

# Offsite Concrete Construction



A guide to the design and construction  
of precast concrete in buildings

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## Introduction

Offsite concrete solutions range from whole building and structural systems, to precast construction components including walls, stairs and floors. They can be of bespoke design or standardised components offering the opportunity for creativity and efficient construction best suited to the project criteria.



**Cover image and left:** Arena Central is a two block (17 and 22 storeys) residential development in Birmingham. The project utilised precast concrete systems including the building's structural frame, cladding and balcony units, which fit the client's brief for a robust finish which would limit the amount of ongoing maintenance required. Courtesy of Creagh Concrete Products Ltd.

**The use of precast concrete elements is a well-established construction method and provides solutions with a great variety of use, location, shape and finish. Precast concrete can be incorporated into any building type, below or above ground or water, enclosed or outside. In fact, precast concrete is virtually unlimited in its potential application, for both single and multi-storey construction and can be considered as an option for any construction project.**

The use of offsite precast concrete is a Modern Method of Construction (MMC) offering advantages of pre-manufactured value (PMV) gained from factory production. By manufacturing elements of a building offsite they are subject to tight quality controls away from the impacts of weather and other complexities of a construction site. Other benefits include improved health and safety and speed of construction.

Offsite solutions using concrete have the added advantage of providing the inherent high-performance benefits of concrete itself. These include durability, material efficiency, non-combustibility and high thermal mass.

It is not necessary to take an 'all precast or no precast approach' to design. The most economical solution might well be a hybrid or composite concrete solution, using a mix of cast in situ and factory produced, precast units. 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. This considered approach, starting in the design phase, is known as design for manufacture and assembly (DfMA).

### Modern Methods of Construction (MMC)

Earlier this year a new framework, categorising different forms of innovative construction methodologies was published by the Ministry of Housing, Communities and Local Government (MHCLG). This MMC definition framework aims to regularise terminology within the sector and aid understanding and ultimately greater uptake of offsite manufacturing for UK housing. It is closely associated with a drive to increase pre-manufactured value (PMV). Of its seven categories, the first five are identified as Off- or Near-site pre-manufacturing and the last two relate to site-based process improvements.

**Examples using concrete can be found in each category:**

**Category 1:** Pre-Manufacturing of 3D (volumetric) primary structural systems such as a volumetric stair or lift cores.

**Category 2:** Pre-Manufacturing of 2D (panelised) primary structural systems such as concrete crosswall construction.

**Category 3:** Pre-Manufacturing components of primary structure not part of a systemised design such as concrete floor and wall panels, stairs, columns and beams.

**Category 4:** Additive Manufacturing – structural or non-structural elements created remotely or onsite based on digital design and manufacturing techniques, such as 3D printed concrete.

**Category 5:** Pre-Manufacturing of Non-structural assemblies and sub-assemblies such as bathroom pods.

**Category 6:** Traditional building product led site labour reduction and productivity improvements such as large format blockwork and prefabricated reinforcement.

**Category 7:** Site process led labour reduction and productivity improvements including insulated formwork system; systemised in situ concrete systems such as tunnel form; standardised formwork and temporary works; robotic site processes for bending rebar or laying block paving; use of BIM for digitally enabled workflow planning; site working planning tools like GPS; site worker augmentation like AR/VR and digital site verification tools for striking in situ concrete.



The facade of Victoria Gate in Leeds combines polished and acid-etched precast concrete finishes in a tour-de-force of geometry and texture. Architect: ACME; Structural engineer: Waterman Group; Precast concrete cladding: Techrete. Image courtesy of British Precast.

# Design opportunities



V&A Dundee is clad with 2,429 precast concrete "planks" up to 4.4m long and ranging in weight from 0.9 to 2.8 tonnes.

The UK precast industry has a wealth of knowledge and experience and can help optimise:

- Maximising standardisation
- Lead-in times
- Detailing
- Surface treatments
- Erection

**A wide range of precast concrete options are available to suit design and budget requirements. These include standardised off-the-shelf products, panelised building elements, construction systems and unique elements made from bespoke forms and mixes. Precast concrete manufacturers offer a complete service from design through manufacture to installation.**

## Proven designs and methodologies

Precast construction incorporates proven technologies and methodologies which have been developed over many years. There is a suite of standards to which precast elements are manufactured and that can be used by specifiers with confidence.

## High quality

High quality is achieved through the use of robust formwork, dedicated concrete mix designs and manufacturing expertise made in a factory environment. Samples, approved by the client, can be used as a benchmark of quality control, with products checked prior to leaving the factory.

## Designed to last

Concrete designed and built to the requirements of BS 8500 will have a working life of 50 years, 100 years, or longer if required. Concretes can also be designed to perform well in aggressive grounds and harsh environmental conditions such as marine and coastal applications.

## Variety of shape/form

Concrete can be formed into almost any shape. Precast concrete offers great scope for design, creativity and material efficiency. Repetition of elements can make even complex shapes more affordable.

## Accuracy

Precast elements are cast to tight tolerances, and checked in the factory before delivery to site. Quality control systems, a consistent well trained workforce, and widespread use of self compacting concrete ensure a high standard of workmanship.

## Long clear spans

Reducing the number of columns is often important in projects such as offices, sports stadia and car parks. Prestressing the concrete in the factory can deliver these longer spans with shallower construction depths.

## Range of finishes

Architectural precast offers a wide range of colours and textures, often with mixes developed to resemble stone – hence the term "reconstituted stone" or "recon". Specialist manufacturers offer samples for reference, using a wide range of combinations of aggregates, pigments and finishing techniques (such as acid-etched, grit-blasted, polished etc) as well as embedded surface materials such as stone, terracotta/ceramic tiles and brick.

# Performance in construction

**Early involvement of the precast concrete manufacturer, who will have considerable expertise, can reduce cost and maximise value in the construction phase.**

## Speed of construction

Precast elements are designed by specialists with experience in ensuring that the structure can be erected quickly and efficiently, often using standard lifting equipment.

These offsite manufactured elements can be delivered with integrated services, ready clad, insulated and glazed if required, to save time on site and reduce further the number of following trades and save costs.

Speed of construction and tight construction programmes are primary considerations in most building projects. Installation times for precast units vary with each project, but indicative rates of installation are shown in Table 1.

Type of units	No. of units
Single storey columns	12 to 14 per day
Spine and edge beams	12 to 15 per day
Structural wall panels	12 to 16 per day (approx. 150 m <sup>2</sup> per day)
Floor units	250 to 350m <sup>2</sup> per day
Stairs or landings	12 to 15 per day
External cladding panel	5 to 6 per day (approx. 100m <sup>2</sup> per day)

**Table 1:** Indicative installation (based on one erection crew/one crane).

## Economy on site

Using precast elements reduces requirements for formwork and access scaffolding. This saves cost through reduced resources and by shortening the programme, and there is less reliance on following trades.

Depending on the type of element used, there may be no temporary propping or minimal propping required. This increases productivity and reduces the temporary works. The need for scaffolding may be avoided.

There are also benefits in using precast elements for specific areas of the building such as stairs, where safe access is immediately available once installed, or floors with immediate safe, weather durable working platforms.

On site storage is not necessary as precast elements can be stored at the factory and delivered just-in-time and ready to install straight from the lorry, particularly beneficial for tight urban developments.

## Improved health and safety on site

Offsite construction can reduce the level of activity on site and this can enhance safety. Uniquely concrete floors once installed, provide a safe, non-combustible, and weather durable working platform for site operatives, and precast concrete stairs offer the means of safe and easy access between floors.

## Reduction of waste on site

Precast concrete is manufactured to specific dimensions with no further trimming or cutting required, and can include cast in services or the channels for services. This avoids drilling and alterations on site. Just-in-time delivery and the robustness of concrete both enable minimal packaging needed during delivery and, therefore, its associated waste on site. If, in the unlikely event that, an element is accidentally damaged beyond sensible use, it could be taken back by the manufacturer for recycling.

