Castings in Architecture: Technology and Application

Richard Desgrand

ABSTRACT

Current casting technology has made available to building designers a high strength, wide application, cost efficient way of making structural components uniquely tailored to the particular project. The technology and experience is available in Australia to produce castings of a wide range of materials and sizes.

1. CASTINGS IN ARCHITECTURE

The structural use of cast metals has a history of about two hundred years which includes a lengthy hibernation when cast connectors began to be replaced by welding and bolt plate connections earlier this century.

In the late 18th century and 19th century cast iron elements were used almost entirely in compression such as the cast iron columns of the English cotton mills and the earliest skyscrapers of Chicago or the ingenious use of voussoir shaped cast iron panels emulating stone arch construction in the Sunderland Bridge, England (1793–96).

The reimergence of castings in the last 20 years in contrast exploit the high tensile strength of metal alloys and dispel the general conception that castings are brittle and unweldable.

The most prominent pioneer in the re–introduction of castings into Architecture was the Pompidou Centre in Paris (Architects; Piano and Rogers, Engineer; Peter Rice, Ove Arup Partnership). Turning itself inside out to expose the structural steel skeleton it sought further structural clarity by using solid sections for all tension members, hollow tube for compression members and cast steel for the joints to the columns (gerberettes) and the truss nodes. So seminal was this building that it is worth noting Peter Rice's explanation for the introduction of castings into the design:

> *"When you build a steel building all the other steel buildings that people have seen become part of the way they react to what they are looking at. It was then that I principally conceived the idea of introducing the cast steel because I wanted to break some of these prior prejudices and produce something which would be unexpected, and in being unexpected would challenge people to look at it, and in the process of challenging them to look at it would actually make them think; "What is it? what is it that I am looking at?"*

So successful were the castings in their expression that it is no surprise to see them used in the Piano/Rice collaboration on the Menil Collection Building, Houston Texas.

The essence of this building was a platform roof which controls light and heat gain as well as providing protection from the elements. Composed of a series of specially profiled shells (reflection elements) of ferro–cement acting compositely with a series of truss elements of ductile iron (or spheroidal graphite cast iron) castings.

Castings were chosen in part for their ability to be made into an organic shape similar to the ferro–cement shells. Ductile iron differs from cast steel in that it is more fluid while being cast, flowing more easily into fine, irregular shapes, and does not require to be heat treated to reduce the castings brittleness. It does not distort or change shape after casting and can thus be made very accurately.

Although repetitive use of specially shaped components is the strength of castings they also provide smooth, sealed profiles which can be an advantage in external use. This was amongst the considerations for selecting castings for the Renault Parts Distribution Centre, Swindon, England (Architects; Foster and Assoc.s, Engineers; Ove Arup Partnership). The structure is composed of a continuous bending column and continuous bending beams pinned to the column, connected and stiffened by members capable of taking tension only. To achieve uniformity of the connection between the ties and columns for the two types of ties a mechanical coupling was the only option and castings of spheroidal graphitic iron were chosen as they are cheaper to cast, heat treat and machine.

Economical use of castings generally requires repetition of elements but there are instances where low numbers has not ruled out castings as competitive. Lee House, London has probably the largest castings to be found in a building. 2.2m long, 1.4m across octagonal shaped castings weighing approximately 17.5 tonnes form the main nodes of the 4 cable–stayed trusses in the centre of the building. The primary ties are adjustable length bars fixed to the far side of the castings to keep the node in compression. Originally envisaged as grout filled, fabricated hollow steel sections castings were used to avoid tolerance problems in fabricating such large octagonal sections and the time delays that would have been required while testing grout for creep and shrinkage.

The structural arms that support the glazing to the Western Morning News, England, provide an example that one mould does not necessarily have to produce only one shape. In part of this building the length of the arms vary according to their level on the column, this was achieved by providing a straight segment on the casting which was segmentaly shortened on the mould.

