Edward Diestelkamp, 'Building Technology & Architecture 1790–1830', *Late Georgian Classicism*, Georgian Group Symposium, 1987, pp. 73–91

BUILDING TECHNOLOGY & ARCHITECTURE 1790–1830

Edward Diestelkamp

In 1802 the architect François-Joseph Bélanger proposed that the recently destroyed timber roof of the Halle au Blé in Paris be replaced with an iron dome.[1] He had visited England during the late eighteenth century and had learned about the structural use of iron in this country.

Bélanger wrote to the magistrates in 1802:

> 'It is appropriate to teach the learned of Europe that we have no longer any need to borrow from the English our knowledge in the art of construction . . ., and that if they have been the first to substitute cast iron in order to supplement stone and carpentry in the construction of different beams, it is that they lacked stone and wood, but that long before one had the example also in France of equally bold concepts which one has also known how to perfect and to execute in dimensions which they have not yet dared to attempt.'[2]

Bélanger's designs of 1808 were accepted, and the iron dome was constructed between 1809 and 1813. It was undoubtedly a remarkable achievement, being some 40 metres in diameter, composed of 52 cast iron radial ribs connected together with fifteen concentric rings of cast iron. It was the most extensive use of iron in a building at that time and for several years to come.

In referring to the English use of iron in construction, Bélanger was no doubt thinking of the Ironbridge in Coalbrookdale, erected in 1778 by Abraham Darby and Thomas Farnolls Pritchard, which had drawn much attention from Europe. British engineers continued to experiment with iron arches in the design of bridges throughout the late 18th and early 19th centuries[3]. Telford's Buildwas Bridge (1795–96) and Pont Cysyllte Aqueduct (1795–1805), which was carried on cast iron arches spanning some 45 feet, are but two examples out of many.

The claim by Bélanger that the English use of iron for construction was due to a shortage of timber and stone is not entirely true. Masonry and timber remained the most common materials for buildings, bridges and other engineering works.[4] Several other factors were connected with this development. Need, demand, entrepreneurial skill, money and availability of new materials influenced the development of the use of iron for construction purposes.

Bélanger's concept for re-roofing the Halle au Blé was certainly bold. For the most part contemporary British architects did not use or experiment with iron on such a bold scale. John Nash, however, was the exception from an early stage in his career. At the beginning of the nineteenth century other architects were attracted by new technology.

John Nash and Samuel Wyatt were two architects who produced designs and entered patents for iron bridges. Nash built two iron bridges for Sir Edward Winnington on his estate, Stanford Court in Worcestershire. The first was erected in 1795 and spanned 98 feet over the River Teme. Unfortunately it collapsed when it had only just been completed. Undeterred, Nash devised another design which he patented in 1797. In that same year he erected a second bridge to his patent design for Sir Edward Winnington. His patent design was for arches formed of hollow boxes constructed of iron plates and bolted together in an arched form like stone voussoirs. The hollow boxes could be filled with earth or masonry. This bridge survived into the early years of this century.[5]

Two factors which encouraged the adoption of new building materials during the early nineteenth century will be discussed in this paper, namely an interest in fire resistant materials and construction methods, and an interest in novel ways of admitting natural light into buildings and greenhouses. Iron was one of the materials used, but there were others which were experimented with as well.

One reason for the adoption of cast iron in particular which will not be discussed was the fact that it permitted repetition. Thomas Rickman used moulded decorative castings in many of his churches instead of carved stone. William Porden and other architects used cast iron in the same way. The use of iron was applicable to all styles of architecture whether Classical, Gothic, Hindu, or even J. C. Loudon's Curvilinear style.[6] Because of its nature, cast iron could be moulded and cast in identical proportions to imitate stone. This was particularly useful for Gothic mouldings and tracery. Humphry Repton, however, recognised that such uses of cast iron did not take account of its physical properties and characteristics. He explained that, 'if the architects of former times had known the use we now make of cast iron, we should have seen many beautiful effects of lightness in their work'. He argued 'surely in ours (i.e. contemporary architecture), we may be allowed to introduce this new material for buildings, in the same manner that we may fairly suppose they would have done, had the invention been known in their time', thereby advocating construction in iron which recognised the material's greater strength in relation to size of structural member.[7] Rickman's church, St George's, Everton, in Liverpool (1813–14), exemplifies Repton's ideas perhaps best of all. Here, Rickman achieved a lightness of effect previously unknown. Light cast iron columns, arches, spandrels, ceiling framework and tracery combine to create a light and airy interior. The iron structure both inside the building and of the roof, as well as the stone elevations with large generous pointed openings, are similar in character to those of a conservatory.

One factor which encouraged the search for new construction materials and methods was fire. Destructive fires such as that which in 1791 completely gutted the Albion Flour Mill, one of the most important eighteenth century industrial buildings from a structural point of view, may have influenced the decision taken in the following year by the Association of Architects to investigate methods of better construction and use of new materials to prevent the spread of fire in buildings.[8]

At a meeting on 2nd February 1792 the Association, whose members consisted of Robert Brettingham, Joseph Bonomi, John Carr, Sir William Chambers, Samuel Pepys Cockerell, George Dance, Thomas Hardwick, Henry Holland, Richard Jupp, James Lewis, Robert Mylne, James Paine, Nicholas Revett, Thomas Sandby, John Soane, James Wyatt and John Yenn, agreed to examine the causes of frequent fires within the scope of the existing building regulations. From the outset they recognised the need for better construction of party walls.[9] A sub-committee was formed to investigate various means of fire prevention. They procured two street houses and had them fitted out in order to test by experiment different theories.

Their report identified four important causes of fire: first, the existing insurance practice which they believed encouraged the destruction of property by arson; second, the improper installation of stoves, grates, coppers and furnaces; third, the uncontrolled passage of air behind wainscot linings and panelling found in almost all buildings; and fourth, the easy spread of fire from storey to storey through floors and wooden staircases.

The sub-committee examined many different fire-prevention methods, but two of them were deemed effectual: David Hartley's invention which used plates or sheets of metal nailed to floors and ceilings, and Lord Stanhope's method which was a special pugging composition consisting of lime, sand, plaster of Paris, brick dust, coal and ashes, forming a cement that was spread upon laths. The sub-committee also recommended floors constructed of arched cones, bricks or tiles as equally effective but recognised they were much heavier and more expensive. They presented their findings on 3rd January 1792, and in March that same year the Association resolved that it should be published.

At the same time, and no doubt influenced also by the destruction of the Albion Mill and other similar disasters, mill-owners were concerned to develop a fire-resistant method of construction. The development of a system of iron frame and brick arch construction occurred simultaneously with the investigations of the Association of Architects.