## Fire resistance

Concrete is completely non-combustible (classified as an A1 fire resistant material under EN 13501-1), and has a slow rate of heat transfer, making it a highly effective barrier to the spread of fire during construction and in use. Designers are more easily able to discharge their CDM responsibilities related to fire risk if designing in concrete. This is particularly beneficial for party walls and buildings located close to site boundaries.

## Resilience to weather

Precast concrete aids efficiency of construction as bad weather will not delay production. Precast products arrive on site ready to use, often requiring no further treatment. The concrete itself is not susceptible to adverse weather conditions, i.e. does not rust, rot or warp in the damp, and is resilient against damage from wind and wind-borne objects. The inherent resilience of concrete reduces the risk of damage during delivery and on site during construction.

## Whole building savings

Frame choice and design can have an influential role in the performance of the whole building, and importantly, also have an impact on the people using it.

Using concrete as structure can reduce the amount of other materials required in construction. These include the avoidance of fire encasements, additional linings to meet fire and sound performance requirements. For example, a concrete wall can provide both stability, load bearing support and enclosure without the need for additional coatings or linings. For more information refer to The Concrete Centre's publication *Material Efficiency*.

Many issues should be considered when choosing the optimum structural solution to give best value for construction and operational stages. Inherent benefits – fire resistance, sound insulation and fabric energy storage (thermal mass) – mean that concrete buildings tend to have lower operating costs and lower maintenance requirements. This is also important when considering the environmental performance of a building.

# Performance in use

**Precast concrete combines the benefits of factory production with the inherent performance benefits of concrete. Performance in use credentials related to fire, durability and acoustics – together with the ability to use concrete as a finish and avoid the need for additional materials – enables project teams to meet and exceed client's expectations on sustainability performance using concrete.**

## Fire resistance

Concrete has inherent fire resistance - it does not burn and has low heat conductivity. Unlike other structural materials, concrete does not need additional treatments to achieve fire performance standards. Concrete achieves the best fire rating possible under European fire standards. Concrete maintains structural capacity longer than other materials in a fire.

Following recent fires, at Grenfell and Barking, there are now restrictions on using combustible materials for cladding and balconies. Concrete is non-combustible and continues to be permitted, even for high-risk residential buildings. Further information can be found in *Concrete and Fire Safety* by The Concrete Centre.

## Thermal mass and energy efficiency

A concrete structure has a high thermal mass. By reducing the building's heating and cooling energy load, and potentially avoiding the need for air conditioning, operational and maintenance carbon emissions and energy costs are reduced.

Exposed concrete, typically floor soffits, allows the fabric energy storage to regulate temperature swings. The high quality finish of precast concrete, whether exposed or painted, is an excellent means of providing the internal surfaces of concrete necessary to optimise the use of thermal mass. For more information, download *Thermal Mass Explained* from The Concrete Centre.

Manchester Metropolitan University Business School utilised a precast concrete system which included pre-installed pipework for services. Image courtesy of Feilden Clegg Bradley Architects.

## Thermal mass and reducing overheating

The thermal mass, inherent in concrete, together with adequate ventilation, provides a simple and effective means to provide thermal comfort and reduce overheating – a growing health and wellbeing issue, particularly among the elderly.

The combined benefit of thermal mass and night ventilation is accounted for in the Standard Assessment Procedure (SAP) overheating check for new dwellings, which gives a reduction in the peak internal temperature of up to 3.5°C when comparing lightweight and heavyweight construction.

For more information, download *Overheating guidance* from The Concrete Centre.

## Vibration control

Concrete meets the vibration criteria for most buildings without any change to the normal design. For uses with more stringent requirements such as laboratories or hospitals, additional measures may be needed, but these are significantly less than for other materials.

A study by Pavic et al [1] demonstrated that the vibration criteria for a laboratory with a grid of 6.6m x 7.3m could be met with a 400mm deep hollowcore unit and screed. Less onerous hospital vibration criteria was shown to be met with an even shallower unit.

Information on how to design structures to control vibration can be found in The Concrete Centre's publication *A Design Guide for the Footfall Induced Vibration of Structures*.

[1] Pavic A, Reynolds P, Prichard S and Lovell, M, Evaluation of mathematical models for predicting walking-induced vibrations of high-frequency floors, International Journal of Structural Stability and Dynamics Vol. 3, No. 1, 107-130, 2003.



## Flood resistance

Guidance for designers for flood resistant and resilient construction (BS 85500:2015), recommends the use of a concrete structure. Concrete retains its structural integrity in flood conditions and precast elements can be designed to limit water ingress through the joints. Concrete has the strength to resist very high loads to keep water at bay and is robust enough to withstand impact from debris.

## Thermal performance

Thermal mass is not the only means by which precast concrete can provide excellent thermal performance. Its smooth surfaces offers an excellent solid backing for placing insulation against, either on site or in the factory, thereby reducing the risk of thermal bypass. Insulated concrete sandwich panels provide a slender, high performance wall construction that can combine structure, surface finish and thermal performance.

Low conductivity connectors and rigid insulation reduces thermal bridging and the concrete provides continuous protection to the insulation from damage during construction and occupation.

## Acoustic performance

Precast components can meet the highest standards for resistance to sound transmission. Robust Details, under Part E of the Building Regulations, includes building examples using precast concrete.

**Project Capella, Cambridge.** A key challenge with hospital projects is to construct with minimal disruption to surrounding buildings. A hybrid DfMA (design for manufacture and assembly) process was used to deliver this laboratory building by PCE Ltd.

## Air-tightness

Part L of the Building Regulations requires pre-completion pressure testing. Precast cladding improves air-tightness because the large units reduce the number of joints. These joints are also easier to seal because the edges of the units are typically flat, formed surfaces.

## Durability and low maintenance

Concrete is a hard wearing material which offers long lasting structural performance without the need of additional finishes and little maintenance. It is particularly useful for areas vulnerable to high levels of wear and tear or difficult to access. This durable finish offers additional lifecycle cost savings through reduction in maintenance (and replacement) that would be required for other 'wearing' finishes.

## Extending in-use lifespan

Avoiding the need for new build by reusing a building's frame and foundations is an increasingly pragmatic way to cut redevelopment costs and improve whole-life CO<sub>2</sub> performance. The decision not to demolish and rebuild is also proving popular in the commercial environment where the durability of concrete frame buildings has seen a significant number undergoing a complete renovation.

### Precast concrete supply chain benefits include:

- Well-established industry
- Experienced teams
- Local manufacture
- Complete service through design, manufacture and installation
- Responsibly sourced



# Sustainability and precast concrete

There are many ways in which precast concrete can be used as part of sustainable buildings. In this section the focus is on the sustainable benefits that are available due to the manufacture and supply chain, including low waste production, lower carbon concrete, responsible sourcing and the use of recycled content. Designers can influence the sustainability credentials of the material. More information is available in The Concrete Centre guide *Specifying Sustainable Concrete*.

## Sustainability charter

The UK precast sector is represented by the trade body British Precast. As part of membership of British Precast, all manufacturers commit to a sustainability charter which includes the collection of performance data and the annual publication of performance data. This annual report *Sustainability Matters* can be downloaded from [www.britishprecast.org](http://www.britishprecast.org). The precast concrete sector is also part of the wider UK Concrete Industry Sustainable Construction Strategy. For more information visit [www.sustainableconcrete.org.uk](http://www.sustainableconcrete.org.uk).

## Local manufacture

Concrete is the local construction material, with production facilities throughout the UK. Although precast concrete can travel further distances than ready-mixed concrete, there is still a regional network of producers throughout the UK. Data collected by British Precast shows that an average lorry carried 18.32 tonnes of precast product per delivery to site. The average delivery distance in 2018 was 102.2 km. This is in comparison with alternative materials, such as timber and structural steel, that are usually imported, increasing the carbon emissions associated with transport.

