

Iron before steel

Steel is now widely used to support buildings – whether as reinforcing in concrete, hot rolled sections for multi-storey tower blocks or cold formed sections for smaller-scale buildings – but iron came first.

By Nigel Isaacs, BRANZ Principal Scientist and Teaching/Research Fellow, Victoria University of Wellington

It was centuries after the start of the Iron Age, around 1200 BC, before iron was widely used in buildings. Because of limited and costly supplies, its first uses were in conjunction with stone or brick. Unlike stone or brick, iron performs well in both tension and compression, although it's about five times stronger in compression.

Iron in construction

The strength of iron largely relates to the proportion of carbon: cast iron has around 3% carbon; wrought iron under 0.1%; and steel a controlled proportion from 0.15 to 1.5%.

Smelting iron ores into metal invariably involved the use of fuels and furnaces (wood or coal) that created an uncontrolled carbon environment. Repeated striking with hammers (and in the industrial revolution, by power rollers) forced out carbon and other impurities to create wrought iron – less brittle than cast iron although not as strong as steel.

By the 1st century, Vitruvius was recording the use of iron clamps for binding stone or brick walls to prolong their life and iron frameworks to support vaulted ceilings.

In medieval buildings, wrought iron rods were used:

- to stabilise the stone voussoirs in arches
- as ties to transfer the tension forces between the tops of walls or columns
- in the mullions and frames in large stained glass cathedral windows.

Bigger buildings needed greater strength

As buildings became larger, wrought iron's tensile strength became ever more important. Filippo Brunelleschi's great Duomo, the 42 m cupola on the Cathedral of Santa Maria del Fiore in Florence, was completed in 1436. It used three iron 'chains' formed of sandstone blocks linked by wrought iron cramps embedded in the masonry to encircle the dome and resist the horizontal thrust.

Once sufficient iron was being produced at a reasonable cost, it was used as a major construction material. The first cast iron bridge – 'Ironbridge' at Coalbrookdale, England – was completed in 1779. The five cast iron ribs span 47 m, supporting cast iron spandrels on which the roadway is carried. Reflecting the lack of experience with this new material, 'timber' jointing techniques such as dovetails, wedges, and mortise and tenons were used.

Wrought iron and riveting

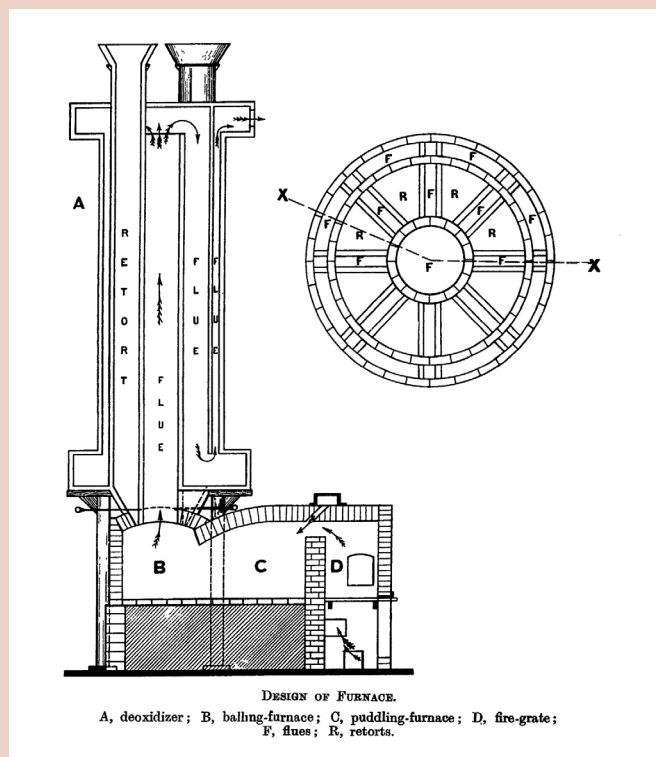
Henry Cort's 1784 patent for 'puddling', where a shallow tank (puddle) of molten iron was heated by flames from a separate furnace, enabled production of wrought iron. Wrought iron could be rolled into plates or rods. Plates could be riveted to form boilers or shaped into corrugated iron. Rods could be used to make nails and form ties for masonry or timber trusses.

Riveting, developed by boilermakers and ship builders, could create spans longer than 60 ft (18.3 m). Girders could then be made of wrought iron plates and angles as well as Z, H and I shapes.

The 1851 Great Exhibition, ancestor of the modern World Fair (including Expo 2010 Shanghai), was housed in the Crystal Palace, a 70,000 m² expanse covered with a glass and steel framework, designed by Joseph Paxton. The prefabricated, modular construction, self-scaffolding frame system was erected in only 27 weeks. It made extensive use of wood and iron – 24 ft (7.3 m) nominal span wooden trusses assembled with screws, wooden pins and wrought iron straps, 24 ft cast iron girders and 48 ft (14.6 m) and 72 ft (21.9 m) combined cast and wrought iron trusses assembled with rivets.

Iron houses make it to New Zealand

By 1855, portable iron and timber-framed houses were being imported into New Zealand (see *Build* 108, pages 94–95). The benefits of iron construction were recognised in The City of Auckland Building Act 1854,



Puddling furnace built to smelt ironsands at Onehunga in 1883. (Source: Chambers, 1917, 'New Zealand ironsands', *Transactions of the New Zealand Institute*.)



East Cape Lighthouse (1900) made in cast iron by the Thames Iron Works. (Source: Cyclopaedia of NZ Vol. 2, Auckland 1902.)

which permitted buildings to be constructed of 'iron or other incombustible material' without restriction – presumably due to their lack of flammability.

Blacksmiths could work with imported iron to meet a wide range of industrial, agricultural, residential and building needs. Early foundries include the Vulcan Foundry started in Wellington in 1847, John Anderson's Canterbury Foundry in Christchurch in 1857, the Phoenix Foundry in Auckland in 1861 and A & T Burt in Dunedin in 1862.

The first publication of the *Statistics of New Zealand* in 1865 recorded imports of bolt, bar, hoop and pig iron totalling 5,506 tons (5,594 tonnes) – equivalent to 23 kg per head of population. In 2010, the national steel consumption is about 150 kg per head of population, although about 58 kg of this is from New Zealand ironsand and about 46 kg is from steel that has been recycled here.

The 1867 *Census of Manufactories, Works, etc* recorded 16 'iron and brass foundries' throughout the country. By 1870, there were 28 foundries employing 855 people.

Cast iron from household items to lighthouses

Cast iron items in everyday household use included coal stoves from 'iron-master' Henry Ely Shacklock's South End Foundry (started in Dunedin in 1871) and kettles and pots. It could also be used as decorative balustrades, valances and brackets.

Structural cast iron was also available. The first Canterbury races held in Christchurch on 19 January 1864 had a new grandstand supported by cast iron pillars made in the Canterbury Foundry.

Although cast iron housing was being produced in England in 1843 and being promoted in New Zealand newspapers, it doesn't seem to have been used here, possibly because of the wealth of other portable and reasonably durable materials. On a far larger scale, the Thames Iron Works made cast iron lighthouses for Cape Campbell (1905) weighing 63 tons (64 tonnes), Cape Brett (1910), East Cape (1900) and Kahurangi Point (1903).

Wrought iron was also widely used in early New Zealand, including as corrugated iron (see *Build* 95, page 115). A two-room 'wrought iron cottage', imported from England, was auctioned in Auckland on 14 May 1851.

The story continues in the next Build with the building history of steel framing. ◀