

Offsite Concrete Construction The Solutions



Precast concrete is virtually unlimited in its application including the entire structure or selected elements such as frame, floors, walls, stairs or balconies.

The long track record of the precast concrete industry, combined with the inherent benefits of concrete, provide compelling reasons to use precast concrete for projects where offsite solutions are applicable.

The solutions discussed in this publication include:

- Precast concrete walls: twinwall, solid walls and cladding
- Precast concrete floors: hollowcore and lattice girder slabs, which can contain active cooling
- Precast concrete elements, including columns, beams and stairs
- Volumetric construction
- Crosswall construction
- Hybrid concrete construction

Introduction

The use of precast concrete elements is well established as a construction method throughout the world and provides solutions for a great variety and complexity of layout, shapes and façade treatments.

It provides the benefits of all concrete elements, including material efficiency, quality control and speed of erection.

Precast concrete can be incorporated into any building type. Whether the building has a regular or an irregular shape, the entire structure or elements of that building, such as frame, floors, walls, stairs or balconies, can all be precast. Precast construction is virtually unlimited in its application and is suitable for single and multi-storey construction. In fact, precast building elements can be a considered option for any construction project.

Bespoke designs can be achieved using standard precast components, which need not imply a modular appearance. Precast elements, including floors, stairs and wall panels can combine seamlessly with non-precast elements to produce free-flowing spaces. Curved precast panels with a wide range of attractive and durable finishes can meet the most challenging of design requirements.

It is not necessary to take an 'all precast or no precast approach' to design. The key issue for designers is to identify which construction method, or mix of construction methods and materials, is most appropriate for the specific requirements of the building.

Thorough consideration of construction options at an early design stage is critical to optimise speed of construction, structural performance and delivery of the most economical frame package for each project.

In this guide we highlight some of the methods of construction and construction solutions that use offsite, factory-produced concrete. This includes hybrid concrete construction, where a combination of cast in situ and precast units are used.

This guide is a companion document to *Offsite Concrete Construction: The Benefits* which provides information on

- Performance in construction
- Performance in use
- Design opportunities
- Supply chain benefits
- Sustainability

USING PRECAST CONCRETE ELEMENTS CAN:

- SPEED-UP CONSTRUCTION
- PROVIDE HIGH-QUALITY FINISHES
- REDUCE COSTS



Chapel Wharf, Manchester, 995 apartments in four offsite-engineered hybrid constructed towers, up to 23 storeys. Image courtesy of PCE Ltd.

Precast concrete walls

Twinwall

Twinwall consists of two precast concrete panels held apart by a lattice girder, manufactured from steel reinforcement. The precast concrete panels form both a permanent shutter for the in-situ concrete and contribute to the final structural element. The surface finish of the panels are good quality and may only require a skim coat of plaster, or paint finish. The advantage of using an in-situ concrete infill is that the elements can be readily tied together to form a robust structure.

Potential uses for twinwall panels include:

- Basement walls.
- In combination with lattice girder slabs to form cellular structures.
- Core walls or lift shafts.
- Residential structures with load-bearing party walls.



Solid precast walls

Using precast walls provides a rapid construction technique and a strong, durable, robust and fire-resistant structure. Crosswall, which is included in more detail on page 6 of this guide, is the most common form of solid precast walling.

Core walls can also be supplied as volumetric precast, fabricated as four sides in a box and bolted together on site, providing excellent rigidity and stability. The boxes tend to be half a storey in height to enable the elements to be transported by road.



Cladding walls

Precast concrete cladding can be used to create the external facades of buildings of any height. They provide a durable, low maintenance weatherproof envelope while fulfilling architectural, structural and other requirements in terms of fire resistance, thermal performance and sound insulation. Architectural precast concrete is available in a wide range of colours, textures and forms, of bespoke design to suit project requirements, and often designed to replicate the colour and texture of stone, masonry and terracotta. The term 'recon cladding' – short for reconstituted stone cladding, is commonly used to describe architectural precast cladding, reflecting its use as a cost-effective alternative to stone.