## Environmental management systems

90% of precast concrete produced in the UK (by British Precast members) is covered by an ISO 14001 environmental management systems. Quality and Environmental management systems include commitments to address environmental aspects and impacts but also a willingness to embrace new technologies and innovation as part of continuous improvement.

**BREEAM 'Outstanding' UCL Student Centre, London utilised offsite precast concrete solutions in its sustainable design. Architect: Nicholas Hare Architects; Structural Engineer: Curtins. Image: Nicholas Hare Architects © Alan Williams Photography.**

## Responsibly sourced to BES 6001

The concrete industry adopted independent certification to the responsible sourcing standard BES 6001 from its launch in 2008. Constituent materials such as cement and aggregates are now 100% responsibly sourced to BES 6001 (see [www.sustainableconcrete.org.uk](http://www.sustainableconcrete.org.uk)). The latest published data from British Precast shows that 76% of all concrete produced by their members is certified to responsible sourcing standard BES 6001. This standard gives confidence of the ethical sourcing and traceability of concrete products, another advantage of a UK supply chain.

## Quality control

Virtually all precast concrete produced in the UK is covered by an ISO 9001 quality management system. Precast products are produced in a factory environment allowing high levels of quality control and uniformity. Precast factories have dedicated material suppliers ensuring there is consistency of supply, particularly important for architectural precast where uniformity of colour and texture are critical. A consistent product is facilitated by the multiple reuse of quality moulds.

## Health & safety

As with sustainability, all members of British Precast commit to a health and safety charter. Operating safely is a key priority for the precast industry and offsite production means that more work takes place in factory-controlled conditions.

Precast concrete elements must always be erected/installed using the manufacturers' recommended installation details, equipment and instructions, and in accordance with all relevant health and safety regulations, relevant codes of practice and national and European regulations, including the Construction (Design and Management) Regulations 2015. Reference should be made to published codes of practice, for example Precast Flooring Federation's guidance on safe installation at [www.precastfloors.info](http://www.precastfloors.info).





## Low carbon production

The precast concrete sector, and the UK concrete industry, has targets to reduce the carbon emissions of production, or embedded carbon, from its products. The manufacturing carbon emissions of the UK precast concrete sector has dropped by 30% since 2012 and 43% since 2008.

Factory carbon emissions equate to 10kgCO<sub>2</sub>/t. The rapid reductions over the last decade have been achieved from efficiency improvements and the use of low carbon energy switching from fossil fuels.

## Low carbon concrete

Ground granulated blast-furnace slag (GGBS), fly ash and powdered limestone can reduce the carbon footprint of concrete. In the precast concrete sector, over 20% of cement has been replaced with alternative cementitious materials.

The precast sector has also published a number of generic Environmental Product Declarations (EPD) and 70% of British Precast members have their products covered by valid third party certified EPDs. These EPDs support the use of Building Information Modelling (BIM) and manufacturers can also provide further information to support BIM.

## Material efficient production

The manufacturing process for precast concrete products is becoming more efficient with a 40% reduction in water use and a 95% reduction in waste to landfill since 2008, now down to 0.25 kg/t. As well as ensuring that any production concrete waste is recycled on site, precast concrete also utilises secondary and recycled aggregates – with this representing around a fifth of the aggregates used.

Concrete waste is minimised during manufacture due to efficient processes in the factory and the control of materials. As precast concrete elements and systems are typically made to order this reduces waste in production. Post-production, the robustness of the product reduces the risk of waste through damage or degradation in transport or storage.

Centreport, London demonstrates the durability of precast concrete, with its iconic cladding simply needing a clean as part of its transformation, after 50 years of use. © Alamy.

## Circular economy and whole-life performance

Concrete is durable and structures using concrete can be designed to have a long service life. This allows greater potential for extending the useful life of the structure and building or element reuse, rather than demolition and replacement. When eventually demolished, precast units have the potential to be reused, or crushed to create recycled aggregate.

The intrinsic properties of concrete mean that fire and flood resilience, acoustic isolation, longevity and thermal mass are all inherent in concrete buildings. Concrete's performance enables material efficient and energy efficient design.

Concrete has the unique advantage in offering 'more for less' construction solutions, where more slender wall and floor build-ups are possible. High quality finishes can be left exposed or simply painted, avoiding the additional environmental footprint of extra linings. High performance in terms of fire and acoustic isolation often avoid the need for additional finishes to meet building standards. For more information download *Material Efficiency*.

If designed appropriately, the benefits of concrete's thermal mass can add to the energy efficiency of the building by reducing both heating and cooling loads and therefore running costs. This can contribute to a significant reduction in carbon emissions over the life of the building. For more information, download *Whole-Life in Carbon Buildings* by The Concrete Centre.

## Sustainable Concrete

Concrete is a local material, supporting local economies and reducing emissions associated with transportation.

- 99.9% of aggregates used in the UK are sourced in the UK (80% are used within 30 miles of extraction)
- Primary aggregates are predominantly UK-sourced, their extraction is tightly regulated and adverse environmental impacts are minimised
- 100% of UK manufactured cement is responsibly sourced and certified to BES 6001
- Concrete can use by-products from other industries, including fly ash and ground granulated blast furnace slag (ggbfs)
- UK manufactured reinforcing steel is made from 100 per cent UK-sourced recycled scrap
- Concrete is 100 per cent recyclable



# Precast concrete cladding

Precast concrete cladding offers opportunities to create high quality facades requiring little maintenance. It provides a weatherproof envelope, while fulfilling architectural, structural and other requirements in terms of fire resistance, thermal performance and sound insulation. Panels can be delivered with windows, insulation, and balcony connections pre-fitted in the factory thus further accelerating the construction programme.

## Architectural precast

A wide variety of low maintenance and extremely durable surfaces are available, including self-finished options and a range of other facing materials. The options for architectural expression are almost unlimited, with opportunity to create bespoke mass, form and pattern from a large palette of colour and texture, with incorporation of details such as cornices and sills.

### Self-finished surfaces

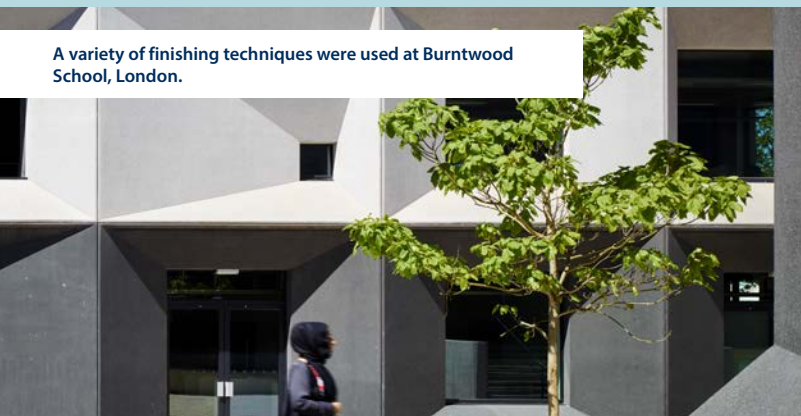
Often referred to as reconstituted stone, or 'Recon', these panels use carefully selected materials to create an appearance intended to mimic a particular natural stone. The surfaces produced may be highly polished, or textured using a range surface treatments including acid etching, abrasive blasting, surface retarding and grinding. Formliners can be used to create further pattern and texture.

Self-finished precast concrete cladding panels are typically no more than 150mm thick and their size is limited only by site craneage and/or transportation constraints. These are frequently installed by use of low-loader trailers which allow storey-height panels to be delivered ready for off-loading and hoisting directly into place on the structure.

