A short history of precast materials

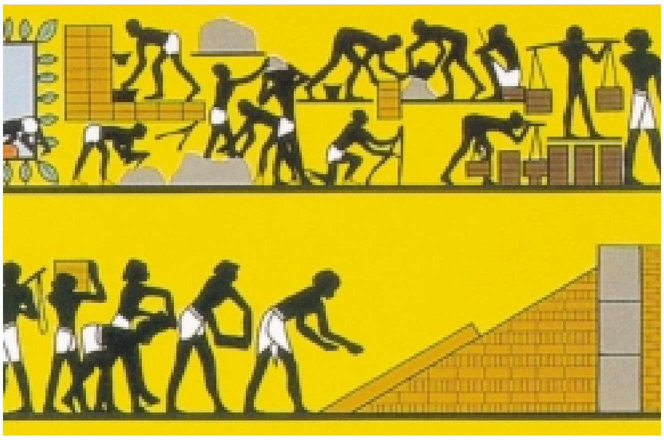
Concrete was used extensively in Roman times but only emerged as a significant building material in the late 19th century with the invention of Portland cement. Originally it was seen as a substitute for natural stone and was used extensively in precast reconstructed stone blocks. Later, as the building industry became more mechanised, larger precast units were developed which could be lifted by crane. Today's precast can combine the structural properties of concrete with the appearance of natural stone.

The beginnings of concrete

Concrete based on Portland cement is a relatively recent innovation, but early forms of binding material based on lime date back to around 7000 BC. Hydrated lime was used for the construction of Babylon, and a lime kiln dating from 2450 BC has been found. This process was known to the Egyptians – it was illustrated in a mural from Thebes, of about 2000 BC.

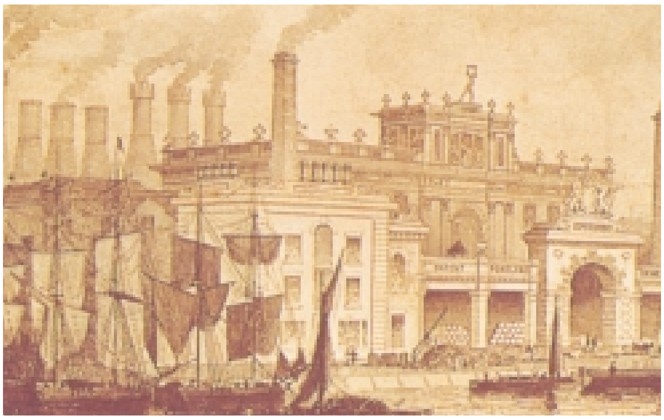
It was the Romans who really developed concrete – the very word comes from the Latin 'concretus' meaning grown together or compounded. The development was largely based on the discovery, in the second century BC, of pozzolana, a fine volcanic ash containing silica and alumina which when mixed with lime resulted in a stronger material than anything produced previously. The result was used as a mass infill material for stone and brick-faced walls and for foundations, but also for daring and innovative structural elements, particularly vaults and domes. One of the greatest achievements in concrete construction was the Pantheon in Rome, built in AD 127, whose dome, 43 metres in diameter, was formed of lightweight pumice aggregate concrete. These concrete domes and vaults were monolithic and had no lateral thrust; they acted like an inverted saucer, and supported their own dead weight, which was considerable as some were more than 2 metres thick.

One of the earliest uses of precast concrete can be traced to Roman times; a breakwater made of concrete blocks which had been allowed to harden before use was built at Naples in the reign of Caligula (AD 37- 41).



Top: an Egyptian mural shows stages in the manufacture and use of mortar and concrete.
Bottom: the Pantheon, Rome, has a domed roof of concrete with lightweight pumice aggregate

Pozzolanic cement was also combined with other materials to simulate stone – one of the first examples of this use is lintels cast from sandstone, aggregate and lime/pozzolana cement used in the repair of the Visigoth walls at Carcassonne, south-west France, in AD 1135. Although the Romans had introduced the art of concrete-making to Britain, and there is evidence that it was re-introduced by the Normans, little concrete, apart from some burnt limestone products used in



Above top: Coade stone details from the front entrance to a 18th century London terrace house
Above below: Aspdin's cement works at Gateshead, 1852, was the largest in the world

foundations and wall cores, was used in medieval and renaissance periods.