From the early eighteenth century traditional mill construction had consisted of an internal timber frame of heavy wooden beams, joists, columns and trusses within brick or masonry external load-bearing walls. The earliest example was John Lumbe's silk factory built near Derby between 1718 and 1722. Iron columns were first introduced to carry timber beams and joists at Calver Mill in Derbyshire in 1785.[10] William Strutt's mill in Derby of 1792 and his warehouse at Milford of 1793 employed cast iron columns and wooden beams, and introduced floors made of brick arches and hollow clay pots. Strutt's ideas directly influenced the first complete iron-framed multi-storeyed mill with cast iron columns, and beams carrying brick-arched floors, the Ditherington Flax Mill in Shrewsbury, which was designed by Charles Bage and erected in 1796–97.[11]

In spite of this development of an iron frame system during the 1790s, most architects seemed uninterested in any possible application to their work. Samuel Wyatt, however, was the exception. The Albion Mill disaster had led him to plan its rebuilding in a fire-resistant construction and though this was never realised, he did incorporate his ideas into a patent which he entered in 1800, for 'a new . . . method of . . . constructing bridges, warehouses, and other buildings, without the use of wood'. Samuel Wyatt's patent involved the use of cast iron columns supporting arches made up of iron plates.[12] It is possible that Samuel's brother, James, used this method of construction in the 'Castellated Palace at Kew' designed for George III in 1800. Construction began in 1801 but was halted in 1811 with the building in a half-finished state, in which it remained until 1827–28 when it was demolished.

It was really not until the 1820s that certain architects began to adopt cast iron beams of considerable size for the construction of floors. Robert Smirke had used cast iron 'bearers' somewhat earlier, at Cirencester Park in 1810–11 for Lord Bathurst. With the advice of John Rastrick he adopted enormous girders over 40 feet long in the construction of the King's Library at the British Museum in 1824.[13] William Wilkins used cast iron beams in the construction of the floors at University College, London in 1827–28, and later again at the National Gallery in 1833.[14] John Nash used cast iron girders extensively throughout his remodelling of Buckingham Palace in 1825–28. Supplied by Messrs. Crawshay of Merthyr Tydfil, some of the largest were 35 to 36 feet in length. A few years later, during the inquiry into the mismanagement and gross overspending on the rebuilding of Buckingham Palace, Nash described himself, somewhat grandly, as 'the principal user, and perhaps I may add the introducer of cast-iron in the construction of floors of buildings'.[15]

As mentioned above, William Strutt constructed sections of the arched floors in his Derby mill of 1792 and Milford Warehouse of 1793 with hollow clay pots. The use of hollow clay pots for constructing floors and roofs had recently been revived in Paris by an architect, M. de St. Fart, a designer of hospitals. Victor Louis employed them in his reconstruction of the theatre at the Palais Royale in 1785–90.[16] John Soane used hollow clay pots in the construction of the roof vaults of the Bank of England. Hollow clay pot vaults were much lighter than brick or masonry and therefore less thrust was placed upon the walls. The construction also had the advantage of being completely of incombustible materials.[17] A coloured perspective dating from 1799 by J. M. Gandy, of the Consols Office before plastering, clearly shows the construction of the vaults — the hollow clay pots with holes on the bottom side, sandwiched between courses of brickwork (Fig. 1). Another coloured drawing of 1818, this time of the Old Colonial or Five Per Cent Office, illustrates the construction of the vaults with hollow clay pots in the foreground stacked on their sides, ready to be placed in position (Fig. 2).

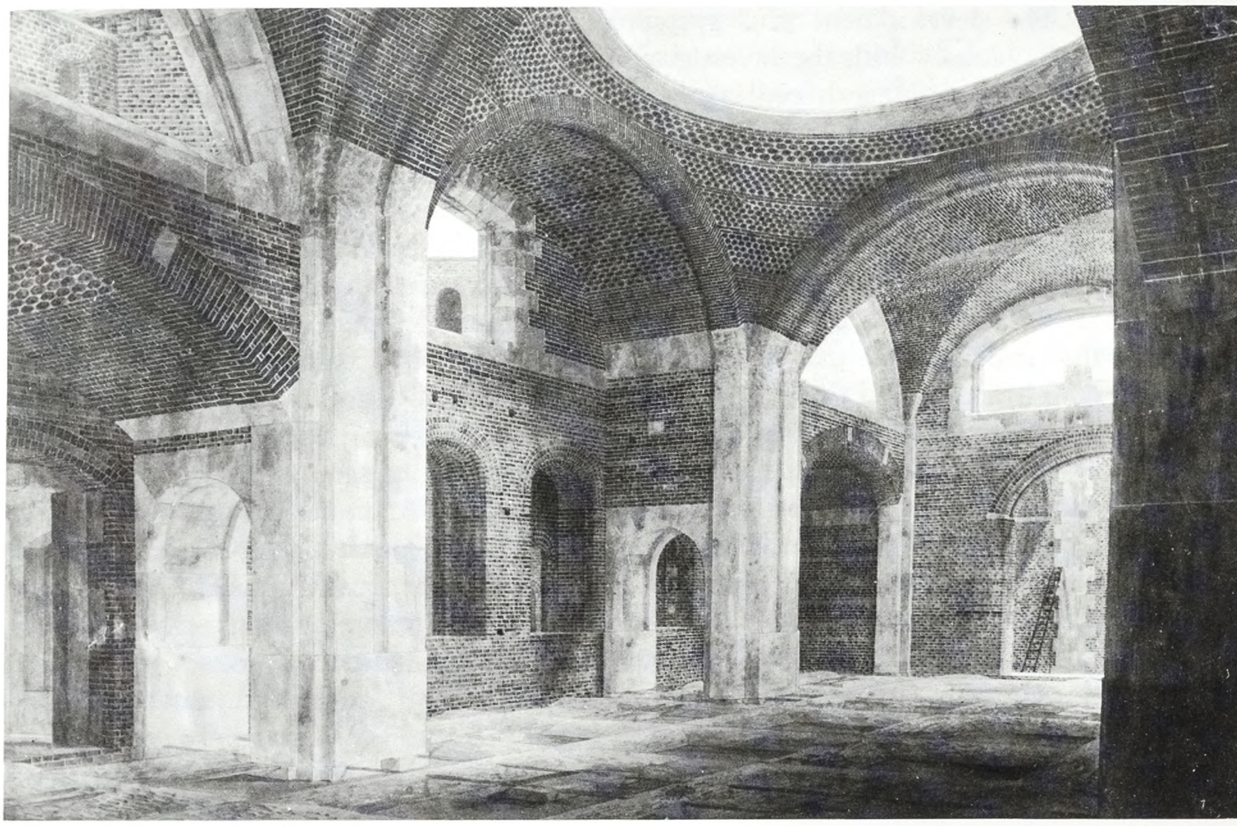


FIG. 1. J. M. Gandy: the Bank of England, interior perspective of the Consols Office showing the unplastered walls and vaults, 1799. (By courtesy of the Trustees of Sir John Soane's Museum)