Castings in Architecture need not necessarily be ferrous based. Bronze castings have been used in facade structure such as the gunmetal castings of Bracken House, London, and the cast bronze connections between the mullions and the glass framing to the North and South walls of the Sydney Opera House.

2. GOVERNOR PHILLIP TOWER: GLASS ROOF AND SCREENS

In the design of the glass roof of the Governor Phillip Tower Foyer it was the intention that the structure be as unobtrusive and as elegant as possible. The structural system derived from a cable truss supporting a 2–way mullion system holding glass panels. The cables were replaced with rods with opposite threaded ends screwed into the cast nodes and held apart to form an arch and a catenary by tubes taped and turned onto studs cast in with the nodes. The system was pre–stressed to limit deflection.

Investigation had shown that the elegance of most space frame or truss systems used in similar applications was lost in the connection details and from an early stage castings were chosen because of their ability to make a more refined connection that was also expressive of the forces that they were conducting. In this regard castings can be quite sculptural and bring back to architecture a sense of the hand made. It was possible to produce connections where the rods appear to thicken as they pass through the struts, the thickness mainly being determined by the requirements for threading and the geometry of the connection rather than the limitation of the casting.

Stainless steel was chosen as the casting material mainly for its durability of finish as the roof would be difficult to access for maintenance. Investment castings were chosen for their accuracy, the arms of the nodes could only vary by one half of a degree from design to ensure that the trusses could be assembled without complications, and for their fine finish, the castings were reused in the vertical glass screens at the building entry and some would be at eye level. Stainless steel can present problems in post–casting machining and thread locking during assembly.

3. CASTING METHODS

There are two methods for producing castings; sand castings and investment (or lost wax) castings.

In sand casting wooden patterns are prepared from drawings and assembled in a pattern box. Moulding sand against which the molten metal will be poured is then packed into the box to the shape of the pattern inside and the pattern removed. These castings are generally coarse in finish and this method is appropriate for large and less complicated or less detailed castings.

Investment Casting also starts with a timber pattern from which a split, (usually resin mould is taken. Machined inserts or additional moulds may be included within the main mould to form block outs or undercuts. Wax is then injected into the mould to produce as many masters as castings are required. It is these masters that give the process its more common name of ”lost wax castings”.

The wax master, often in numbers if small in size, is heat welded to a wax feeder to form a ”tree” which is repeatedly immersed into a ceramic solution to build up a shell which is the final mould for production after the wax is melted out. The ceramic shell is sufficiently porous at a microscopic level to permit air to escape during pouring. Hence this process can produce castings with very fine detail (including undercuts) and fine finish, sufficient to produce threads. It has the advantage of minimising machining and finishing processes and is less prone to containing air pockets or dislodgement of mould particles into the casting and consequent weakening it produces.

Some resistance to using castings is due to the misconception that castings contain unacceptable cavities inherent in their manufacturing process. Manufacture by high integrity foundries can produce structurally sound castings and this can be verified by testing.

Testing of castings can be made by;

1. ultrasonic inspection; this technique relies on the reflection of sound waves from an interface within the material and it is possible to detect cracks and 2 dimensional faults as well as 3 dimensional defects greater than about 1mm.

2. radiographic inspection; a more expensive procedure which can only detect 3 dimensional faults but does result in hard copy evidence of the defects.

Routine testing during casting can include ladle analysis where samples are taken from the furnace prior to pouring and checked form chemical composition using a spectrometer.

Repairs can be made to cracks and voids by cutting out and filling the cavity with sound metal by welding.

Ponds Forge Swimming Pool, Sheffield, UK.
Cast Joints at arch hinges and bases

Details of World's First Cast Iron Bridge over the Severn.
Built by Abraham Darby 1776–1779 at Ironbridge, Wales

General Exterior View of the Renault Headquarters – Cable (rod) supported roof.

Renault Parts Headquarters Swindon – UK. Cast Connection Details.