The search for a stone substitute

Interest in stone substitutes revived in the eighteenth and early nineteenth centuries. One example, Coade stone, looks remarkably like stone and its provenance was a mystery for many years. It was manufactured by Eleanor Coade and her daughter from 1769 to about 1840 in Lambeth, on the site of what is now the Festival Hall, and was used by many eminent architects (Robert Adam, Sir John Soane and James Wyatt). In fact it was not stone at all: Alison Kelly (*Mrs Coade's Stone,* Self Publishing Association, 1990) has established that it was a ceramic body, or type of stoneware. Its composition included fine sand, flint, crushed glass and crushed stoneware or 'grog'. The latter, pre-fired clay, was the vital ingredient which reduced the shrinkage rate of the pieces on firing to just over 8 per cent. (Mrs Coade advertised her product as Lithodipyra, 'stone twice fired' in Greek). Pieces were cast in plaster moulds and fired continuously for four days and nights in a 3metre long muffle kiln. Coade stone was frost-resistant and had a pleasant stone-like texture and buff or light grey colour. It was used to embellish London brick terraces with crisp stone-like details. Sir John Soane's Portman Square houses (1773–76) have Coade stone plaques, paterae and string courses. James Wyatt's Coade stone Ionic capitals at Heaton Park, Manchester, are so crisp and well-preserved that they were formerly thought to be cast metal. The Coade stone factory did not long survive the death of Miss Eleanor Coade in 1821. Its decline may also have been due to the parallel discovery of Portland cement.

The discovery of Portland cement

Many experiments were made to re-invent the binding material used by the Romans. In 1756 John Smeaton, a Leeds engineer, was commissioned to rebuild the Eddystone Lighthouse, set on a rocky outcrop in the English channel; previous timber structures had blown away in gales. He chose to use stone blocks, and tested many different limestone products in an attempt to find a mortar which might set underwater. The material he ultimately used was a combination of burnt limestone and Italian trass (a material similar to pozzolana) but his research, published in *A narrative of the Eddystone Lighthouse,* had much wider implications. In 1813 a copy was bought by young Leeds bricklayer, Joseph Aspdin. It changed his life. Inspired by Smeaton's example he continued the research and in 1824 took out a patent for the manufacture of 'Portland Cement' (so called because it resembled Portland stone in colour). Aspdin saw his invention as a method of producing a rendered

Left: cast stone was used extensively in the 1920s on commercial buildings. This is Regent Arcade, designed by Gordon Jeeves
Below left: Wellington Court, a 1930s mansion block with cast stone ashlar masonary

imitation of stone over brickwork, like the contemporary 'Roman Cement' (lime stucco and oil mastic) renderings of the time. These renders were lined out in imitation of fine-jointed ashlar and sometimes rusticated heavily or cast in moulds.

It was Aspdin's son William who recognised the real potential of the new product and refined it. He set up a cement works with beehive kilns at Rotherhithe and subsequently at Gateshead which produced the first genuine cement as we know it today. Isambard Kingdom Brunel sought his help when the Thames tunnel between Whitechapel and New Cross collapsed during construction. Aspdin claimed that his cement sealed the break in the tunnel roof, and was subsequently used (1825–45) to reline it. (The tunnel is still used to carry underground trains.)

Portland cement was used initially only in mortars and renders; in the mid-1800s it began to be mixed with aggregate to make mass concrete, usually cast in-situ. It was used in this way in the construction of Queen Victoria's country home, Osborne House, on the Isle of Wight, designed and built by Thomas Cubitt in 1845–48. In 1850 William Aspdin started to build himself a vast concrete mansion, appropriately named Portland Hall, at Gravesend in Kent. It was abandoned when only half complete and only part of it has survived, including a small section of boundary wall which is capped with what must be some of the first commercially produced precast elements.

The development of cast and reconstructed stone

A large number of stone substitutes was developed in the latter half of the nineteenth century. These were compositions of Portland cement, fine aggregates including dust of the stone type to be matched, and pigments. Cast blocks were sometimes carved while still green, with paraffin oil and french chalk commonly used as release agents. While a few of these materials were good matches to the real thing, many were composed of too strong a mix, and developed surface crazing. Two of the earliest recorded buildings which used precast materials as a substitute for stone are the Presbyterian church at Loanhead near Edinburgh built in 1875, and the medieval manor house at Baddesley Clinton, Warwickshire, a National Trust property, where repairs were carried out using a precast substitute stone in about 1885.

By the early years of the twentieth century a reliable material had been developed which could be cast in blocks and which gave a good match to natural stone. It consisted of a mix of crushed stone and cement, cast by the semi-dry or 'moist earth' method, and is the material we know today as 'cast stone'. Cast stone has a lower strength and higher porosity than the material which today we generally describe as 'reconstructed' or 'reconstituted' stone and which is produced by the 'wet-cast' method.

