formwork of precast factories) offers more freedom to alter panel sizes and total numbers without significant cost penalties. While not all panels need to be identical, the manufacturing nature of concrete panels results in reduced costs where consistency and repeatability in panel shape are achieved. This can include panel height, size of window openings, panel width, joint spacing, etc. If repeatability is used creatively, it can assist with unifying the design of the house or even become a feature in itself.

This does not mean that the house design needs to consist of four plain uninteresting walls. Often, the savings that are gained from panel repeatability for the majority of the house will deliver freedom to include one or two unique feature panels.

Similarly, the concept of modularization should be explored with concrete panel homes. Once modular rooms or spaces have been created, they can be re-used to link spaces and expand areas. A modular style design may even allow for a house to be expanded at a later date as the need arises or as the use changes.

PERFORMANCE BENEFITS

Some distinct performance benefits can be gained that are unique and should be well understood and incorporated into the design and construction phases. A brief outline of some of these follows, with more in-depth details available from: **www.concrete.net.au**

ACOUSTIC PERFORMANCE

Solid walling systems such as concrete panel walling provide good acoustic insulation, particularly at the sort of low frequencies that cause many complaints (eg use of home theatres, stereos, televisions). Innovative new systems incorporating concrete panel walling can economically achieve ratings of 60 to 65 dB for party walls, enabling the most stringent requirements to be met.

Concrete panels can economically provide acoustic performance well in excess of the required 45 dB given in the Building Code of Australia. In fact, the panel thicknesses commonly used will give values in excess of 50 dB easily and cost effectively with single-element solid walling options. Higher ratings can be obtained using various finishes and double-wall systems[1].

The mass of solid systems makes them excellent barriers to the transmission of airborne sounds, and various lining board systems can economically provide more than adequate insulation against impact sounds. Quality can be assured by paying attention to a few basic detailing and construction issues.

THERMAL PERFORMANCE

Recent testing carried out for the Cement and Concrete Association of Australia by the CSIRO investigated the overall energy efficiency of various walling systems.

The results indicate that the thermal mass offered by solid construction makes a significant contribution to the overall energy efficiency of the building when it is to be cooled. In fact, buildings using solid walling options require no insulation when cooling is required, and outperform insulated brick veneer construction. However, when the building is to be heated, the use of insulation does improve the energy efficiency. Once insulation is added there is virtually no difference between the performance of various solid walling systems and, say, insulated brick veneer construction. For example, the use of a solid concrete wall with a 10-mm-thick foil-backed polystyrene board against the internal face of the wall plus battens and plasterboard gives about equal performance to other insulated walling systems such as AAC and insulated cavity construction (all with much higher R-values).

Based on the research work with the CSIRO, the National Housing Energy Rating System (NatHERS) now has the option to select various solid walling options and take into account the thermal mass of these systems when assessing the overall energy efficiency or Star Rating of the building for compliance with Building Regulations.

The mass provided by solid walling construction results in a more comfortable living and work environment within the building as maximum temperatures are not reached and the moderated peak temperature corresponds to a cooler part of the evening due to the thermal lag. Other factors such as orientation and glass area will combine to maximise the benefits of solid construction.

Considerably less energy is required to maintain a comfortable internal temperature when thermal mass is incorporated into the building. Thermal mass will not only considerably reduce the running costs, but also provide opportunities for cost savings on the walling type used. For climates requiring the building to be cooled, the omission of insulation may also be possible, offering further savings.

The use of concrete or other solid construction systems to either offset thermal gain (usually in summer), or store up and release thermal warmth via passive solar principles (usually in winter), is highly beneficial to ensure the optimum use of finite energy resources.

CONDENSATION PERFORMANCE

Understanding the processes involved with condensation and utilizing an appropriate design strategy can avoid condensation problems in not only solid construction but in other forms of construction as well. Walling systems may include the use of composite construction assemblies consisting of concrete, insulation, vapour barriers and dry lining. The position of vapour barriers is also important and the location of these is dependent on the type of climate and environmental control strategy used. The general rule is to place the vapour barrier on the warm side of the assembly, thus minimising the flow of water vapour through the wall or building element and reducing the potential for interstitial condensation to form. This can cause deterioration to the internal fabric of the building element.

Full details on how to design for condensation can be found in Condensation - Design Strategies[2] which can be viewed at www.concrete.net.au.

Good detailing provides a sense of scale

FIRE RESISTANCE PERFORMANCE

All solid concrete panel walling systems provide very effective fire resistance levels (FRL). That is, the ability for the concrete panel to withstand the effects of fire and remain structurally sound to carry loads, provide insulation against the heat and remain intact to prevent smoke and heat from passing through the wall, for a given time period.

STRUCTURAL PERFORMANCE

(Construction, Dead, Wind & Seismic Loads)

One of the many inherent properties of solid concrete panel walling systems is their capability to be designed to withstand all loading conditions that could be expected to be experienced by a home during its lifetime.

Each individual concrete panel is a structural component and as such is designed to perform and withstand applied loads during the manufacture, transportation (if required) and installation, as well as the applied loads during the lifetime of the home. Panels are designed and detailed to be connected to each other and other building elements such as concrete footings, floor slabs (ground and suspended) and roofs in a manner such that, as a combination, they form a rigid, structurally sound framework for the building.