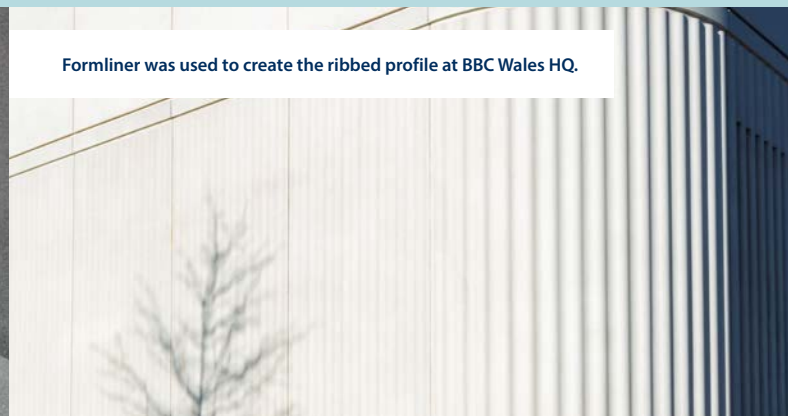
### Other facing materials

Concrete cladding can be faced in other materials, cast in place during manufacture, providing cost-effective and material efficient high-quality facades. Typical factory finishes include bricks, brick slips and tiles, terracotta, and stone facings such as granite, limestone and slate (used in thicknesses from 30mm to 50mm depending upon the stone). Panels may also include a mix of applied and self-finishes that on-site would demand separate trades or skills with attendant sequencing and management.

A variety of finishing techniques were used at Burntwood School, London.



Formliner was used to create the ribbed profile at BBC Wales HQ.



The brick-faced cladding features a raised diamond pattern at Buckingham Green, London.



An exposed aggregate finish was created by applying a retarder to the moulds during the production stage at V&A Dundee.



## Types of precast cladding

Precast concrete panels can be designed to be structurally loadbearing or non-loadbearing. The arrangement of the precast concrete panels is primarily influenced by the geometry and number of apertures or openings within the facade. Common arrangements are illustrated in figure 1.

**Loadbearing cladding systems** – Typically consist of an inner structural panel, an insulation layer and an outer non-structural panel. This type of cladding is mostly used instead of perimeter beams and columns, to transfer the vertical forces down the structure to the ground.

The most common type of loadbearing cladding system is sandwich panels. The structural concrete inner layer is designed to withstand the applied loadings from the floor and the structure above. The thinner outer layer acts as a weather and airtight barrier and provides the desired architectural finish for the building envelope. An insulation layer is sandwiched between the inner and outer layers to provide the required U-value. The three layers are linked by connectors to ensure low thermal conductivity (figure 2).

Loadbearing sandwich panels transfer the load from their self-weight (and the panels above) and the dead and imposed loads of the supported floors on to the foundation or supporting structure below. Additionally, these walls have to withstand lateral wind forces on the face of the cladding panels. Vertical continuity such as steel dowel bars or couplers are usually provided between cladding panels to resist the lateral forces applied. The structural layer of loadbearing cladding panels are also tied back to the floor using U-bars and horizontal tie bars.

**Non-loadbearing cladding systems** – Non-loadbearing cladding systems, such as solid or single-leaf precast cladding, have no structural function. These precast cladding panels act as weather and air barriers and provide the desired architectural finish to the building envelope.

Non-loadbearing panels are either stacked off the foundations or ground beams, or supported by the main frame on or near column positions in order to avoid excessive mid-span deflections in slabs/beams. When stacked, loads are transferred vertically through the panels down to ground through dowelled connections (figure 3). When supported, stainless steel brackets mounted on to the base of the panel transfer the vertical and lateral forces to the floor slabs – or secondary structure (figure 4).

**Restraint** – Restraint fixings are designed to hold panels back to the structure and transfer all horizontal forces (such as wind loading) to the structure. They should be designed to be adjustable to accommodate any differential movement between the structure and the cladding. Tolerances in the main structure and the manufacture of the precast units require particular attention. Four restraints are commonly provided in average sized panels, typically at the corners of the panels (figure 5).

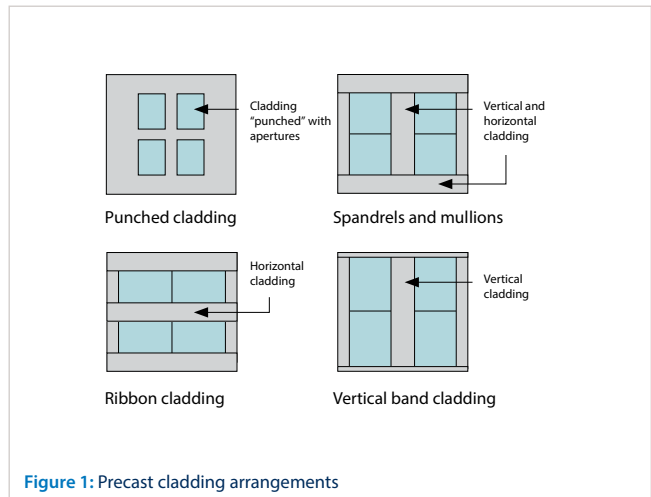


Figure 1: Precast cladding arrangements

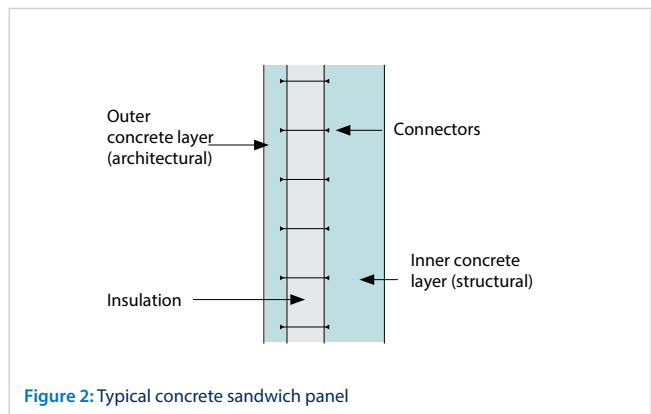


Figure 2: Typical concrete sandwich panel

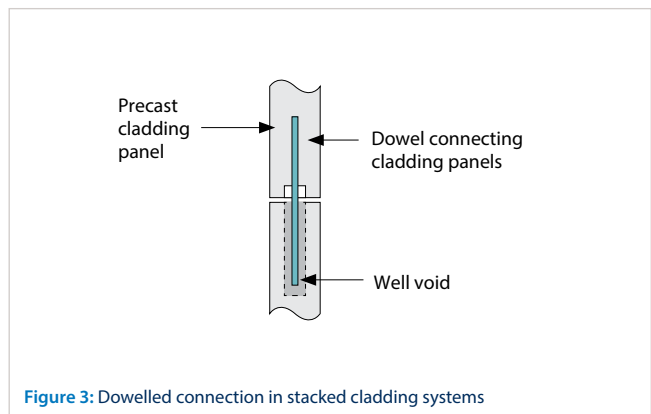


Figure 3: Dowelled connection in stacked cladding systems

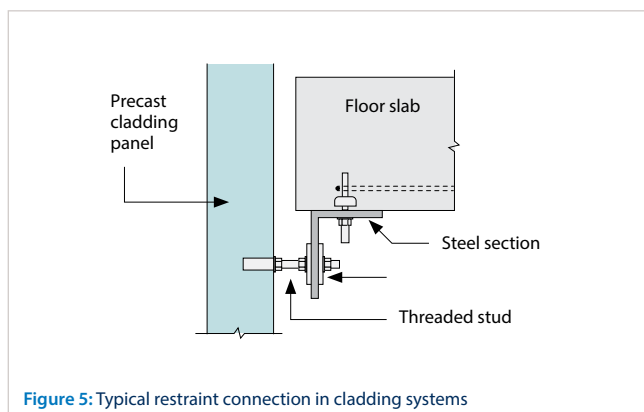


Figure 5: Typical restraint connection in cladding systems

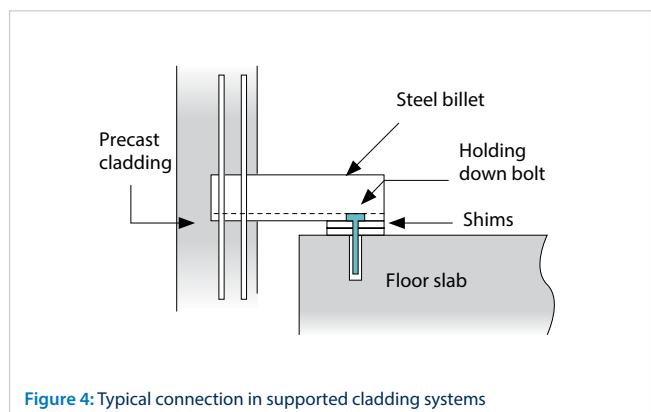


Figure 4: Typical connection in supported cladding systems

## One Station Square, Cambridge

Acid-etched cladding | Precast cladding supplier: DECOMO

**One Station Square, a six-storey BREEAM 'Excellent' mixed-use building utilised a precast concrete facade.**

The facade's design was driven by the need to minimise solar gain whilst maintaining excellent levels of beneficial daylight along with a view out. The final facade solution was selected to achieve these objectives whilst creating a high quality design. The design includes high performance glazing and external solar shading.