The revival of neo-classical forms in England in the 1920s and 30s gave a boost to the use of cast stone, particularly in London where it was used to imitate, with great economy, the natural Portland stone facades of classical Georgian London. It was cast in blocks as a 75mm semi-dry facing mix backed with granite concrete (also semi-dry mix) and incorporating reinforcement where required for lintels and cornices. The blocks were tied back to a load-bearing brick inner leaf, which, in the case of large commercial buildings, usually enclosed a steel frame encased in concrete.

The great department stores in Regent Street and Oxford Street feature large areas of cast stone, often above a ground floor constructed in natural Portland stone, or on side elevations. The entire eastern facade of the department store on the north-east corner of Oxford Circus (Clarkson & Hall, 1924) is of cast stone, as are the Regent Arcade, Argyll Street (Gordon Jeeves), the Chapel Street facade of D. H. Evans (Louis Blanc, 1936), and the rear of the Cafe Royal (Sir Henry Tanner, 1924). A simple office building in Hatton Garden, London, by Clifford, Tee and Gale, still survives in more or less its original form, and provides a good example of the durability of precast materials. (The materials were produced by Empire Stone of Narborough, Leicestershire, founded in 1900.)

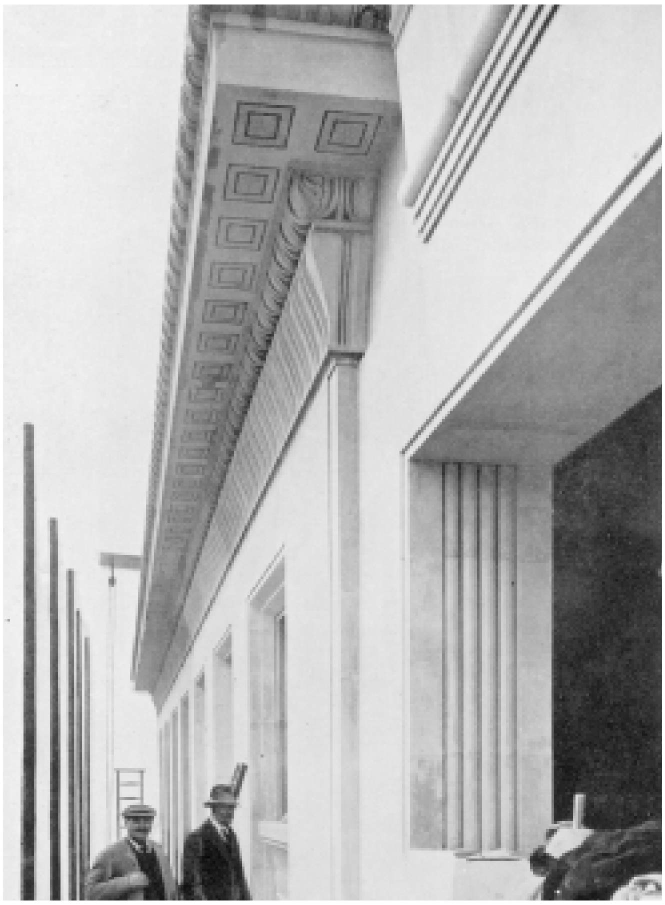
Cast stone was also used during the short-lived period of art deco: for instance on the facade the Kensington 'Kinema', Kensington High Street, London; the Princess Cinema, Dagenham (1930); and Constantine & Vernon's 1927 shop facade at 100 Oxford Street which still survives.

Many large 'mansion block' flats of the 1930s and 1940s had cast stone features such as Wellington Court, St John's Wood, London, which was built with cast stone ashlar masonry walls, bays and canopies.

Precast panels clad with other materials were developed at this time. The Dorchester Hotel, Park Lane, London, was built in the late 1920s with a façade of precast terrazzo panels provided by the Marble Mosaic Company, a Bristol-based manufacturer founded in 1905.

The development of precast materials

It is ironic that at the same time as cast stone with classical detailing was being used in imitation of real



stone, the pioneers of the Modern Movement were exploring the potential of concrete as a structural material.