Panels can be manufactured as a whole wall system, with insulation sandwiched between two layers of concrete, or simply as the external panel, with or without factory-applied insulation. Services, balcony fittings and glazing can also be factory fitted. Precast concrete cladding can be designed to be structurally load bearing or non-loadbearing. The most common system is sandwich panels, the structural inner layer designed to withstand the applied loadings from the floor and structure above. Non-loadbearing systems have no structural function but may be either stacked off the foundations of ground beams (a stacking system) or supported by the main frame directly or via a secondary structure (a supported system.) Glass fibre reinforced concrete (GRC) panels are a form of non-loadbearing concrete cladding panel. Ultra-high performance concrete (UHPC) offer an alternative concrete cladding solution.



Precast concrete floors

Hollowcore floors

Hollowcore slabs derive their name from the voids or cores which run through the units. The cores significantly reduce the self-weight of the slabs, maximising structural efficiency, and can also function as service ducts. The cores reduce the volume of material used. Units are generally available in standard 1200mm widths and in depths from 110mm to 400mm. Non-standard lengths, splays and notches can readily be accommodated.

Hollowcore slabs have excellent span capabilities, achieving a capacity of 2.5 kN/m² over a 16m span. The long-span capability is ideal for offices, retail or car park developments. Units are installed with or without a structural screed, depending on requirements. Slabs arrive on-site with a smooth pre-finished soffit. In car parks and other open structures, pre-finished soffits offer a maintenance free solution.

Prestressed units will typically have an upward camber dependent upon the span, level of prestress, etc. This will be reduced when screeds/toppings or other dead loads are applied.

Hollowcore units with reinforcement (not prestressed) are also available, generally 225mm deep and 1200mm wide. They have a shorter span capability but do not have any camber. They can also be made available with an integral layer of expanded polystyrene on the soffit to provide insulation for ground floor situations.

Solid (prestressed) floors

Solid prestressed units, 75mm or 100mm thick, are often produced on the same prestressing beds as hollowcore floors with the purpose of being used compositely with an in-situ concrete structural topping between 75mm and 150mm thick. Alternatively thicker units can be cast with simply a screed for levelling applied on-site.

For shorter spans, and to avoid camber, non-prestressed solid units can also be designed and manufactured. These can be used without any topping or screed – structural or non-structural.

Coffered floor units

An advantage of coffered floor units is the increased surface area of the slab, and therefore greater potential to benefit from the concrete's thermal mass - as part of a low-energy servicing strategy. Often bespoke, there can be a cost premium, but with careful planning the moulds can be reused many times, making them more cost effective. The units are designed to be exposed and can carry conduits for services.

Lattice girder slabs

Lattice girder units comprise a thin precast concrete 'biscuit' into which a lattice girder made of steel reinforcement is cast. The units are usually 2400mm wide and can be supported with in-situ or precast concrete beams.

Once in position, reinforcement is fixed to the top of the lattice girder and an in-situ concrete topping is poured which acts compositely with the precast concrete. The overall floor depth is generally in the range of 150mm to 300mm.

The floor slab can be designed to act continuously across several spans. Void formers can be introduced in the form of polystyrene blocks or spheres made from recycled plastics. Different systems are available from various manufacturers. The void formers reduce the quantity of concrete used and also the self-weight of the slab.

Double-tee floor units

Double-tee floor units are ribbed precast prestressed concrete units. They can be procured in a variety of depths from 300mm to 800mm and even beyond but the most common unit is 600mm deep as this conveniently carries office loading over 12m and car park loading up to 16m. The top flange is usually 50mm or 60mm deep and the ribs taper from a minimum of 140mm at the base, widening upwards towards the underside of the top flange, the taper of 1 in 20 each side allowing for easy lifting out of a fixed mould.