DETAILING AND CONSTRUCTION ISSUES

GENERAL

A Concrete Panel Home has the capacity of providing a home that is not only as comfortable as any in the market, but one that has the added value of providing a structure that is stronger and more solid than most conventionally built homes. This is due to each of the individual structural components of the house (footings, floor slabs, concrete wall panels) being intrinsically solid in nature and being combined or connected to work together to support and brace each other to form a solid structural shell.

As with any building system, there are some key areas that require attention at both the design and construction levels. This area in itself is extensive and cannot be covered in adequate detail in this briefing. However, several ‘Do’s’ and ‘Don’ts’ can be raised to ensure key areas are addressed at the planning stage, before they become a significant issue during construction.

FOOTINGS

For concrete panel homes, the footings of the house structure are critical to the overall long-term performance of the structural shell. The footings support the ground floor slab as well as the wall panels, which in turn typically support the suspended floors and the roof. They basically take all the load of the structure and then distribute it into the surrounding foundations.

Continuous strip footings or localised pad footings/piers are typically used to support concrete wall panels. However, the footing type will need to be determined by an engineer with careful consideration of the surrounding soil/foundation conditions and topography of the site.

A variety of designs for footing systems can be found in Section 3 of the Australian Standard AS 2870 Residential Slabs and Footings - Construction[3]. Note that a table of

equivalent constructions is included to enable selection of the appropriate footing system and details. Also that whichever footing system is chosen to suit on-site conditions and the builder's preference, it is essential that it is designed and constructed in accordance with either AS 2870 or AS 3600 Concrete Structures[4], and satisfies the requirements of the Building Code of Australia (BCA)[5].

Further information and details can be found in the C&CAA's publication Residential Floors[6].

Panels can be used for any architectural style

GROUND SLAB

A typical ground floor for a concrete panel home will consist of a concrete slab-on-ground to complement the structural, thermal and acoustic properties of the concrete walls. The use of concrete floor slabs is very common in Australian homes today.

In combination with the footing, a concrete slab-on-ground will provide the structural support for the building loads above it and will minimise the effects of possible ground movements from the foundations due to moisture variations.

As with the footings, the ground slab must satisfy the requirements of the BCA and relevant Australian Standards AS 2870 and/or AS 3600.

WALLING - LOADBEARING / NON-LOADBEARING

One of the greatest advantages that concrete panel walling has over many of the other walling systems is its loadbearing capacity. That is, a single leaf concrete panel wall can be designed to support loads from suspended floors, stairs, balconies, roofs, etc. This can reduce the requirement to provide other supporting framework to serve the same function. As the walls are capable of supporting the building loads, the requirement for intermediate columns and beams may be reduced. This can result in a reduction in building costs and greater clear spans of internal living spaces.

It also means that lightweight floor construction is not the only method of construction that is available for second or subsequent storeys in residential buildings. The benefits of using solid concrete suspended floors, stairs and balconies can therefore be obtained, as they can be directly supported by the concrete wall panels. Conventional lightweight walling systems would not be able to accommodate these loads.

One distinct benefit of a suspended concrete floor is a quieter home.

The advantages of using concrete panel walling should be exploited to its fullest to obtain cost savings in the building design and construction. The maximum advantage can be determined by the consultant and/or panel design engineer to suit each individual concrete panel home.

RETAINING ABILITY / SLOPE OF BLOCK

Another structural benefit that can be exploited by using concrete panel walling is its ability to be designed to withstand lateral loads, thus providing retaining capabilities at ground or lower-ground levels of the home.

A good example of this ability is when the concrete panel can be used as a retaining wall on a sloping block that may require cutting to provide a level building platform. Normally, cut situations require the use of batters which reduce the useable outdoor space. However, a vertical concrete panel retaining wall can be used to do away with the batters and retain the uncut portion of the block, thereby increasing the overall useable area.

It can even be used as the walls of a basement to resist below-ground soil pressures, and provide additional living space, or garage, below the existing ground level. Exploitation of a concrete panel walling system's retaining capacity to its fullest can be determined by the consultant and/or panel design engineer, taking into consideration soil and site conditions.

CONCLUSION

Concrete Panel Homes offer some unique and innovative solutions to housing while still retaining the distinct benefits of solid construction which our housing industry so firmly embraces and on which it rests.

> Concrete panels allow architectural design freedom, while structurally capable of resisting many different loads

While being one of the oldest and yet still most widely used construction materials to this day, concrete continues to offer up new and innovative solutions for the 21st century. The recognition that a concrete wall panel is a premium quality building material has been exploited in the civil, commercial, industrial and residential apartment sectors for decades. This knowledge is now being transferred to the housing industry.

The success of a Concrete Panel Home relies heavily on the efforts dedicated to up-front planning and design. Time and resources allocated at the front-end of the project will pay dividends time and again during construction and the life of the structure.

Concrete panels allow architectural design freedom and choice of surface finishes

FURTHER INFORMATION

The Association's website at www.concrete.net.au contains extensive information on various aspects relating to concrete. In particular the Concrete Panel Handbook which contains specific details on building homes using concrete panels is availabe to download free of charge.

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