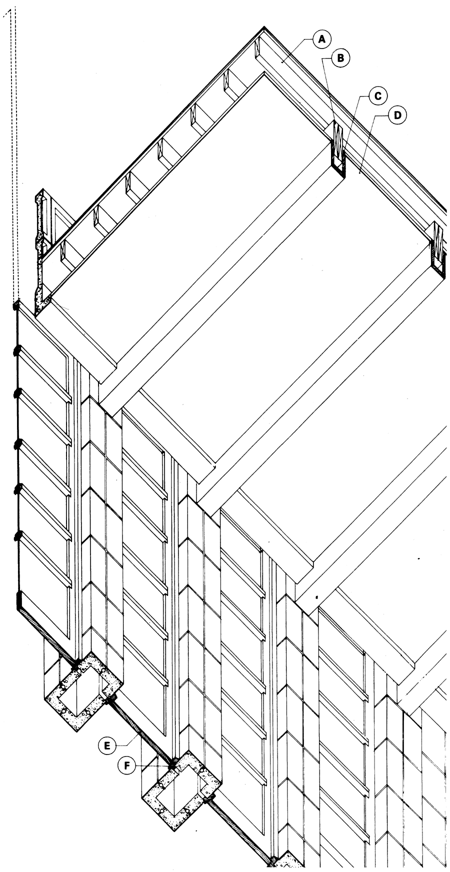
A Newcastle builder, William Wilkinson, is credited with the invention of reinforced concrete; in 1854 he took out a patent for embedding a network of iron bars in floors and beams, and seems to have been the first person to appreciate the composite nature of the material. Little interest was shown in his ideas, and it was a Frenchman, Francois Hennebique, who developed reinforced concrete on a commercial scale. In 1898 the first multi-storey reinforced concrete framed building in the UK, Weaver's Mill in Swansea, was built using the Hennebique system.

Architects and engineers in the early years of the 20th century soon recognised the potential of reinforced and prestressed concrete, though in most cases the material was cast in-situ rather than precast.

Frank Lloyd Wright was one of the first architects to experiment with precast – in the form of hollow blocks made of a semi-dry mix cast in embossed wood moulds. (Wright was also fond of adding earth and sand found on site to the mix to give the blocks a 'natural' colour). The Storer House and Millard House, Los Angeles, were built in 1923 using his 'Textile-block' system: the blocks were stacked up to form walls and columns which support timber roof beams. Wright textured the precast surface of the blocks: in his view this demonstrated the poured character of the material compared to wood and stone which, he suggested, should have plain surfaces to bring out the qualities of veining, grain and texture. The system did not flourish; it was unable to compete economically with the timber platform frame, the most popular method of house construction in the US.

In 1930 Le Corbusier completed the Maison Suisse, a university building on the outskirts of Paris. It is a rectangular four-storey block built on pilotis, with a lightweight curtain wall assembly on the two long elevations and blank side-walls of precast concrete panels. This was probably the first use of precast on a large scale and it was a design which had a great influence on subsequent tall buildings.

In England, one of the first buildings to pioneer the use of both structural concrete and cast stone was Frank Broadhead's 1932 Viyella House, Nottingham. The



Facing page top:the Cafe Royal has a cast stone facade built in 1924
Facing page bottom: a contemporary photo of the installation of a rich cast stone cornice in Hanover Square
This page left: worm's eye axonometric of Frank Lloyd Wright's Storer house, Los Angeles, showing how hollow reconstructed stone blocks were stacked into colmns which support the roof beams
Below: Le Corbusier's Maison Suisse was the protoype of many later precast buildings

structure consisted of mushroom-headed concrete columns which reduced the thickness of concrete floor slabs. The exterior was clad in curtain walling, with stainless steel mullions, between lightly tooled semi-dry mix cast stone spandrel panels which were produced by a local manufacturer, Trent Concrete, founded in 1917 on the banks of the River Trent.

During the late 1940s and 1950s a significant change took place. Increasing mechanisation of the building industry, particularly the development of cranes, led to changes in the construction process. Architects wanted to maximise glazed areas of the façade to create deep-plan, column-free open-plan interiors for office use. A demand was created for large precast cladding units to achieve economies of labour and equipment and to speed erection. The increase in size put greater stress on the structural properties of precast and led to a change in the type of material used. Compared with the traditional semi-dry mix cast stone, with its low strength and need for dry tamping, wet-cast, with its high strength and easy compaction in moulds by mechanical vibration, was a more suitable product for large panels. In addition, crushed natural stone of the types traditionally used in a semi-dry mix were rarely suitable for high-strength concrete. Unlike semi-dry mixes, the surfaces of these new wet-cast panels had to be treated to remove surface laitance, either by exposing the aggregate – granite, flint, river gravel or other hard material – or by exposing only the finer sands and aggregates to produce a finer texture, similar to traditional cast stone.