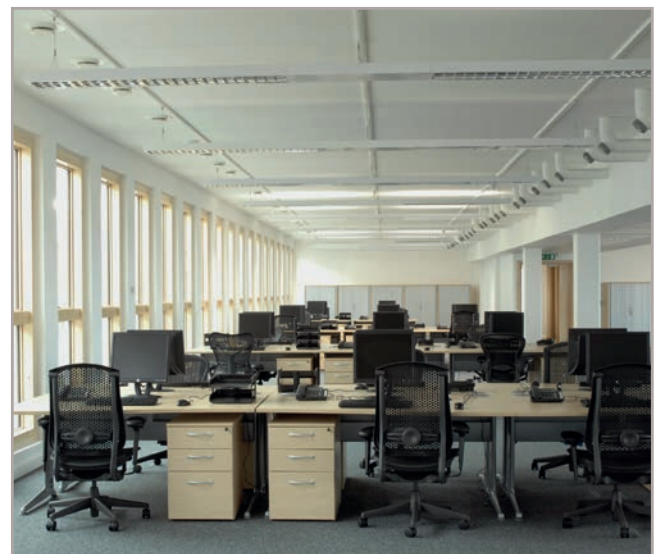
Double-tee floor units are produced in standard widths of 2400mm. They offer greater structural capacity at longer spans than hollowcore or lattice girder but often require a deeper floor zone.

The ribbed soffit profile can provide improved aesthetics in many situations. Account should be taken of the camber of the units, particularly for longer spans.

Precast active floor slabs

Precast floors can be used as part of a passive and/or active cooling strategy that utilise the thermal mass of concrete to reduce the energy needed to cool and heat a building. Fresh air from a mechanical ventilation system can be channeled through the cores of a hollowcore slab, enabling good heat transfer between the air and slab.

Precast slabs can also be cast with plastic pipework embedded near the soffit for heating and cooling.



Innovate Green Office, Leeds utilised exposed hollowcore slabs and mechanical ventilation. Courtesy of Rio Architects.

Other precast concrete elements

Precasting elements in concrete can be used to speed up construction, provide high quality finishes or reduce the costs for specific elements of the frame.

As well as floors and walls, common structural elements made in precast concrete include:

- Columns - for a quality finish / to reduce programme.
- Stairs - for a quality finish / for safety.
- Balconies - to allow pre-assembly in a safe environment.
- Lift cores
- Beams
- Bathroom pods

Columns

Precast columns are generally square, rectangular or circular, although other shapes are possible and can be cost-effective where there are a large number of repetitions. Increments of 50mm on the dimensions of faces of square and rectangular columns are preferred. The preferred increment for the diameter of circular columns is 50mm.

Circular columns are routinely cast vertically, limiting them in most cases to single-storey height. Rectangular and square columns can be cast horizontally and the maximum height of columns without splices is generally between 20m and 24m although 15m to 16m is often more economic. Where the columns are continuous through one or more floor levels they can have corbels or structural inserts to provide support for beams.

Beams

Precast concrete beams are reinforced with either steel reinforcement or prestressed with steel strand. They may be designed to act compositely with the floor. They can also be designed to be monolithic with columns especially where these are in-situ elements.

Where the beams are supporting precast concrete floor units the beam profiles are generally inverted T-beams or L-beams with the nib designed to support the floor unit. However, other profiles can be manufactured.

Stairs

Precast concrete stairs offer a quick method of providing robust, safe access routes during construction. They remove the need for complicated on-site shuttering and provide a high quality finish. They generally do not require temporary propping and are often connected to floors and landings using steel angle joints. Other connections such as continuous halving joints and intermittent halving joints are also used. Combined stairs and landing units are also available.

Precast concrete stairs are particularly cost-effective when duplicated or based on manufacturers' standard mould sizes. The greater the number of identical units required, the lower the cost.

Bathroom pods

The structure for a bathroom pod can be manufactured in precast concrete. The structure generally consists of thin concrete walls and floor with a single layer of reinforcing mesh. Services such as electrical conduits and pipework can be incorporated into the concrete structure.

