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The Great Builders

Kenneth Powell

A unique survey of forty architect-engineers who have been pioneers in both aesthetic design and technological innovation

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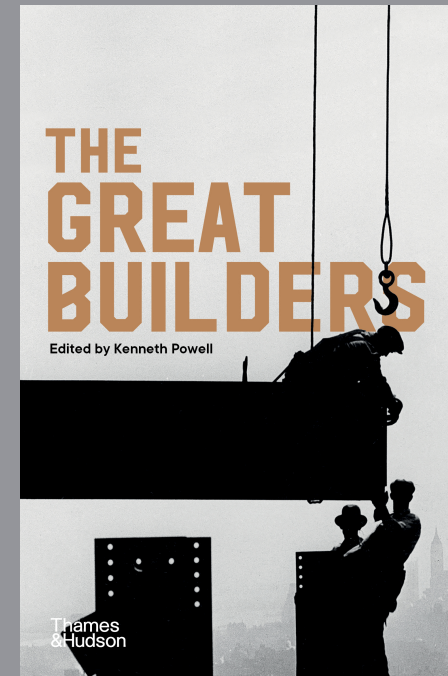
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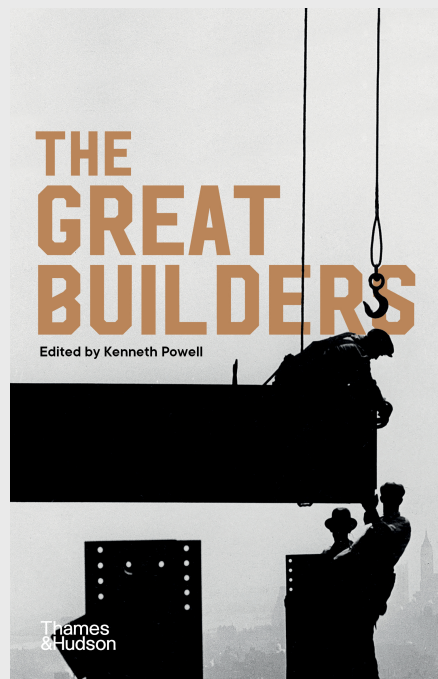
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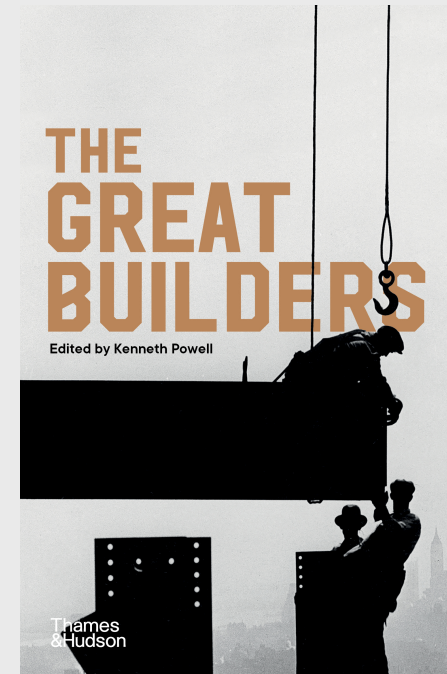
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- Written by leading architectural historians and practicing architects – all experts in their fields.
- Features many of the world's most iconic structures, such as the Taj Mahal, the Eiffel Tower, the Sydney Opera House and the Guggenheim Museum, Bilbao.
- A carefully chosen selection of plans, prints, photographs and drawings bring the builders and their creations to life.
- Covers 700 years of engineering innovation, from ingenious scaffolding to the role of computer software in design.



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THE AGE OF IRON

The 19th century is sometimes characterized as the age of the battle of the styles, in which the romantic force of Gothic was pitted against the strength of the classical tradition, expressed in the genius of architects such as Karl Friedrich Schinkel in Germany, Claude-Nicolas Ledoux in France and John Soane in England. But the 19th century was equally the age of iron, which provided the raw material for a new transport infrastructure of turnpike roads, canals and railways. The arched cast-iron bridge over the river Severn at Coalbrookdale (by Abraham Darby III and T. F. Pritchard, 1779) was the first large-scale iron structure in the world, but it was essentially a handmade one-off. The bridges designed by the Scottish architect-engineer Thomas Telford, including the road bridge across the Menai Straits in Wales, were far more economical in structural terms. The domed roof of the Halle au Blé in Paris (1811), a collaboration between the engineer J. Brunet and the architect François-Joseph Bélanger, marked a move towards the use of standardized components. Despite the rhetoric of A. W. N. Pugin, John Ruskin and others, the use of iron, including increasingly large quantities of wrought iron, could not be confined to engineering structures – railway and canal bridges, markets, mills and warehouses – but soon invaded the world of architecture. Schinkel, for example, who toured Britain to inspect the new buildings generated by the Industrial Revolution, made free use of iron in his buildings.

In Britain the 1851 Crystal Palace, brainchild of Joseph Paxton, showed what could be achieved when iron was married to another material now also in mass production: glass. The structural ideas behind the Crystal Palace were established by Paxton in the glasshouses he designed for the 6th Duke of Devonshire and by the Irish engineer and iron-founder Richard Turner in his palm houses in

Dublin and at Kew Gardens near London. The lessons of the pioneering glasshouses and of the Crystal Palace were applied in the design of the great railway stations of Britain. Richard Turner was co-designer of the roof at Lime Street Station in Liverpool (1849): fabricated in wrought iron, at 47 metres (154 feet) it was the greatest clear, unsupported span yet achieved anywhere. Perhaps the finest of them all, London Paddington (1852), was the work of Isambard Kingdom Brunel. Like A. W. N. Pugin, he was the son of a French émigré father, and a figure of colossal achievement and even greater aspiration, who created the Great Western Railway and built the first ocean liners. London's most prominent railway monument, St Pancras Station (1868), with a train shed by the engineers W. H. Barlow and R. M. Ordish, was prefaced by a hotel (1876) designed by the great Gothic Revival architect George Gilbert Scott, but inside Scott used iron freely and frankly. Even the University Museum at Oxford (1861), of which Ruskin was the principal promoter, had an interior of iron and glass behind its elaborate Gothic exterior.

