Precast concrete offers durable, flexible solutions for floors, walls and even roofs in every type of domestic construction from individual cottages to multi-storey apartments. Concrete’s high initial embodied energy can be offset by its extended life cycle (up to 100 years) and high potential for reuse and relocation.

Common production methods include tilt-up (poured on site) and precast (poured off site and transported to site). Each method has advantages and disadvantages and choice is determined by site access, availability of local precasting facilities, required finishes and design demands (see ‘Typical domestic construction’ below).

The advantages of precast concrete include:

- speed of construction
- reliable supply — made in purpose-built factories and not weather affected
- high level performance in thermal comfort, durability, acoustic separation, and resistance to fire and flood
- inherent strength and structural capacity able to meet engineering design standards for housing ranging from individual cottages to multi-storey apartments
- highly flexible in form, shape and available finishes
- ability to incorporate services such as electrical and plumbing in precast elements
- high structural efficiency, low wastage rates on site
- minimal waste, as most waste in the factory is recycled
- safer sites from less clutter
- ability to incorporate waste materials such as fly ash
- high thermal mass, providing energy cost saving benefits
- simply designed for deconstruction, reuse or recycling.

Precast concrete does have disadvantages:

- Each panel variation (especially openings, bracing inserts and lifting inserts) calls for complex, specialised engineering design.
- It is often more expensive than alternatives (can be offset by reduced construction times, earlier access by following trades, and simplified finishing and services installation).
- Building services (power, water and gas outlets; conduits and pipes) must be accurately cast in and are difficult to add or alter later. This requires detailed planning and layout at design stage when plumbing and electrical trades are not usually involved.
- Erection requires specialised equipment and trades.
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- High level site access and manoeuvring room for large floats and cranes free of overhead cables and trees is essential.
- Panel connection and layout for lateral bracing requires detailed design.
- Temporary bracing requires floor and wall inserts that have to be repaired later.
- Detailed accurate design and pre-pour placement of building services, roof connections and tie-down are essential.
- Cast-in services are inaccessible and more difficult to upgrade.
- It has high embodied energy.

Performance summary

Appearance
An almost endless variety of shapes, colours, textures and finishes is available for precast concrete. It can be moulded and shaped to suit almost any design or form.

Simple surface treatments are:
- rebating and grooving
- surface coatings
- cement-based renders.

Other more complex treatments can also be used, such as:
- form liners
- oxide colouring

- applied finishes such as etching, grit-blasting, honing, polishing and exposed aggregate (off-site only where highly alkaline wash-down water and sediment can be recycled to avoid pollution of waterways).

Minor variations in finish between design intent or specification and the actual outcome are common. Assessment of samples and prototypes is highly advisable. Established, professional precast companies usually deliver quality assured finishes to the standard specified.

Four types of aggregate: [top to bottom] exposed, polished, sandblasted, stained.

Complex or detailed methods and finishes require a high degree of quality control and are often best handled under the controlled conditions of an off-site precast factory.

The detailing of joints, inserts, openings and fixings is critical. Typically, each precast panel is connected to the next or other building structure with metal components and anchors.

Joints between panels are usually filled with sealant to allow for expansion and contraction. Internal joints can be concealed behind abutting walls or, more usually, are
set using typical plasterboard methods. Careful detailing is required to achieve a stable, watertight and visually pleasing result.


**Structural capacity**

Structural precast concrete panels are a strong, durable and versatile building material, particularly suited to Australia’s harsh climatic extremes and requiring minimal maintenance. They can be engineered to meet the structural needs of every type of domestic construction.

Concrete is flood and fire resistant and doesn’t shrink, rot or distort. It gains strength as it ages and in structural terms is ideally suited to the unpredictable conditions associated with climate change.

The inherent structural properties of precast walls mean that they do not require additional bracing to resist racking loads and that simple design of cross walls and junctions can provide adequate lateral bracing. Tie-down inserts to resist cyclonic winds are simple to design, install and connect.

Precast finishes are highly impact resistant, withstand wear and tear, and require minimal repairs and maintenance.

**Thermal mass**

Precast delivers high standard internal finishes off the form (mould providing internally exposed thermal mass at a low cost without the need for insulation or other linings.

At 2060 kJ/m²Kelvin (K), dense concrete has the highest volumetric heat capacity of any commonly used housing material (e.g. brick 1360 kJ/m²K). (see Thermal mass)

**Insulation**

High insulation levels are simply achieved.

Insulated, 220mm-thick, precast sandwich wall panels (70mm concrete externally, 50mm XPS foam, 100mm concrete internally) commonly used in residential construction achieve a total R-value of 2.42. This can easily be increased by selecting foam of 80mm or 100mm.