Precast concrete was chosen due to its ability to create the facade profiles and detailing required in the design which gave the building a natural and solid look. Larger precast pieces were manufactured offsite to reduce the programme for onsite works and provide a cost-effective solution to achieve the expression of solidity and scale.

The sandwich panels on the ground floor cladding reduced the need for further trades on site. The horizontal solar shading fins to the south and north facade are manufactured using extruded aluminium profiles matched in the colour of the precast concrete.



## Cartwright Gardens, London

Brick-faced cladding | Precast cladding supplier: Thorp Precast

**Located in the heart of Bloomsbury, Central London, Cartwright Gardens is a nine-storey development of high quality, affordable student accommodation.**

The brick-faced cladding façade is made up of approximately 1,100 precast concrete panels incorporating four brick types across the entire scheme. All panels were supplied to site fully finished and factory-pointed on specially adapted trailers prior to installation on site. Originally the facade was designed for traditional hand set brickwork, so one of the key criteria for adopting a precast construction approach was the need to conceal panel joints, maintaining a nominal 10mm joint between panels.

In order to minimise the number of panel joints it was decided to manufacture the vertical emphasis corbelled brickwork mullion units as one-piece three storey high units in the form of elongated Ts weighing 12 tonnes.

The main brick clad facade has all the architectural integrity and beauty of a hand-set masonry building built by craftsmen, made from high quality materials and defined by simple crisp detailing.



# Crosswall construction

**Crosswall is a modern and effective method of construction that employs factory-produced, precision engineered, concrete components. It uses precast floors and load-bearing walls, and is ideal for buildings of a cellular nature, for example hotels, student accommodation, housing and apartments.**

This method of construction has been developed to facilitate swift construction and is adaptable to suit different building types. 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 typically of 200 - 250mm, helping to maintain a high degree of sound insulation between adjacent dwellings and rooms.

Crosswall construction provides:

- High quality finishes – often it is only necessary to have a skim coat or sprayed/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 can exceed the minimum acoustic requirements of Part E, by a significant margin.

Frequently fully fitted out bathroom pods are specified and these can be easily integrated into the structure. Crosswall construction normally includes staircases and core walls as part of the precast system, allowing safe and easy access to all floors as the construction progresses. The cost savings from these and other benefits should be fully considered when comparing the costs with alternative structures.

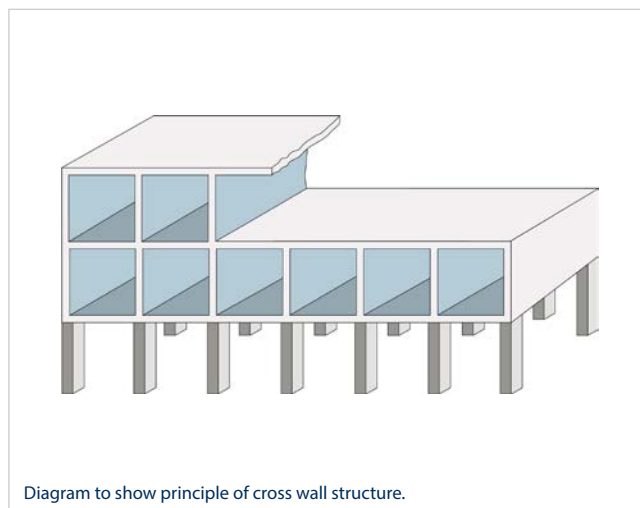


Diagram to show principle of cross wall structure.

## Concrete for crosswall

To make efficient use of the moulds, it is important to strike the elements in the factory as quickly as possible. For this reason, precast concrete manufacturers prefer to use higher-strength concrete - the typical class of concrete used for crosswall panels is C35/45. Self-compacting concrete is also increasingly used in the precast factory to reduce the use of vibrators to compact the concrete. This improves working conditions as it reduces a noisy operation within an enclosed environment.

## ✓ Crosswall construction - Checklist

### Markets:

- ✓ Residential
- ✓ Prisons
- ✓ Housing
- ✓ Student accommodation
- ✓ Hotel
- ✓ Hostel

### Benefits:

- ✓ Speed
- ✓ Robustness
- ✓ Reduced risk
- ✓ Sound control
- ✓ Thermal mass
- ✓ Minimal deliveries
- ✓ Fire resistance
- ✓ Durability of finishes
- ✓ Accuracy for prefabricated elements
- ✓ Safety

## Crosswall construction continued...

### Building with crosswall

Crosswall buildings are quick to erect, offering the client a rapid room occupancy programme. As an indication, six to eight rooms can be erected in a day and the lead time will be 12 weeks.

Generally, the walls are sized to be as thin as possible to increase the net floor area. There may be occasions when a thicker wall is required, such as in tall buildings where there are high compressive loads, or adjacent to long floor spans where there are high bending moments due to the notional eccentricity of the wall.

Wall thicknesses are usually in the range of 150 to 175mm, although this should be checked with the precast manufacturer as their proprietary product may have a specific minimum wall thickness. Where the walls are party walls a thickness of 180 mm is generally used, for acoustic reasons. The walls are normally reinforced with two layers of mesh reinforcement. Where a wall element has a lot of openings or the openings are close to the end of the wall, then care should be taken to ensure that the unit has sufficient strength during lifting operations.

The panels are delivered to site in a “just-in-time” operation and are lifted directly from the lorry into their final position. They must then be temporarily propped until the floor above has been placed and grouted. Usually push-pull props are used and these are fixed to wall panels and floor units via cast-in fixings. These are made good once the props are removed. Edge protection can be attached to the panels before erection to provide a safe working platform immediately.

Units are tied together using a series of hidden joints that are grouted as the works progress. To avoid using formwork and to avoid unsightly grout runs thixotropic grout can be used, which is mechanically mixed to ensure consistency and strength and then pumped into place. The minimum number of joints enables rapid erection on site, with the added visual benefit that all the structural joints are hidden. The joints include steel ties to ensure robustness in the system. These ties are always inspected prior to grouting so that full fixity is maintained.

Typically as soon as the ceiling units at roof level are erected, 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 programme.

Exterior walls can be constructed as fully finished sandwich panels, which removes the need for scaffolding. The wall finishes can include brick, concrete or render, giving a wide range of options to choose from.

Structures up to and including 22 storeys have been completed in the UK using crosswall construction.



**Selly Oak student accommodation, Birmingham. The client has future proofed the building by leaving out every other solid wall so that it could potentially be changed from student accommodation to residential in the future by removing these walls. Image courtesy of FP McCann.**

## Marriott Hotel, Manchester

### Crosswall case study



**This new 4-star AC Marriott hotel in Manchester employed a complete precast concrete frame solution for the nine-storey, 172-bedroom project.**



In total, some 1,000 individual units make up the precast structural frame including 250 solid floor slabs, 300 crosswalls and 251 brick-faced facade panels. Also included in the build are precast stairs and landings and stair and lift cores.

The units are delivered on a 'just-in time' basis from the precast-supplier's local depot. The build-team erected an entire floor every two weeks, and completed works which also included the decorative cladding to the ground floor podium slab and columns. The operation ensures that the components are installed with minimal risk of damage.