Whereas very few architects adopted cast iron as a structural material in their buildings, many more were attracted by the obvious advantages of metallic sash bars and sashes from the 1780s onwards. There were many firms, particularly in London and Birmingham, specialising in metallic sashes. Firms such as Underwood, Doyle and Underwood of High Holborn, London, Lloyd and Livermore of the Strand, London, Joseph Bottomley of Cheapside, and the Eldorado Company, both also of London, are but a few of many firms who specialised in this trade. The Introduction to Joseph Bottomley's catalogue of 1793 explained the importance of the recent development in the metallic sash business:

> 'The modern improvements in Architecture are so replete with conveniences, elegance and taste, that whoever surveys the edifices erected a little more than half a century back, and compares them with those of the present time, must be astonished at the improvements in this science; amongst the advantages, those of admitting light, are not the least conspicuous . . . The change now taking place in the materials for sashes, skylights, fan-lights, staircases &c. &c. from **Wood** to **Metal**, has, besides the elegance of appearance, the advantages of strength and extensive durability.'[18]

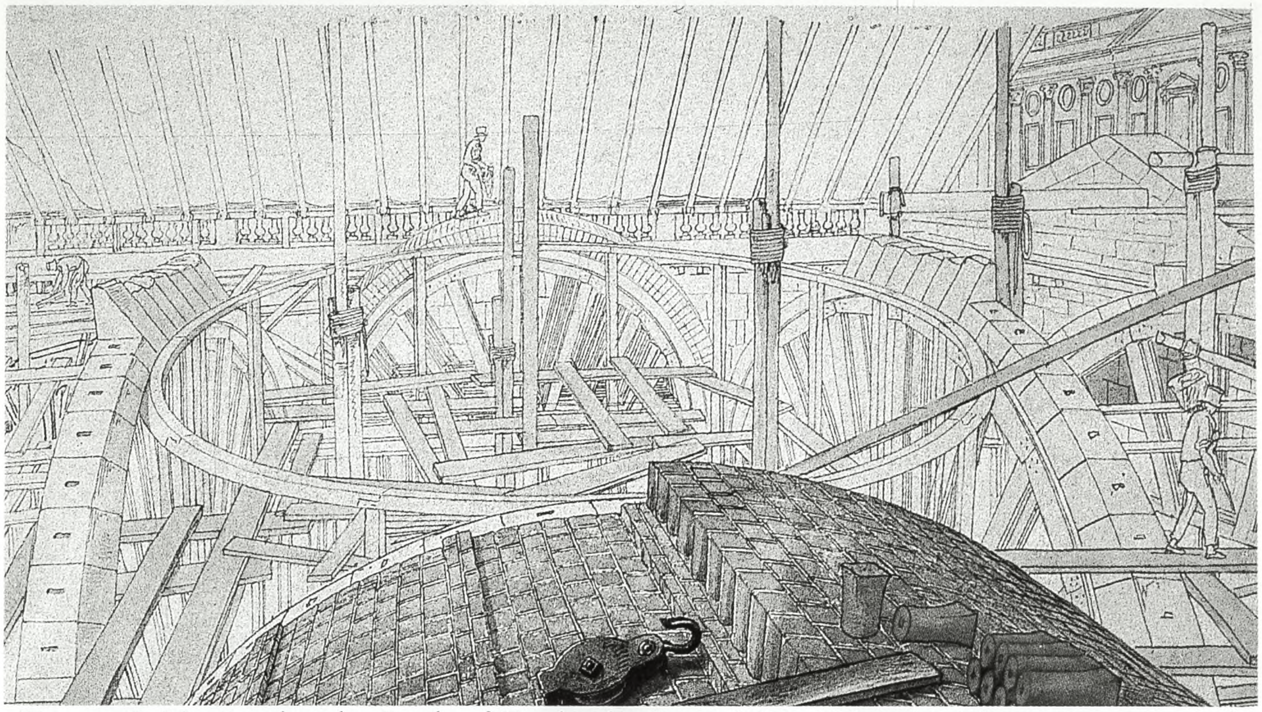


FIG. 2. J. M. Gandy: the Bank of England, view of the Old Colonial or Five Per Cent Office showing the vaults under construction, 1818. (By courtesy of the Trustees of Sir John Soane's Museum)

During the late eighteenth and early nineteenth centuries metallic sash bars of brass, bronze, copper, iron, gun metal and combinations of these were available. As Bottomley claimed, one of the major interests of contemporary architects was the admission of light into interiors.[19] Dance, Soane and Nash were particularly interested in new lighting effects. Nash's picture gallery at Attingham (1805–07) was constructed of cast iron members supplied by the Coalbrookdale Company. Arched ribs of cast iron spring from brick walls and carry the plaster ceiling and cornice. Coved glazing fills the space between the walls and the ceiling. Originally double-glazed, the outer glass surface was supported on cast iron glazing bars (Fig. 3). The inner painted glass surface is held in place by decorative bronze sash bars. Nash's other picture galleries, for Corsham Court (1797–98), Nash's own house in Regent Street (1822–24), and Buckingham Palace (1825–30), were also particularly interesting for their handling of light.

The most innovative and exciting use of metallic sashes and sash bars during the early nineteenth century was in conservatories and greenhouses. Metallic bars did not rot like wooden ones and were thinner in section, therefore allowing more light to fall upon the plants. Gardeners were very quick to recognise the horticultural advantages of metallic sash bars, and many horticultural writers of the later eighteenth century and early nineteenth century argued for their adoption.

One of the earliest cast iron conservatories was that attached to the Royal Lodge in Windsor Great Park, an extravagant *cottage orné* retreat designed by Nash for the Prince Regent in 1814. It was on a considerable scale (Fig. 4). Built of cast iron and supported on trellised cast iron pilasters, it was 120 feet long and placed so as to screen the offices from view.[20]

Debates over the best type of metallic sash bar raged throughout the early nineteenth century. One school held that non-ferrous metallic sashes were the best, as they did not rust.