In contrast with the successful appearance of cast stone buildings of the 1920s and 1930s, some buildings with precast panels of this period, particularly prefabricated tower blocks produced by industrialised methods, have suffered badly in appearance. The reasons for this are complex; sometimes an unfortunate choice of cement and aggregate was to blame, sometimes a lack of awareness by the designer of how to design and detail what was then a relatively new building product. But several buildings of the 1960s prove that careful design and detailing will produce cladding panels which enhance a building and weather well. Skidmore Owing & Merrill's Heinz Research Centre at Hayes Park, Middlesex, 1965 has a two-storey colonnaded façade of cruciform structural columns and fascias in exposed

An early modern concrete building, Viyella House, Nottingham

The Russell building, Wexham Springs, showed no signs of staining for 30 years

Little weathering or streaking can be seen on the Heinz Research Centre, designed by SOM in 1965

Cornish granite aggregate. The colonnade shades a deeply recessed window, and equally importantly, the design avoids the condition which affected many contemporary buildings – water run-off from glazing streaking the surface of cladding below it. Similarly, St Anne's College, Oxford, (1966, by HKPA Architects), has a strongly modelled facade of exposed granite and Derbyshire spar aggregate panels and projecting window balcony units which show no sign of streaking. Even panels containing large-sized aggregate, a particularly difficult medium to handle, can weather well. The Russell Building, Wexham Springs, was designed by Casson and Conder as part of the headquarters of the then Cement and Concrete Association; the bold facades of precast panels showed no signs of staining for 30 years (it has recently been demolished).

Recent developments in precast materials

Most architects today are aware of the difference between wet-cast reconstructed stone and semi-dry cast stone. But there is also a difference in the perception of an architect who is looking for a material to resemble natural stone – reconstructed stone -and one who sees it as a heavyweight structural material with a variety of textures and finishes – precast concrete. In fact both wet-cast reconstructed stone and precast concrete are terms which describe a material of exactly the same specification and appearance.

The boom in office building in the 1980s led architects to re-examine the potential of precast cladding panels and, as many of the new buildings were in historic sites in London, the panels were required to have a stone-like appearance. The material used was a precast material produced by the wet-cast process and generally known as reconstructed stone. Reconstructed stone can be produced with mixes which give a close match to natural stones such as Portland stone and Bath stone. Reconstructed stone cladding provides a façade of solidity and 'gravitas' which can relate to a historic context yet has all the advantages of a fast track construction product. Examples of its use are shown in the accompanying case studies.

It was soon realised that a high-strength material with an attractive appearance was not only suitable for cladding panels, but could also be used for the structural elements of a building. Michael Hopkins & Partners used precast structural elements with exposed finishes in Bracken House, London, 1992, Glyndebourne Opera House. Sussex, 1994 and the Inland Revenue offices in Nottingham, 1996. The radiating precast beams at Bracken House are exposed as part of the ceiling to make maximum use of the restricted height of the building. The auditorium at Glyndebourne Opera House is encircled with two horseshoe-shaped balconies composed of wedge-shaped precast panels which butt together to form a curved front. The exposed precast finish of the soffits enhances the acoustic and allows integral lighting to be incorporated.

MacCormac Jamieson Prichard has explored the use of precast in the historic context of Oxford and Cambridge colleges. Fitzwilliam College chapel, Cambridge and the Garden Quadrangle of St. John's college, Oxford, are magical buildings of delicately detailed precast elements, as finely crafted as a piece of high quality furniture.

Precast can also be moulded into fluid forms and given strong colours and patterns. 'Blitzcrete', a mix of crushed brick aggregate and a coloured concrete matrix, and 'Doodlecrete', coloured concrete inlaid with undercut spiral grooves filled with white grout, were developed by the architect John Outram. They are used as 'logs' and 'saddles' which support the cornice of the Judge Institute, Cambridge.

In the past few years perceptions about the design of the workplace have changed to emphasise the management of energy, with the aims of energy efficiency, good environmental working conditions and low running costs without the use of air-conditioning. A heavyweight material such as precast concrete has the ideal capacity for fabric energy storage (FES), in which the building fabric is used to attenuate and modify peak internal temperatures during the occupied period. The undersides of precast floor slabs are particularly suitable because they form the largest surface area. An example of this is can be found in the case study of the Toyota headquarters in Epsom, by architect Sheppard Robson.

The discovery of concrete is a remarkable story. In the past decade the potential of precast concrete as cladding and structure has been taken further. The case studies included in this book give some idea of the possibilities of this unique material.

Above: precast balcony units at Glydebourne opera house, by Michael Hopkins & Partners

Above and below: A giant order of columns runs across the facade of the Judge Institute surmounted by black precast capitals and an entablature of 'logs and saddles'. The architect was John Outram

Above and right: Fitzwilliam College chapel, Cambridge by MacCormac Jamieson Prichard