The supporting structure of the building comprises precast crosswall units 180mm thick and precast concrete solid floors 200mm thick with a localised pod recess. The crosswall units support the fixing of the external brick facade panels. The architectural panels are of a 'sandwich' construction with

the majority being 695mm thick, with the outer 80mm thick facade being of a detailed light grey brick design. The insulation layer sits between the inner and outer concrete faces. The facade panels have been designed to accommodate the pre-installed 0.15 U value windows.

All precast wall and floor sections were designed for ease of build, linking together with hidden tie rods. Joints are finished with a high-strength non-shrink grout.

Both the structural and architectural facade teams at FP McCann worked closely with the project architects, Simpson Haugh and Partners, to ensure all aspects of the build meets the exacting specification standards.

# Precast concrete floors

The use of precast concrete floors is well established in a variety of building types.

## 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/m<sup>2</sup> 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.

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 onsite.

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.

## Solid reinforced precast floors

Solid reinforced concrete floors are typically 250mm thick and require no screed to finish either the floor or the underlying soffit. The units can be included within the structure with the precast cross walls. Units of 4-6m are available, with longer spans possible if the slabs are lightly pre-stressed.

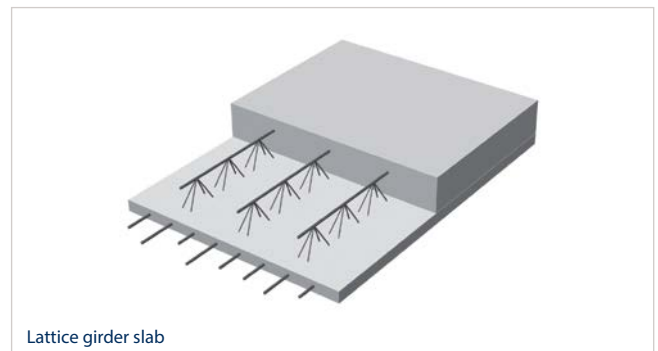
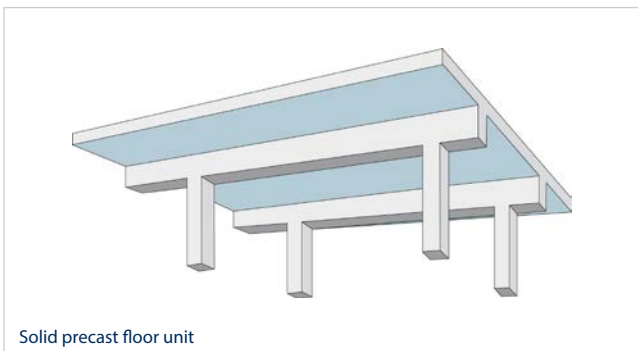
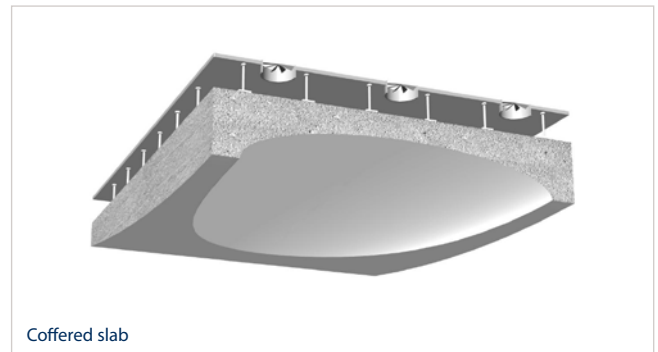
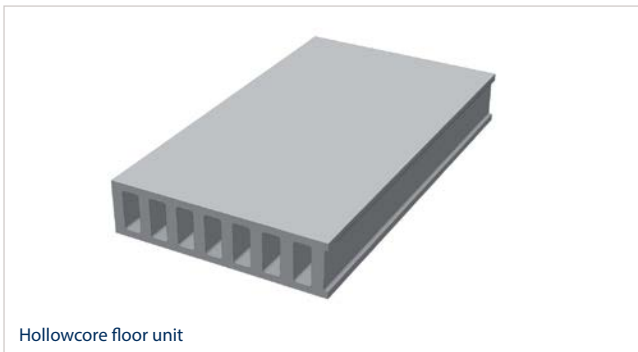
## Coffered floor units

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. The units are often bespoke, but, with careful planning the moulds can be reused many times, making them cost effective. The units are designed to be exposed and can carry conduits for services.

## Lattice girder slabs

Lattice girder units, usually 2400mm wide, comprise a thin precast concrete 'biscuit' into which a lattice girder made of steel reinforcement is cast. 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.

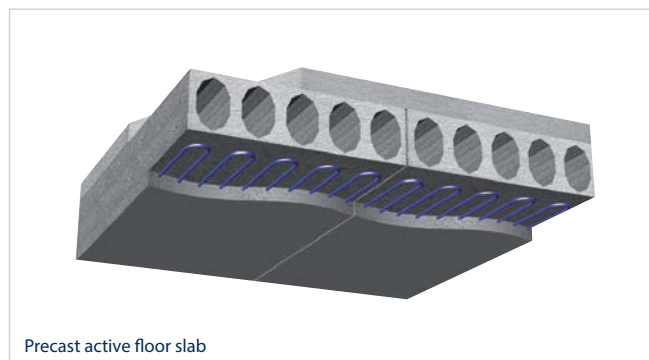
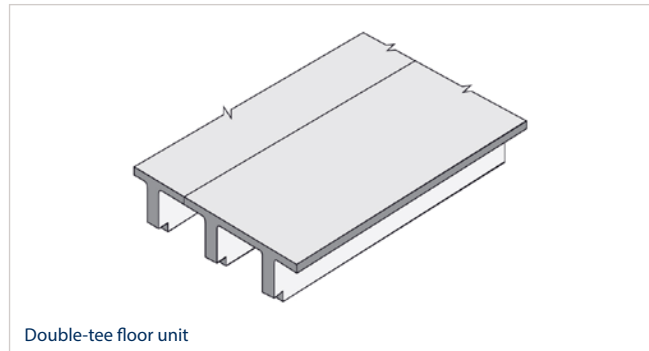
Double-tee floor units are produced in standard widths of 2400mm. They offer greater structural capacity at longer spans than hollowcore or lattice girder but often require a deeper floor zone.

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 channelled 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.



At Roehampton Library a precast concrete frame along with hybrid precast/in-situ concrete flooring slabs were used to create the frame. The amount of repetition suited the process, the project and the site. The cores were erected in five weeks and the frame took 13 weeks to install. Image courtesy of British Precast.



# Hybrid concrete construction

**Hybrid concrete construction uses precast and in-situ concrete together, combining the benefits of both to give a robust, durable construction which is fast on site, with an excellent finish.**

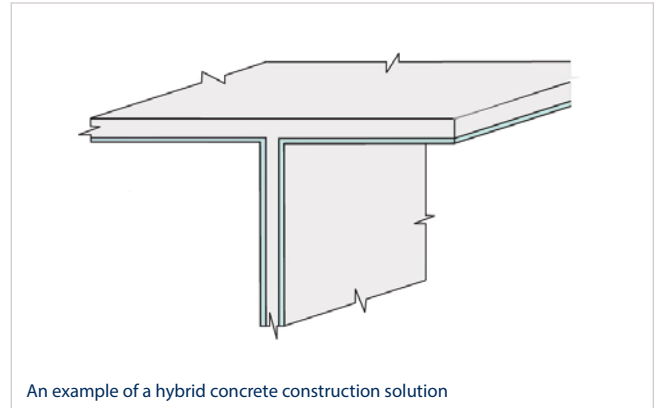
Hybrid concrete construction (HCC) can be designed as a normal reinforced concrete building, with full composite action between in-situ and precast elements. The construction phase needs to be designed, as one of the load cases is normally precast concrete elements supporting the weight of wet in-situ concrete.