After casting the concrete pod the bathroom is fully fitted out, including all the finishes. The finished pod is delivered to site and lifted into position ready for final connection of the services.

Balconies

Precast concrete balconies are manufactured mainly for use in flats and high-rise developments. Units have steel reinforcing bars projecting from the back which tie in with the steel reinforcement in the concrete floor structure. Balcony units are temporarily supported until the structural floor or screed has been placed and reached sufficient strength.

Precast concrete balcony units typically have integral drainage slots to receive drainage outlets and an upstand to facilitate proper weather-proofing details at door thresholds. They may also incorporate tiled upper faces and cast-in fittings for balustrades.

There are proprietary systems available to minimise cold bridging which can be incorporated into precast balconies.

Terracing

Precast concrete is used extensively for terracing in grandstands, stadia and auditoria. Precast concrete provides a strong, durable and versatile terracing unit that is quick and easy to install. Importantly, it can easily be designed to meet the vibration criteria for sports grounds.



Octagonal stair core within South Court of Chadwick Hall, Roehampton University. Courtesy of Nick Kane Photography.

Crosswall construction

Crosswall construction, using precast floors and load bearing walls, is ideal for buildings of a cellular nature, for example hotels, student accommodation, housing and apartments.

Crosswall is a modern and effective method of construction that employs factory-produced, precision engineered, concrete components. Each component is custom designed and manufactured to suit the specific project. This method of construction was developed to facilitate swift and adaptable residential buildings.

Load-bearing walls across the building provide the means of primary vertical support and lateral stability, with longitudinal stability achieved by external wall panels or diaphragm action taken back to the lift cores or staircases.

Crosswall construction provides an efficient frame without structural downstands, resulting in a structural floor zone of 150–200mm, maintaining a high degree of sound insulation between adjacent dwellings and rooms. The system provides a structurally efficient building with main division walls offering a high degree of sound insulation between adjacent dwellings or rooms.

Crosswall construction provides:

- High quality finishes – often it is only necessary to have a skim coat or paint finish on the ceilings and walls.
- Thermal mass – there is a significant thermal mass which is easy to utilise because of the minimal finishes.
- Fire resistance: concrete does not burn and cannot be set on fire like other materials.
- Acoustic performance – tests have shown that crosswall exceeds the Part E acoustic requirements by a significant margin.
- Bathroom pods – these can be easily integrated into the structure and be fully fitted out.

The cost savings from these and other benefits should be fully considered when comparing the costs with alternative structures.

Further information can be found in *Crosswall Construction*, a guide from The Concrete Centre.

Building with crosswall

Crosswall buildings are durable, have good acoustic values and are virtually maintenance free. They are quick to erect, offering the client a rapid room occupancy programme. The precast components are brought to site ready to be placed within the structure.

The construction method incorporates a series of horizontal and vertical ties, designed to meet progressive collapse criteria set out in the Building Regulations. Crosswall construction is designed for ease of construction and can incorporate bathroom pods, which fit together with the minimum of joints to enable rapid sealing.

Units are tied together using a series of hidden joints that are grouted as the works progress. The minimum number of joints enables rapid erection on site, with the added visual benefit that all joints are either hidden or only visible from outside the structure.

As soon as the ceiling units at roof level are erected, roof trusses, external cladding/brickwork, window installation and internal first-fix can commence. It is also possible for following trades to start before the precast erection is complete.

Minimal finishing is needed within each room, which reduces the overall construction.

Structures up to and including 16 storeys have been completed in the UK using crosswall construction.



University of East London. Five seven-storey and four three-storey structures, creating 788 bedrooms, were erected within 33 weeks using crosswall construction.

Volumetric construction

Projects such as prison accommodation, stairs and lift cores can benefit from modular precast construction which offers particular benefits, including:

- Robustness
- Off-site fitting out
- Rapid assembly on-site
- Independence from extremes of weather – project certainty

The on-site construction phase is substantially reduced by using concrete modules cast as five-sided boxes (usually four walls plus a roof) in purpose-

made steel moulds. The modules will generally be delivered to site on low-loaders, with the ground floor units being erected onto a prepared ground floor slab. The subsequent units are then successively erected onto the roofs of the units below.