The National Precast Concrete Association, in conjunction with Adjunct Assoc. Prof Terrance Williamson from the University of Adelaide, has developed a mass enhanced R-value calculator. The calculator recognises the thermal mass benefits of the insulated precast concrete of sandwich panels and offers Building Code of Australia (BCA) compliance.

The R-value calculator and the supporting industry standard are available on the website of the National Precast Concrete Association of Australia, www.nationalprecast.com.au.

Insulation design and detailing should avoid thermal bridging by ensuring continuous insulation between the internal and external skins in all external walls. Bridging through continuous concrete ribs and edge beams or failure to ensure all junctions have continuous insulation is a common design fault.

**Insulated precast sandwich wall panels.**

Source: Composite Global Solutions

Panel to panel square external corner (butt joint).

Proprietary composite or thermo-plastic ties should be used between skins. If using steel ties, the effects of thermal bridging should be considered. Extruded or expanded foam insulation may be used.
Sound insulation

Precast concrete provides one of the highest levels of acoustic separation of any common housing construction system for both internal and external walls.

Solid construction performs well above the minimum Rw45 rating required by the BCA. Single element walls and floors of solid construction (such as a 150mm thick concrete wall panel) have Rw ratings as high as 55.

Joints and openings must be detailed properly to maintain sound ratings. Precast concrete houses have fewer joints, and dimensional accuracy allows for the snug fitting of acoustically sound windows and doors.

Because services outlets are cast into wall panels, sound transmission weakness around switches and power outlets is avoided and transmission through cavities or air spaces is prevented.

Fire and vermin resistance

Fire resistance

Precast panels are highly fire resistant with zero flammability on both external and internal surfaces. The BCA specifies the fire resistance level required in various applications in terms of the fire resistance periods (FRP) for structural adequacy, integrity and insulation.

AS 3600-2009, Concrete structures (Section 5, Design for fire resistance), gives methods for determining the various FRPs for concrete walls. Precast concrete panels must comply with the following requirements:

- Adequacy: to the same level of FRP as structural insulation while satisfying AS 3600, Clause 5.7.4.
- Integrity: must attain the same level of FRP as structural insulation.
- Insulation: effective concrete wall thickness of 80mm achieves a 60 minute FRP and a solid 150mm thick panel achieves a 180 minute FRP.

Joints between panels must also meet the appropriate FRPs. Certified data on the performance of proprietary sealants should be provided by the sealant manufacturer.

Termite proofing

The use of woven stainless steel mesh or other termite barriers is strongly advised, to prevent termites accessing the roof structure via the insulation core. These barriers are placed across the insulation between external concrete skins at the base of the wall.

Durability and moisture resistance

Dense precast concrete is generally not subject to rising damp or structural damage from condensation or dew-point formation. However, condensation problems can arise in any building due to temperature, humidity and ventilation conditions that encourage dampness and mildew.

No type of construction is immune but precast concrete is rarely affected by internal or interstitial condensation (i.e. from water vapour passing through the material).

Surface condensation or dew-point formation is more common and, while often causing unsightly mildew and stains, structural damage in precast concrete is unlikely.

Insulation, ventilation and appropriate heating reduce this risk.

Environmental impacts

Life cycle assessment

Life cycle assessment by the Cement Concrete & Aggregates Australia (CCAA) concluded that there is no significant life cycle difference in terms of energy use and carbon emissions between alternative construction systems used in each of five building types studied (including a detached house).

Construction systems examined included:

- timber floor, timber frame with cladding and plasterboard, steel roof
- slab-on-ground, brick veneer with terracotta tiles
- slab-on-ground, double brick, rendered internally, cement tiles
- slab-on-ground, tilt-up walls lined with plasterboard and battens, cement tiles
- slab-on-ground, tilt-up walls, cement tiles.

The study was conducted over a 50, 75 and 100 year life span using standard assumptions about occupancy rates and operational energy use in accordance with AS/NZS ISO 14040:1998, Environmental management life cycle assessment — principles and framework (CCAA 2001).

The study did not take into account the likely impact of climate change over life cycle. Such consideration might indicate adverse outcomes for high mass construction. These aspects of life cycle assessment are examined in Thermal mass and Construction systems.
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Embodied energy
As with other common high mass construction systems such as brick, the embodied energy of precast concrete is arguably its most significant environmental impact (see Embodied energy). Detailed analysis of the life cycle benefits of high mass construction is recommended for each application.

The life expectancy of concrete structures is more than 100 years. Such a life expectancy requires that precast structures be designed to be reused, extended or retrofitted to ensure that their initial embodied energy is amortised over their life span. Design for deconstruction can also capitalise on the capacity of precast concrete to deliver the best life cycle embodied energy outcomes of all high mass construction systems. (see Construction systems; Thermal mass)

The use of recycled materials such as fly ash or recycled aggregate in precast concrete reduces embodied energy while improving strength and durability.