FIG. 3. Attingham Park, Shropshire: Picture Gallery, cast iron roof light

FIG. 4. Royal Lodge, Windsor: engraving of main elevation

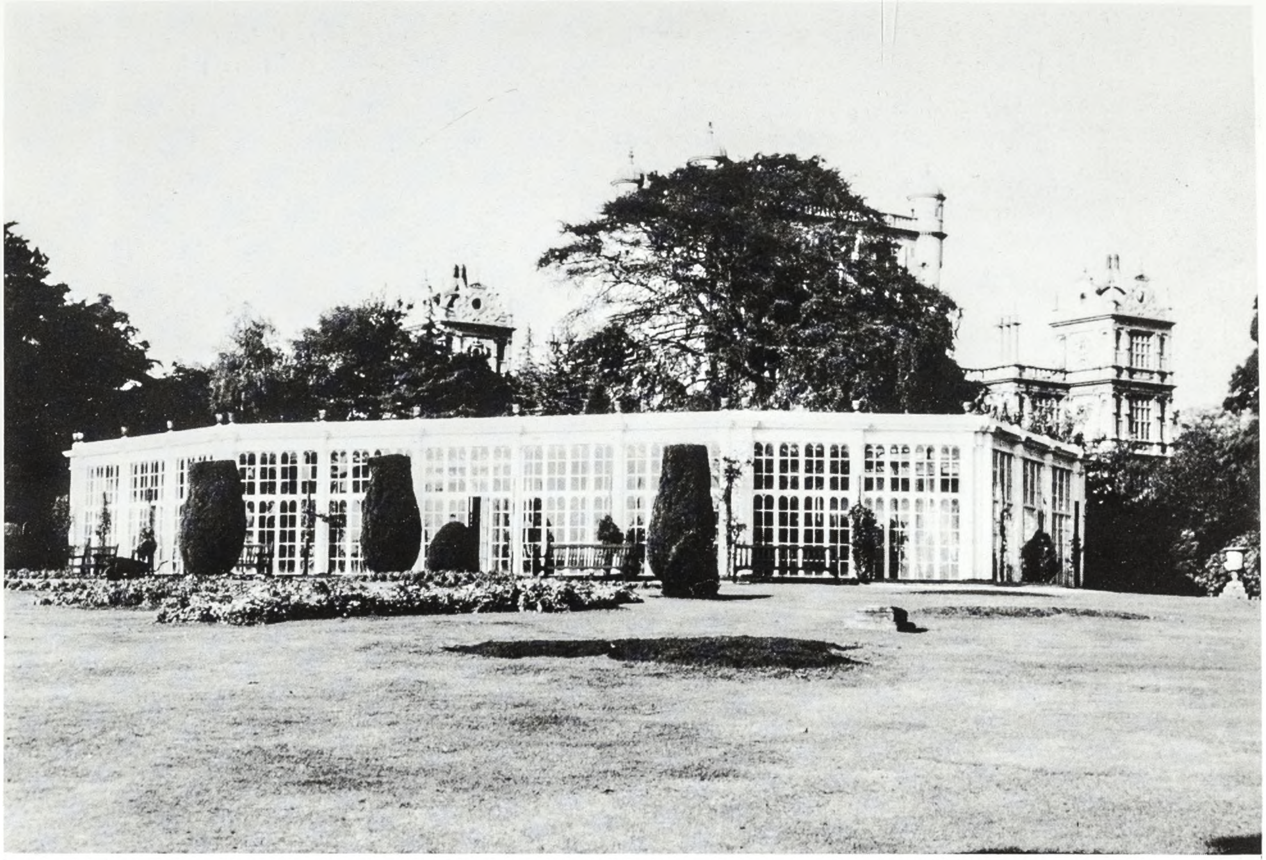
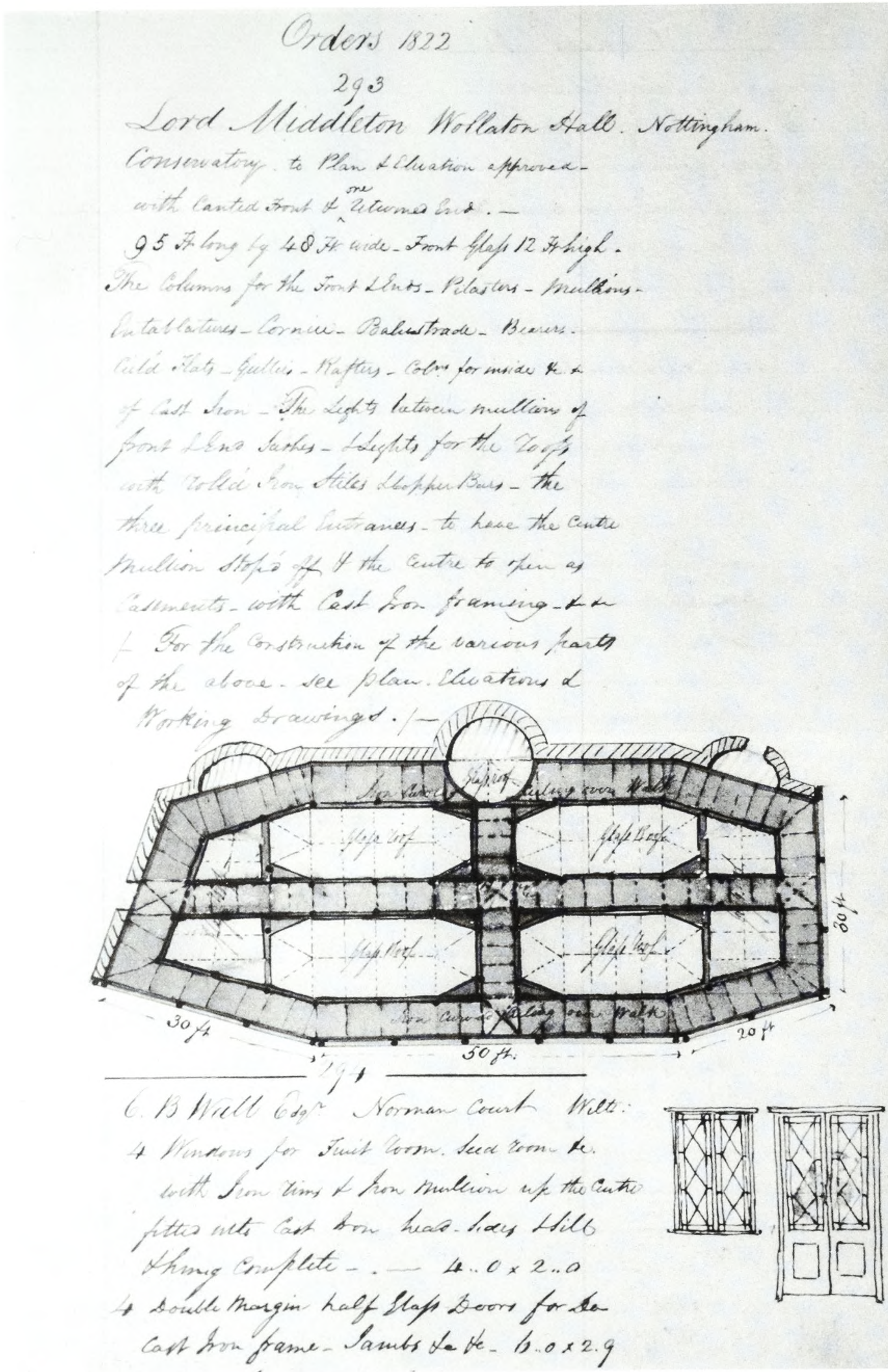