An additional stage may be considered if de-propping happens before the in-situ concrete develops its design strength. Precast elements should be repetitive, as mould costs are a significant factor. For non-standard areas, in-situ concrete could be used instead, or layout altered to allow a standard form.

Full coordination of the services through the building needs to take place early in the design process, as they need to be incorporated into precast elements. Also items frequently sorted out on site must be resolved before the project gets to site, allowing faster and safer construction. The design should be fully coordinated prior to the precast elements being manufactured if coordination affects the precast elements.

Since a standardised layout allows the full benefits of both precast and cast in-situ concrete to be realised, use of HCC should be considered from design concept stage. A lead frame contractor (usually a concrete frame contractor) should be appointed early together with specialist supplier(s) of the precast elements. This will provide the best advice to the design team and hence the best finished building.

For further guidance refer to The Concrete Centre publication *Design of Hybrid Concrete Buildings*.



An example of a hybrid concrete construction solution

## 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.

## ✓ Hybrid concrete construction - Checklist

### Markets:

- ✓ All: particularly suited to offices – bespoke and speculative
- ✓ Schools
  - ✓ Sports stadia
  - ✓ Car parks
  - ✓ Retail

### Benefits:

- ✓ Cost
  - ✓ Speed
  - ✓ Sound control
  - ✓ Safety
- ✓ Robustness
  - ✓ Thermal mass
  - ✓ Durability of finishes
- ✓ Fire resistance
  - ✓ High quality finishes
  - ✓ Accuracy for prefabricated elements

## Burlington Gate, London

### Hybrid concrete case study



**Burlington Gate is a stylish new development of 42 luxury apartments in the exclusive London neighbourhood of Mayfair. Precast columns, spandrel panels and permanent formwork played a key role in both the structural design and aesthetic considerations of the project.**

The nine-storey scheme sits between Old Burlington Street and Cork Street, and comprises two separate buildings separated by an internal courtyard. The project involved transforming an existing commercial building into 65,000 sq ft of residential accommodation, along with 25,000 sq ft of retail spaces on the lower floors, and creation of a new arcade, connecting the two streets.

The choice of precast components was driven by the architect's desire for high quality finishes on the exposed concrete. The vertical columns, and the horizontal spandrel panels which span between the columns, have a black acid-etched finish, and these precast elements are exposed on both elevations of the building.

While the vertical columns are structural, the spandrels are decorative. The floor slabs were cast in situ, using permanent formwork units, which have a black finish. Together with the columns, the spandrels and the formwork create the illusion that the structural frame was created in one seamless pour.

The vertical columns are two-storey height and mostly seven metres long, apart from on the upper four floors of the street elevations, where the facade is inclined. The raking columns on these levels are nine metres in length, and again two storeys high.

Bespoke steel plates for the column and spandrel panel connections back to the floor slabs were fitted and steel nodes for external cross bracing were added on the internal courtyard elevations.

A high strength concrete mix was developed for the precast components. It was a combination of crushed black basalt coarse and fine aggregates, stent with a high mica content, a CEM II/B-V fly ash, plus ordinary Portland cement.

On the street elevations, the grid created by the precast columns and spandrels is infilled with stainless steel-framed windows interspersed with solid panels of handmade bricks, which match the dark finish of the exposed concrete.



Precast concrete stairs at BBC HQ Building, London. Photographer: Grant Smith.

## Other precast concrete elements

**Concrete precast construction elements can be used to speed up construction and enhance quality. Inherently durable and non-combustible they can be provided pre-coordinated, with integrated service where required, and without the need for additional linings or coating to meet sound, aesthetic or maintenance requirements.**

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.

### 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 in the factory, 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 concrete 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.

### 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 13 of this guide, is the most common form of solid precast walling.

Core walls can also be supplied as modular precast, fabricated as four sides in a box and stitched together on site, providing excellent rigidity and stability.

## 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, but adjustable, mould sizes. The greater the number of identical units required, the lower the cost.

## 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 weatherproofing 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

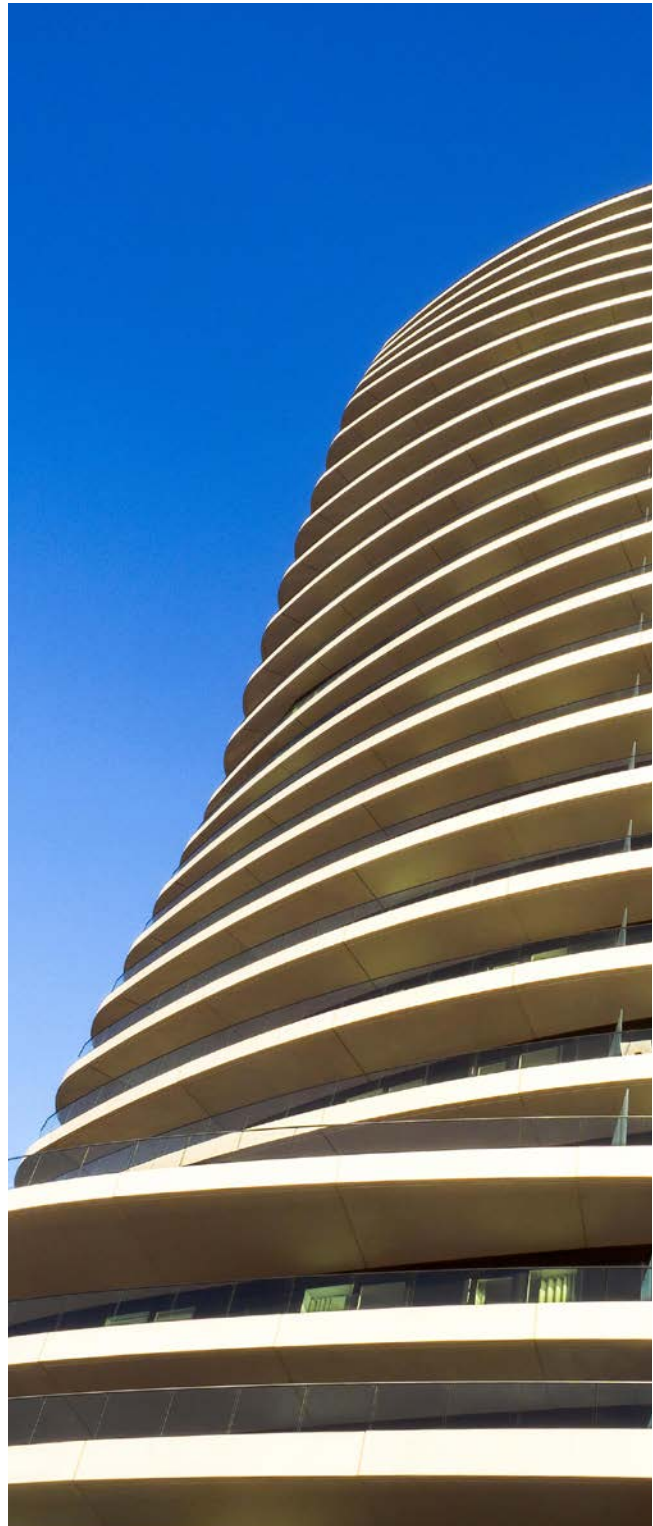
Precast concrete is used extensively for terracing in grandstands, stadia and auditoria. Precast concrete provides a strong, durable and versatile terracing unit that is quick and easy to install. Importantly, it can easily be designed to meet the vibration criteria for sports grounds.

There is a large range of associated products including stairs, vomitories, steps, raking beams and columns that will enable the structure, as well as terracing, to be constructed in precast concrete if required.

## 3D/volumetric structure

Concrete structure can be supplied in a volumetric form, either as two planes (floor and wall) or more commonly as a four-sided box, with or without the floor or roof, depending on the intended use. They are particularly beneficial for stair and lift cores or prison accommodation but with potential for further applications. 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 can be fitted out at the factory with windows, vents, bathroom and other fittings, plus plumbing and electrical fixtures and fittings.