If many British architects, in contrast to the engineers, remained nervous about exposing iron construction, very different attitudes prevailed in France. Eugène-Emmanuel Viollet-le-Duc, on one level an active restorer of medieval cathedrals including Notre-Dame in Paris, was even more significantly a theorist of lasting influence, whose writings were to find a particular resonance in the United States and would influence the pioneers of the Modern Movement. Viollet-le-Duc's championship of rational and honest building, which was in tune with the thinking of Ruskin and Pugin, embraced the use of iron and fostered the development of an architecture in which metallic construction was freely displayed, not hidden away or simply used as a substitute for more traditional materials. This agenda found powerful expression in the work of architects such as Henri Labrouste and Victor Baltard, the former responsible for two monumental libraries and the latter for the extraordinary church of St-Augustin, in which exposed iron is combined with lavish Gothic detail, and for Paris's lost central markets, Les Halles (demolished in 1971).

desire to make a more economic and rational use of the material, this ultimately found its expression in a series of cast-iron arches commencing with Bonar Bridge (1810–12). They were an aesthetic triumph and the beginning of his collaboration with the Shropshire ironmaster William Hazledine. Bonar Bridge was part of Telford's work for the government in the Highlands that had stemmed from his involvement with the Fisheries Society. In 1801–2 he carried out surveys, recommending a range of improvements to harbours and inland communications to stimulate the economy and stem emigration. As a consequence, commissions were set up in 1803 for works in the Highlands and building the Caledonian Canal. Despite the apparent simplicity of linking a series of lochs along the Great Glen to create the canal, the civil engineering challenges were great – none more so than at the eastern end, where a depth of 128 metres (420 feet) of mud was pre-consolidated by the use of fill to enable the lock to be excavated. In all, twenty-four locks had to be built.

The canal was only the most spectacular of Telford's work in the Highlands, which continued until the end of his life. Aside from many small masonry bridges, there were major crossings such as that at Dunkeld (1805–9), numerous piers, road improvements, and work on churches. He built a number of major bridges – at Pathhead, Lothian, and Dean Bridge (1829–32), a tall slender structure in the centre of Edinburgh. Here and elsewhere he employed hollow piers and spandrels to reduce weight and facilitate inspection, a practice widely adopted by others. His Over Bridge at Gloucester (1825–28) was another late masterpiece.

Telford was the last of the great canal engineers. Invited to be 'General Agent' to the Ellesmere Canal Company in 1793, he rapidly mastered the essentials of canal design and construction and proved innovative almost from the first. His advocacy of the use of exposed cast iron for aqueduct troughs, first employed at Longdon on the Shrewsbury Canal (1795–96) but most spectacularly at Pontcysyllte on the Ellesmere Canal (1794–1805), heralded him as a structural artist of premier rank. He was responsible for major

improvements on the Trent and Mersey Canal, and completely re-engineered the Birmingham Canal in the 1820s with deep cuttings to prevent its meandering. He used a similar heavily engineered approach for the Birmingham and Liverpool Canal. Telford was consulted about the Gotha Canal across southern Sweden, the first major overseas consultancy project for a British engineer, and as his reputation grew he corresponded with engineers and clients from Canada to India.

Roads, Harbours and Long-Span Bridges

Described as the 'colossus of roads', Telford set standards for road construction that anticipated modern practice. The Holyhead Road provides the finest examples of his work as a road engineer, with toll houses, mileposts and sun-ray toll gates offering further evidence of his architectural work. He was also responsible for the Glasgow to Carlisle and Lanarkshire roads, surveys of the Great North Road and roads from Carlisle to Portpatrick and Edinburgh. Telford's dock and harbour works were relatively modest compared to those of his contemporaries William Jessop and John Rennie. Nonetheless they included significant harbour work at Aberdeen and Holyhead, and docks at Dundee (1814–34) and St Katharine Docks (1826–30) in London.

More spectacular were Telford's ambitious schemes for long-span bridges. The first to be developed was for a 183-metre (600-foot) cast-iron arch span to replace the medieval London Bridge (1799–1803), a project that brought him national attention. Even grander was the proposal to traverse Runcorn Gap with a wrought-iron suspension bridge over 300 metres (nearly 1,000 feet) in span. When Telford began work on Runcorn in 1814 the modern concept of a level-deck suspension bridge was unknown in Britain, and only at an experimental stage in North America. He realized that no existing technology could deliver a bridge of the necessary span, and although funding for Runcorn was never available he took forward what he had learned into the design of the suspension bridge over the Menai Straits (1819–26). This bridge had the



15 Solomon R. Guggenheim Museum, New York (1943–59), designed by Frank Lloyd Wright. Artworks are displayed on the outer walls of the upwardly spiralling concrete ramp.



16 Frank Lloyd Wright's greatest 'natural' house: Fallingwater (1938), Mill Run, Pennsylvania. Anchored to the rock by solid masonry walls, the reinforced-concrete floors and ceilings cantilever out over the waterfall.

17 Precast concrete panels are assembled on the ribs of the Sydney Opera House (1958–73), c. 1966. Ove Arup's team used early computers to analyse the complex shell structures.