FIG. 5. Wollaton Hall, Nottingham: Camellia House, main elevation

Copper glazing bars were widely used during the early decades. Jones and Clark (later Clark and Hope, and subsequently Henry Hope) of Birmingham were a well known and reputable firm who specialised in metallic sashes composed of iron frames and copper glazing bars. Established in 1818, they produced many remarkable conservatories during their first thirty years of business.[21] Their earliest extant work is the Camellia House at Wollaton Hall, Nottingham, which was ordered in the summer of 1822 (Fig. 5). Jones and Clark's order book for that period includes a rough ground plan of the building (Fig. 6).

The Camellia House was probably designed by Jeffry Wyatt as he is mentioned in the order book as having supplied the design for the internal north-east elevation. An earlier unexecuted design, illustrated many years later in one of Henry Hope's catalogues, is very similar to Wyatt's Camellia House at Bretton Hall of 1815 with a canted projecting bay at each corner.[22] The Camellia House is entirely metallic in its construction. The elevations are made of cast iron, the roof is carried on hollow cast iron columns which function as down pipes, draining rain water from the roof (Fig. 7). Curved plates of cast iron form the barrel-vaulted roofs over the pathways. The glazed lights above the plant beds were originally constructed with wrought iron frames and copper glazing bars.

The small domed conservatory at Hilton Park near Wolverhampton is contemporary with the Camellia House at Wollaton (Fig. 8). It too is completely metallic in its construction (with the exception of the rear half of the building). The front elevation is framed by cast iron pilasters and a cast iron gutter. The main structural ribs of the dome, which spring from the gutter, are of wrought iron and the glazing bars are of copper. These are formed from a copper sheet, folded into a cruciform shape. This was accomplished by drawing the strip of copper sheet through dies or moulds. Several patents for forming glazing bars of metal sheet were taken out by different inventors during the first decade of the nineteenth century. The


Orders 1822

293

Lord Middleton Wollaton Hall. Nottingham.

Conservatory to Plan & Elevation approved - with Canted Front & one Returned End. —

95 Ft long by 48 Ft wide - Front Glass 12 Ft high.

The Columns for the Front & Ends - Pilasters - Mullions - Entablatures - Cornice - Balustrade - Bearers. Gild Flats - Gullies - Rafters - Colrs for inside &c. & of Cast Iron - The Lights between mullions of front & Ends Sashes - & Lights for the Roofs with Rolled Iron Stiles & Copper Bars - the three principal Entrances - to have the Centre Mullion Stopd off & the Centre to open as Casements - with Cast Iron framing - &c &c / For the Construction of the various parts of the above - see plan. Elevations & Working Drawings. / —

294

C. B. Wall Esqr Norman Court Wilts.

4 Windows for Fruit Room. Seed room &c. with Iron Tims & Iron Mullion up the Centre fitted with Cast Iron head - sides & Sill & hung Complete - — 4..0 x 2..0

4 Double Margin half Glass Doors for do. Cast Iron frame - Jambs &c &c - 6..0 x 2..9

Fig. 6. Wollaton Hall, Nottingham: Camellia House, plan from Jones and Clark Order Book, Vol. 1, Order 293. (Summer 1822)