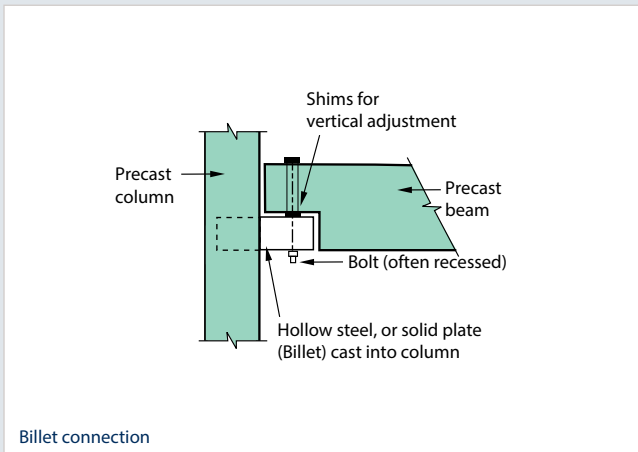
Lombard Wharf, Battersea features precast concrete wrap-around balconies which provided an elegant and robust solution © Alamy.

Architect: Patel Taylor; Structural engineer: O'Connor Sutton Cronin; Precast concrete: Techrete.

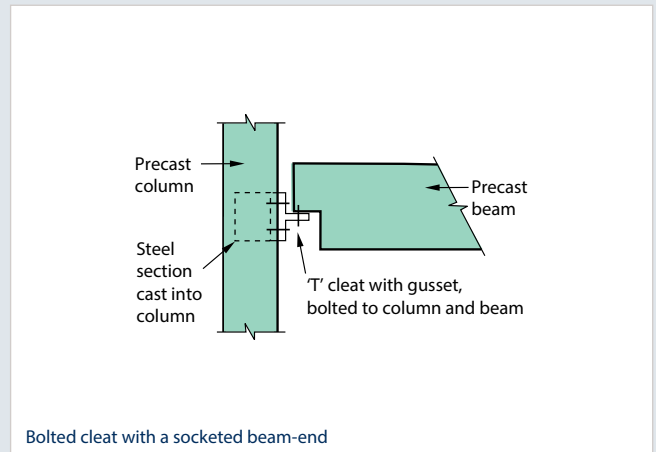
# Joints and connections

There are a number of different methods for connecting precast concrete elements.

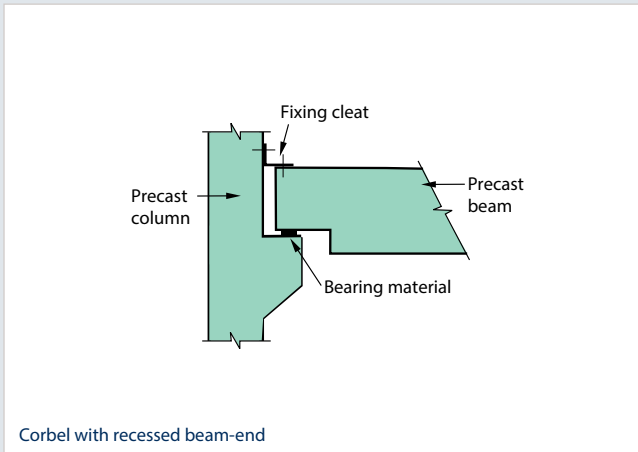
Joints transmit forces between the structural elements, giving the necessary strength and robustness to the structure. The joint must also be capable of withstanding abnormal loads caused by fire, impact, explosion or subsidence. Precast manufacturers have established preferred connections methods to meet regulatory requirements, such as avoiding progressive collapse. They have also evolved details to facilitate efficient manufacture and installation, and can collaborate with design teams to develop project specific requirements details.



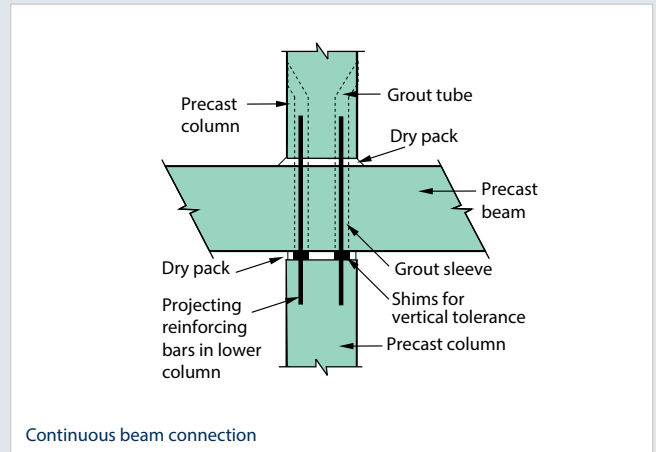
Billet connection



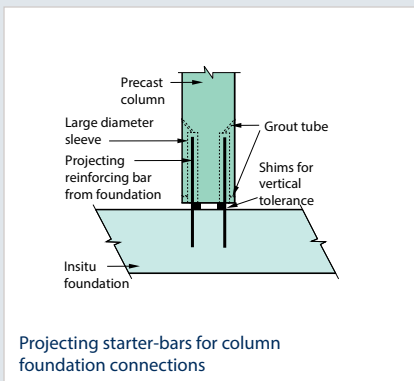
Bolted cleat with a socketed beam-end



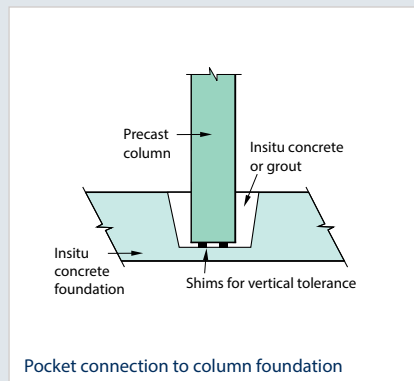
Corbel with recessed beam-end



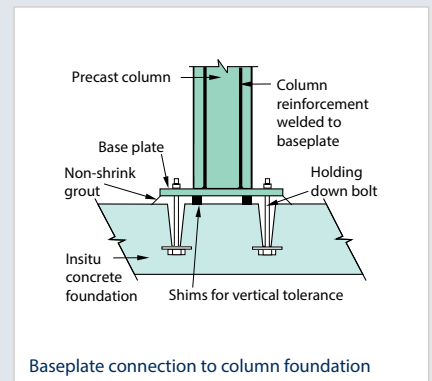
Continuous beam connection



Projecting starter-bars for column foundation connections



Pocket connection to column foundation



Baseplate connection to column foundation

# Innovative offsite housing systems

Innovative new systems are being introduced, capable of delivering a range of both modern and traditional aesthetics. As the examples on this page show, concrete continues to meet the challenges our homes face, now and in the future.



Hexxhomes

## Hexxhomes

HexxHome is a flexible architectural precast system on a hexagonal plan, for one or two-storey single homes or terraces. HexxHome is a robust and resilient product with exceptional fire and flood resistance, and acoustic performance. There are a range of flexible layout options catering for affordable or mainstream housing and even a 'grand designs' type of bespoke property.

## Slimcrete

Apart from the roof, the entire structure of this house is made from 40 precast units, based on crosswall principles, and can be erected in just two days. The external wall comprises a 100mm reinforced structural skin, with 150mm insulation – to achieve a 0.15W/m<sup>2</sup>K U-value – and a 50mm reinforced external skin. Internally, there are 150mm-deep hollowcore floor sections, 100mm reinforced internal partitions, while the stairs are also precast. The largest panel, a wall section, measures 7.5m x 3.1m and weighs 7.5 tonnes.

## I-House

I-House replaces the inner leaf of cavity walls, separating walls and internal partition walls with storey-height Celcon Elements, made from aircrete. The system can deliver a watertight shell in a week, ready for follow-on trades. It has been used for over 500 homes.



Slimcrete



I-House



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The Concrete Centre provides design guidance, seminars, courses, online resources and industry research to the design community.

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