Precast products using calcium-based Portland cement release carbon dioxide as they cure. Emerging cement technology (not yet commercially available) using magnesite-based Portland cement alternatives actually takes in carbon dioxide as it cures.

Other Portland cement substitutes with low embodied energy are currently available.

Reuse and recycling
Careful design and detailing of precast structures increases their potential for relocation and reuse. Alternatively, they can be simply renovated internally, conserving resources and reducing waste and landfill.

Careful design of precast panels for disassembly can facilitate reuse or recycling when the building reaches the end of its useful life. Precast concrete elements can be crushed and reused as aggregate for new concrete or for road bases or construction fill, creating economic and environmental savings.

Recycled aggregate and steel can and are commonly used in precast concrete. Designers should specify their inclusion to ensure best outcomes. Waste materials (such as slag and fly ash) that would otherwise be used in landfill should also be specified and used. These methods can reduce cost while adding to concrete strength.

Controlled mix environments and curing options can overcome water absorption problems associated with the use of recycled aggregate. Stormwater and rainwater can be used in the precast concrete mix design, thereby reducing mains water consumption and allowing highly alkaline wastewater to be recycled into the mix.

Precast concrete methods favour the reuse of formwork, and off-site manufacturing allows most manufacturing waste to be recycled. Precise quantification and dimensioning further reduce waste.

Transport
Materials used by precast manufacturers are usually sourced locally for cost reasons and transport limitations. Precast elements are mostly locally manufactured and transported short distances to sites. This often reduces the transport component of embodied energy relative to other high mass systems.

Buildability, availability and cost
Subject to workable site access and the availability of quality local precasting works or tilt-up contractors, precast concrete construction can provide practical solutions for most housing applications.

For individual homes, costs can range in the upper end of high mass solutions. Reduced construction times and need for on-site trades can offset this to some extent. Economies of scale and repetition can further reduce costs.

Typical domestic construction
Each of the two most common production methods — precast (poured off site and transported to site) and tilt-up (poured on site) — has advantages and disadvantages. Choice is determined by site access, availability of local precasting facilities, the standard of finishes and design requirements.

Off-site precasting
Off-site precasting is carried out in a controlled environment to avoid weather related variables. This minimises waste and delivers the highest level of quality assurance in the range of finishes and dimensional accuracy. It also reduces on-site materials storage and waste.

Controlled pouring environments in the factory also reduce concrete curing times through the use of temperature control and advanced mix design, including low water to cement ratios. They can reduce the amount of cement required (the highest source of embodied energy) to achieve adequate strength to withstand transport and erection loads. Tilting casting tables are also beneficial because the greatest structural loads for precast concrete occur during lifting, transport and erection.
Precasting allows the use of high quality formwork including vibrating casting tables and accurate positioning of inserts (lifting points and structural steel), insulation, services (plumbing and electrical conduits), openings, flashings and termite barriers. Similar levels of quality assurance are difficult or more expensive to achieve on site — particularly on smaller projects.

**Tilt-up or on-site construction**

Tilt-up wall panels are cast on a horizontal surface and require simply tilting to vertical in their final location. This definition is expanded slightly to include all on-site precasting where horizontally cast panels are lifted by crane and moved to their final location.

This is often a more practical solution on small sites or where transport access or site constraints preclude the use of off-site precast methods.

Precast panels are usually formed up on existing concrete floor slabs either as ‘stack casting’ (one on top of the other) or as individual slabs near their final point of erection.

Bond breaker compounds are used to ensure that stack cast slabs are separable after curing. Bond breaker failure (often due to poor application) can lead to considerable waste, cost and delay.

While tilt-up overcomes transport and other logistical problems, it is slower than precast because walls can’t be poured before or during floor construction. Floor space is often limited or shorter than the walls that surround it, necessitating additional joints.

The on-site process can restrict other building work while the concrete cures (it cures only when kept moist). Curing times are often reduced by using stronger mixes (more cement and embodied energy) to allow concrete to achieve adequate strength in shorter periods under less controllable site conditions.

Additionally, small imperfections in the finish or variations in slab level result in corresponding lower grade finishes or ‘twists’ in finished walls. In other words, quality assurance is more challenging on site.

**Design and detailing**

Lifting is generally the most critical design load and dominates the design of the panel in most situations.

The design and planning phases of a precast or tilt-up project are among the most crucial for its success. The entire design and construction procedure for the building must be worked out in advance of the first pour and factored into the design of each panel including size (casting table or space and transportability), detailed set-out of services, lifting and temporary bracing inserts, and lifting procedures (erection sequence, crane positions and lateral bracing).