FIG. 7. Wollaton Hall, Nottingham: Camellia House, interior

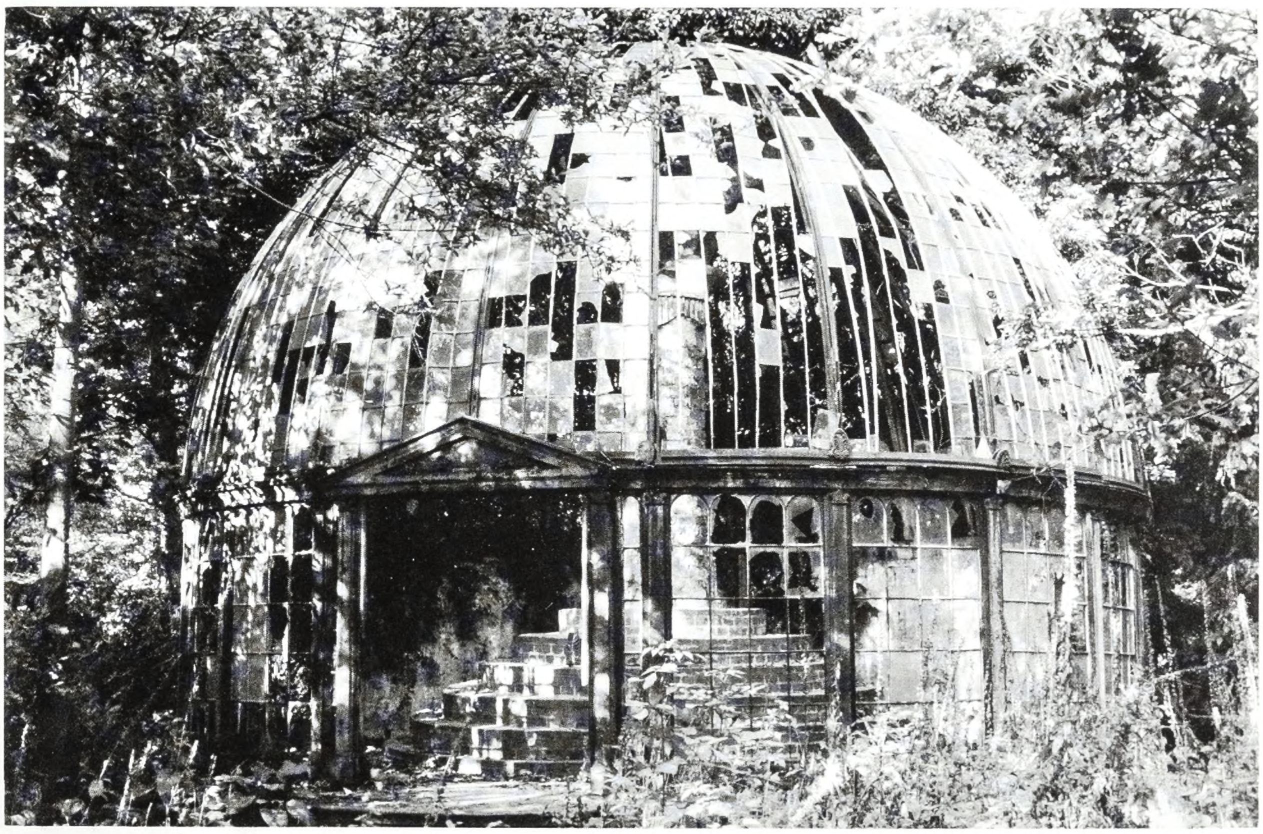


FIG. 8. Hilton Park, near Wolverhampton: Conservatory, exterior

Hilton Park conservatory is typical of the mixed metallic construction favoured by Midlands firms such as Jones and Clark, Richard and Jones, J. S. Jorden and T. and G. Timmons.[23]

In 1816 John Claudius Loudon invented a wrought iron glazing bar and presented a specimen to the Horticultural Society of London. This invention had many advantages over other metallic glazing bars then available. Wrought iron glazing bars were much stronger than other non-ferrous metallic sash bars, and they possessed greater tensile strength than cast iron glazing bars. Wrought iron glazing bars were malleable and could be welded together or bent to the desired curve or shape. The first specimen of Loudon's invention had been produced by W. and D. Bailey of 272 Holborn in London.[24] In 1818 Loudon transferred his rights of the invention to the Baileys and they entered a patent in July of that year.[25]

Early examples of conservatories and greenhouses built of Loudon's wrought iron glazing bar are interesting for the fact that the glazing bars were the primary structural element. The earliest surviving example of these bars is the Pinery erected in 1820 for Thomas Andrew Knight at Downton Castle, Shropshire. It was designed by Knight and reflects his thoughts on the optimum shape for a hothouse or greenhouse.[26] Built by the Baileys, it appears in their list of executed works published in Loudon's second edition of the *Encyclopedia of Gardening* (1824).

Soon after Loudon's wrought iron glazing bar appeared, two architects, Decimus Burton and George Webster, designed conservatories which were based upon Loudon's curvilinear theory and the designs he published.[27] In 1826 George Webster designed a bow fronted curvilinear conservatory for Dallam Tower in Cumbria.[28] It was undertaken at the same time as the building of the stable block, and was erected against the rear wall of the block in order to screen it from the view of the house (Fig. 9). Originally the conservatory was attached to the house by means of a verandah. The wrought iron glazing bars of the roof and elevations are supported by a cast-iron framework of pilasters and gutters, similar in principle to the arrangement at Hilton Park. Inside, the roof is supported by light wrought

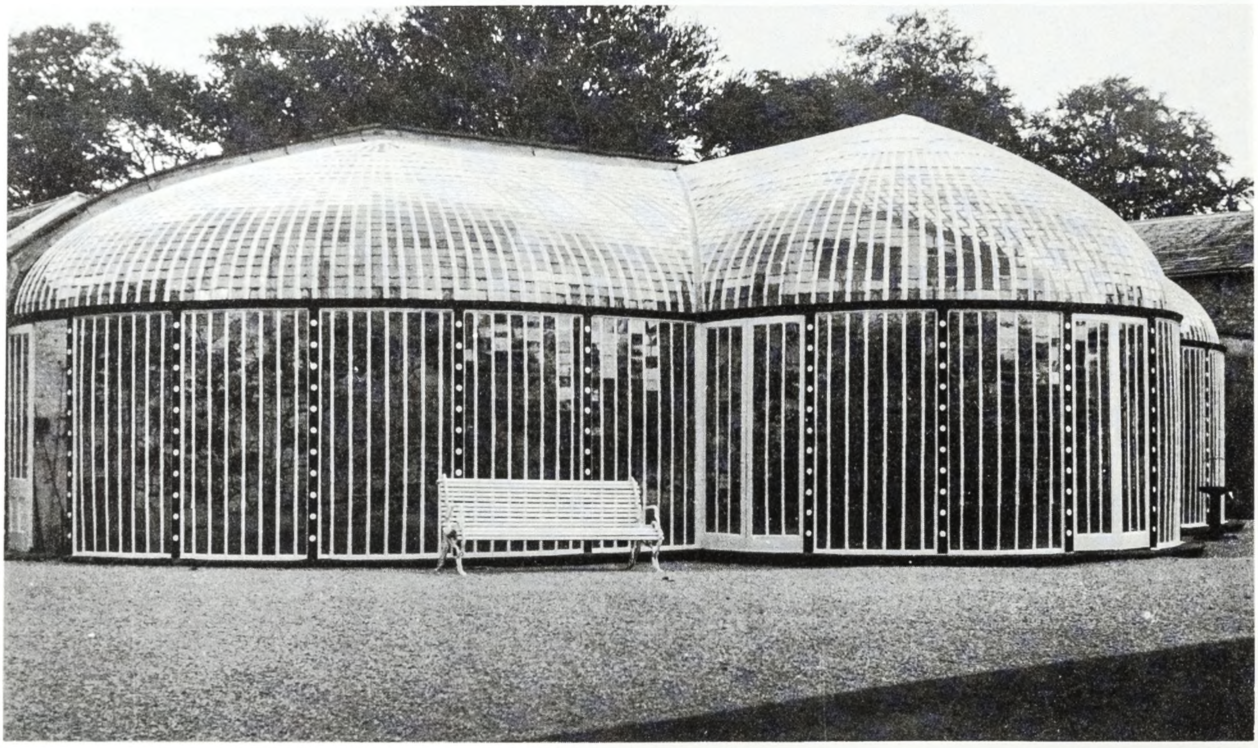


FIG. 9. Dallam Tower, Milnethorpe, Cumbria: Conservatory, exterior

iron purlins carried on thin elegant iron columns. It is possible that the conservatory at Dallam Tower was erected by the Baileys. It is very similar in several ways to the Palm House at Bicton in Devon which has been attributed to them. The cast iron pilasters have similar mouldings and decorative features.[29]

Three years earlier, Decimus Burton designed a conservatory for George Bellas Greenough, an amateur geologist and scientist, at his new villa called Grove House, which was then under construction on the edge of Regent's Park (Fig. 10). Built by the Baileys of Holborn, it was mentioned by Loudon in the second edition of the *Encyclopedia of Gardening* (1824). It is directly based upon the curvilinear semi-elliptical form suggested by Loudon.