Units are generally fitted out at the factory with windows, vents, bathroom and other fittings, plus plumbing and electrical fixtures and fittings. A major benefit of the factory production process is that it can be carried out largely unaffected by weather extremes. Once on-site, in addition to a reduced construction period, there will also be a substantial reduction in site labour requirements.

Hybrid concrete construction

The combination of precast concrete with in-situ concrete can make best use of the advantages of each, which are given in Table 1.

Added to the inherent benefits of thermal mass, durability and fire resistance, hybrid concrete construction can provide straightforward and quickly-built structures that are of high quality and extremely economic.

The use of precast concrete for the major part of hybrid concrete structures will reduce the overall construction time, the amount of traditional formwork which has to be used and the number of operatives engaged in wet-trades on-site. Safe working platforms are created by the adoption of precast floor systems, enhancing the level of safety on-site.

Minimal finishing is needed within each room, which reduces the overall construction period.



Hybrid concrete construction at Cartwright Gardens, London.

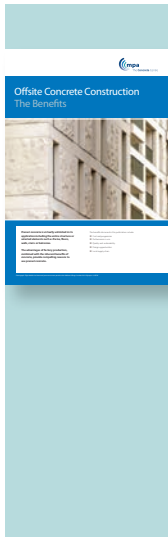
Table 1: Benefits of hybrid concrete construction

Precast concrete	Precast or in-situ concrete	In-situ concrete
Economic for repetitive elements	Inherent fire resistance	Economic for bespoke areas
Long clear spans	Durability	Continuity (structural efficiency)
Speed of erection	Sustainability	Inherent robustness
Buildability	Acoustic performance	Design flexibility
High-quality finishes and consistency of colour	Thermal mass	Services coordination later in programme
Accuracy	Prestressing	Locally sourced materials
Reduced propping on site	Mouldability	Short lead in times
Reduced skilled labour on site	Low vibration characteristics	

Table 1 (above) shows the inherent benefits of concrete provided by both precast and in-situ solutions, as well as advantages particular to precast concrete and to in-situ concrete. Hybrid concrete construction has the potential to optimise all of these benefits. For further guidance refer to The Concrete Centre publication *Best Practice Guidance for Hybrid Concrete Construction*.

Resources from The Concrete Centre

Download from: www.concretecentre.com/publications



Offsite Concrete Construction: The Benefits

Precast concrete is virtually unlimited in its application including the entire structure or selected elements such as frame, floors, walls, stairs or balconies. The advantages of factory production, combined with the inherent benefits of concrete, provide compelling reasons to use precast concrete. This guide gives more information on the wide range of benefits.

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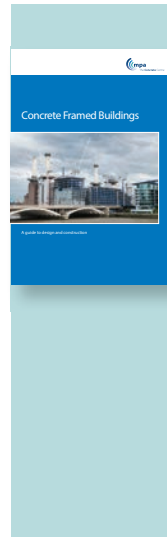


Concrete floor solutions for passive and active cooling

This updated guide details all the various systems currently available, from the simple passive approach to the more sophisticated active systems. Case studies are included to highlight recent projects featuring the various systems covered.

Publication date: 2017

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Concrete Framed Buildings

At the start of each project, a decision is made about the form and material for the structural frame. This publication sets out to help the designer come to an informed decision, giving likely structural options for a concrete frame, with useful points to note written by engineers for engineers.

Publication date: 2016

Ref: TCC/03/024



Visual concrete

The desire to optimise concrete's benefits and express the visual aesthetic of the structure requires high quality and detailed consideration of formwork, workmanship, curing and concrete mix design. These requirements should be understood by architects, structural engineers and other members of the team to ensure a successful outcome. This guide aims to enable designers to realise their aspirations using concrete.

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