The building should be designed specifically for the construction method. Effective planning requires continuous involvement and interaction between every member of the design and construction team from design to completion.

**Panel sizes**

Panel area should be maximised where possible (20m² or larger) to reduce labour, truck movements and cranage costs. Always consider the available casting area on site for tilt-up and casting table size for off site.

The rule of thumb limit for flat lift-out of beds is 10 tonnes total weight, although some tilt tables and transport methods used by precast plants allow greater sizes. These are always dependent on crane size and area on site.

The maximum height of panels transported vertically in ‘A’ frames is generally between 4.0m and 4.5m. Length is determined by trailer configurations and is generally a maximum of 12m. Transportation limitations are set by state road authorities and may differ between states.
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Casting
Accurate positioning of services and inserts is critical.

Cast-in services require that:
- all plumbing be silver soldered with minimum joins, or some other system with proven durability used
- services conduits be oversized and provide access points for future upgrading or maintenance
- the plan (and photographs) of the services layout be retained for reference to avoid potential future damage when drilling for attachments
- all plumbing and particularly hot water lines be lagged to allow for thermal expansion and movement, and prevent heat loss
- the window supplier be notified that windows are for precast openings and must conform to precise dimensions
- precast window formwork and templates be accurate, square and sized to the window supplier’s actual dimensions
- rebates or cast-in flashing details are well resolved
- adequate curing times be allowed for on-site pours
- the concrete strength be certified at pour and before lifting (slump test and test cylinders).

Formwork
While dependent on the precast contractor, accuracy levels with precast systems are usually extremely high due to the quality of reusable formwork and workshop conditions.

A slab not perfectly level, or twisted or warped, can have a problem with tilt-up. Formwork frames must be absolutely square to ensure clean, tight corner junctions and plumb walls.

Openings
Almost any shape or size of connection can be achieved with detailed engineering design. The greatest structural loads usually occur during lifting and transport.

Openings required for alteration and addition can often be simply added (subject to engineering advice) by cutting or removing existing panels.

Transport
The erection sequence determines the order of transport. Careful planning of the erection sequence to minimise crane positions reduces transport and cranage costs.

Site access for trailers and cranes is a critical consideration at the design stage and may preclude the use of precast construction.
Check the delivery route to site before designing panels, and limit wall heights (including truck or float deck height) to fit under bridges, overhead cables and other height restrictions.

Site manoeuvring requirements for trailers and cranes can reduce these allowances.

**Erection**

Specialist erection contractors and specialised lifting equipment are essential for precast work. OH&S risks can be extreme if lifting procedures, temporary bracing and panel connections are not professionally conducted.

- Ensure all bracing is on site and in good order before erection.
- Ensure corners and junctions are waterproof and structurally sound.

**Footings**

In residential construction, precast concrete generally employs similar footing systems to other high mass construction systems.

With appropriate engineering design, walls can act as beams and span between piers or piles drilled or driven to material of adequate or equal bearing value on sites with reactive soils; this can reduce footing size and simplify construction. Precast flooring can span long distances with less need for supporting columns.

**Joints and connections**

Continuous welding of steel angle inserts is often used to join precast walls. These are typically rebated and plaster set internally. Junctions are often visually expressed externally.

Welded joints are problematic during deconstruction. For this reason, concealed or recessed bolted connections are preferable.

Lifting inserts should remain accessible and structurally sound for future relocation. A deconstruction schedule should be prepared that includes plans and photographs of each panel after erection and notes any damage to lifting inserts.

Other joint and connection considerations include:
- waterproofing and fire rating to the same specification as walls
- ensuring the continuity of insulation
- maintaining structural integrity as specified in the engineer’s drawings
- termite proofing.

**Fixings**

Fixings including bracing and lifting inserts (chosen from a wide range of commercially available, purpose designed proprietary products) are accurately cast-in during pouring.

**Safety issues**

- Use specialist experienced tradespeople for erection.
- Use only certified proprietary lifting eyes and temporary bracing.
- Check all brace inserts and lifting eyes before and during erection.
- Ensure adequate concrete strength is achieved before lifting.
- Have a well prepared site with pre-planned crane positions, wall erection sequence and bracing layout.
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These are generally designed to be cast just below the slab surface and located with void formers or removable screw-in plugs with neoprene or other flexible antennae protruding to the surface of the slab so as not to interfere with trowelling.

Fixings for various purposes can be chosen from a myriad of commercially available concrete fixing systems. Take care not to damage cast-in services.

References and additional reading

- Autex. Understanding acoustics. www.stmstudiosupplies.com
- Cement Concrete & Aggregates Australia. CPH5-9 walling. www.concrete.net.au

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