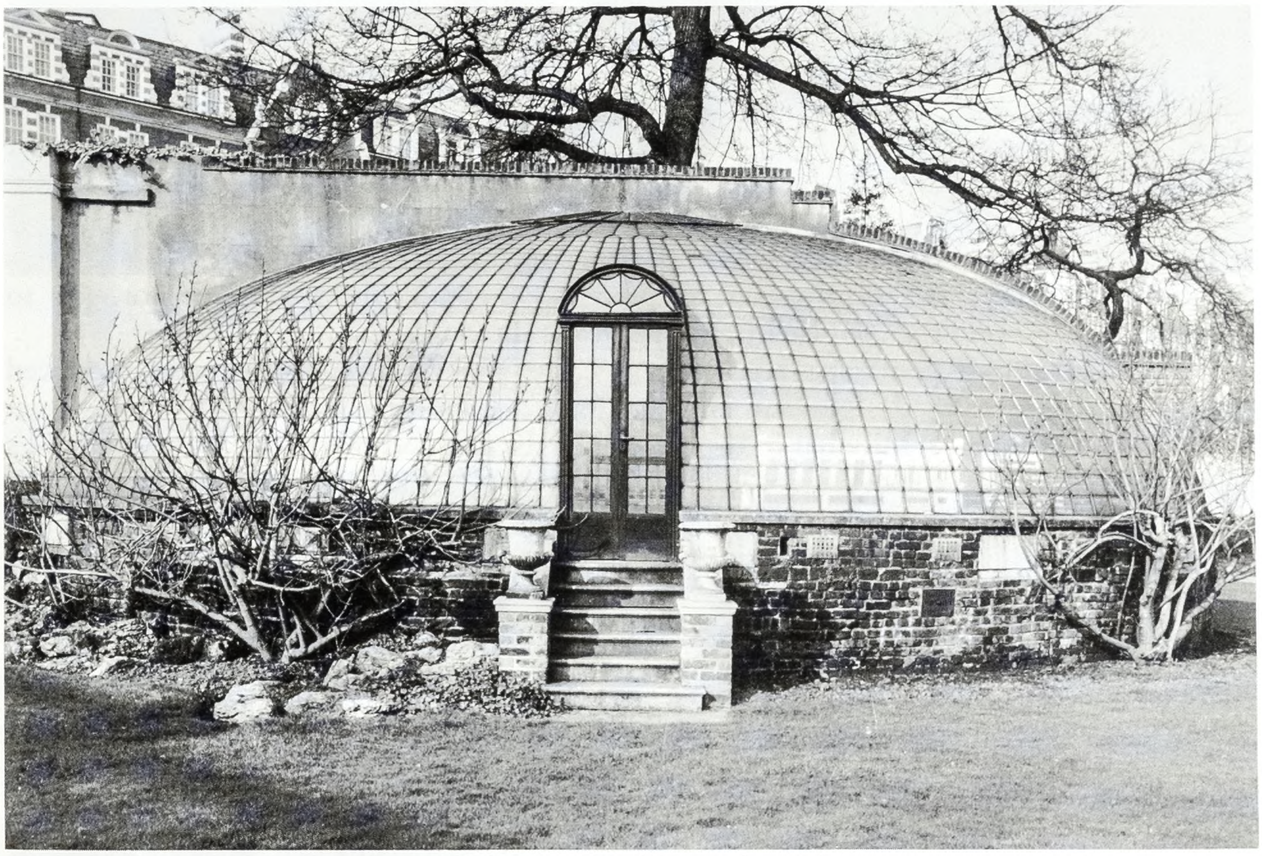


FIG. 10. Grove House, Regent's Park, London: Conservatory, exterior

On 20th November 1823, C. R. Cockerell visited Grove House and recorded his impressions in his diary:

> 'Mr Greenough's house situation beautiful on Regent's Canal well managed that visto from Library looks on conservatory and range of walling classically divided to hide offices stables &c and Portland Town beyond it — an opening left with a patch of planting beyond really well contrived — conservatory has an elegant form but looks as fragile as a blubber.'[30]

Cockerell's use of the word 'blubber' is interesting as it was common usage for jellyfish at that time and indicates his impression of the form and transparency of the structure.

Burton was also responsible for the delightful range of conservatories over 300 feet in length which were erected to the south and east side of the Colosseum in Regent's Park. The

Colosseum was a vast domed panorama of London with a monumentally chaste Doric portico, designed by Burton and erected in 1824–27.[31] The conservatories were an additional attraction for visitors, offering the delight and mystery of ancient ruins, a statuary hall, a marine grotto, rare and exotic flowers and plants and a Gothic aviary. They comprised six interconnected spaces with elegant curvilinear iron and glass roofs of different shapes and sizes. Opened in 1829, the conservatories combined public amusement, recreation and promenading.[32]

Burton's interest in conservatories continued to develop through the nineteenth century and he was associated with some of the largest structures that were built.[33] It is interesting that he used different materials and adopted different designs. During the 1840s he collaborated with Richard Turner, a Dublin ironfounder, on two of the most important curvilinear constructions in wrought iron, the Palm House at Kew Gardens (1844–48), and the Winter Garden of the Royal Botanic Society in Regent's Park (1844–46). Burton also designed many architectural conservatories which were attached to houses. Grimstone Park in Yorkshire (1840), Glevering Hall in Suffolk (1834) and Hertford Villa in Regent's Park (1827) are but three examples. Into some of these designs he introduced cast iron columns and metallic glazing bars. He also adopted ridge and furrow glazing, utilising grooved wooden sash bars similar to the system devised by Joseph Paxton. The conservatory at Glevering Hall, is notable for its combination of different roof shapes and different types of materials. In the roof Burton employs both metallic and wooden sash bars as well as curvilinear and ridge and furrow roof shapes. It is a combination which is not easy to integrate, and the result is confused but nonetheless interesting.

Two of Burton's contemporaries, Jeffry Wyatt and Charles Fowler, also produced striking and innovative designs for architectural conservatories. Jeffry Wyatt designed several large examples, traditional in the sense that they all had elevations with stone piers and a stone entablature (with the obvious exception of the Camellia House at Wollaton Hall), but interesting for the way in which he pared the stonework down to an absolute minimum in order to allow more light inside.[34] The finest example was designed in 1819 for Belton in Lincolnshire where he created an architectural elevation of great simplicity while achieving a light and lofty interior. The roof is carried on light open trellised iron columns which are tied to the walls and to each other by light arched iron ties. The original glazed roof was framed in timber and fitted with sliding wooden sashes, a traditional, if not old fashioned, method of construction. The thin stone piers are connected by wrought iron ties at their tops, presumably to prevent movement during construction and to restrain movement following erection of the lintels and stone entablature.

If Jeffry Wyatt's use of iron appears somewhat timid, Charles Fowler's conservatory at Syon House for the Duke of Northumberland decisively exploits the use of iron in association with a conservative architectural masonry solution (Fig. 11). Designed in 1820 and completed in 1827, it was one of the most ambitious conservatories of the decade, in scale and design. The large domed central conservatory (for stove trees and large plants), connected to two smaller flanking pavilion conservatories (for greenhouse plants and orange trees) by way of glazed quadrants, was on an unprecedented scale, exceeding anything else in Britain.[35] The elevations are in effect architectural masonry screens of great lightness. The stone piers between the round-headed glazed openings are reduced to a minimum thickness. Fowler inserted a pierced hollow box cast iron transom at the springing of the window heads to stabilise the piers. The 65-foot high dome has a diameter of 35 feet and is formed of twenty-three cast iron ribs which are seated into an upper ring beam of cast iron. This is carried on short vertical cast iron pilasters at clerestory level which are in turn seated onto a lower ring beam of cast iron. The lower ring beam is decoratively pierced and is carried on pierced cast iron arches which spring from a ring of sixteen cast iron columns (Fig. 12). The

Fig. 11. Syon House, Middlesex: Conservatory, exterior

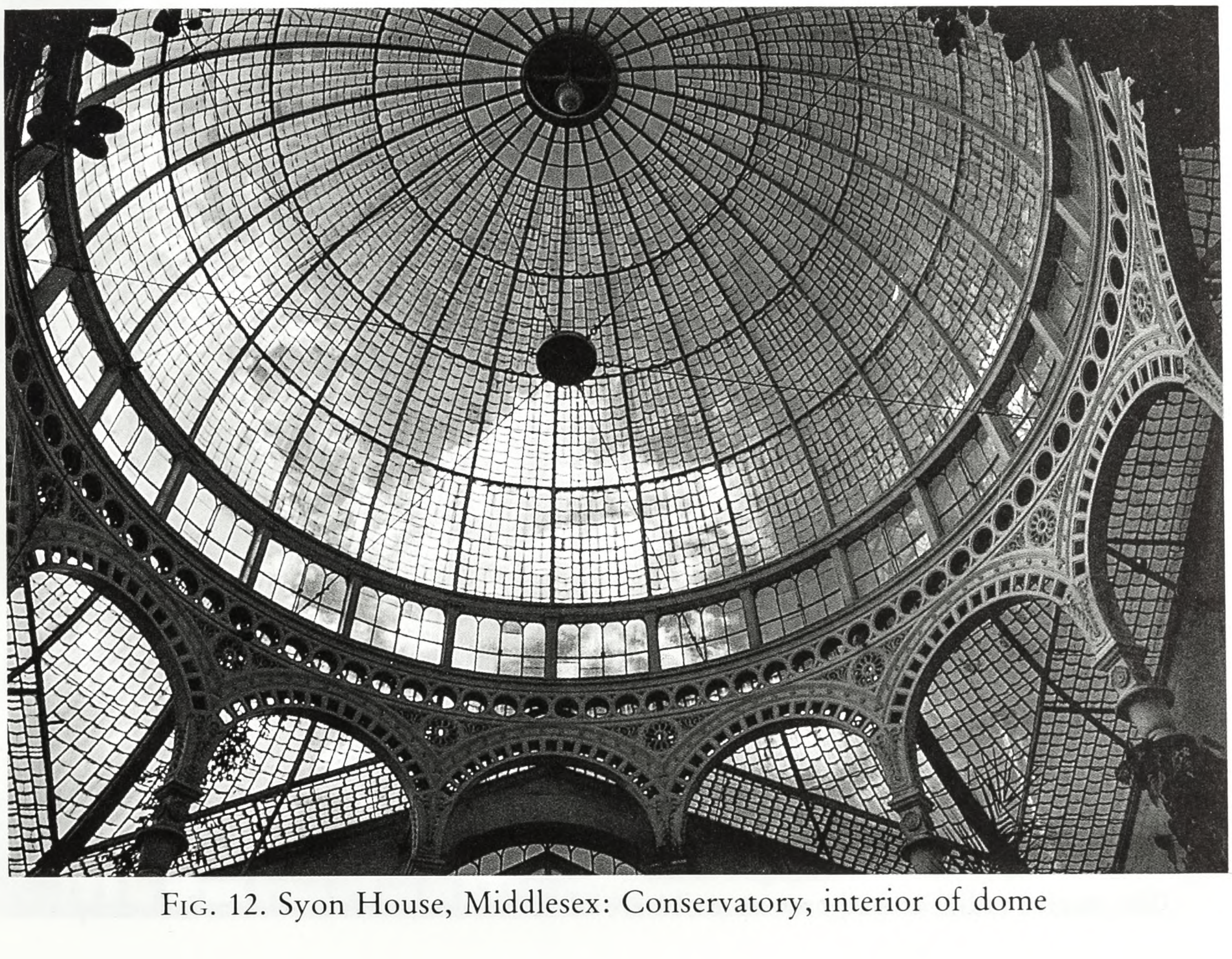


Fig. 12. Syon House, Middlesex: Conservatory, interior of dome

iron work and metallic sashes were provided by Richards and Jones of Birmingham. Like Jones and Clark and other Midlands firms they favoured non-ferrous metallic glazing bars. At Syon they used brass glazing bars, made from sheets and bent into cruciform shape.[36] The sash frames were of wrought iron. At the same time as the conservatory was under erection Richards and Jones erected a range of metallic hothouses for the kitchen garden over 400 feet in length.[37]

Of all the architects working at the beginning of the nineteenth century it was John Nash who experimented most widely with new materials and building methods. His patent iron bridge design and the two iron bridges for Sir Edward Winnington, the iron conservatory at Royal Lodge, Windsor, and his use of cast iron beams in Buckingham Palace have already been mentioned. He also employed iron in the construction of the picture galleries at Corsham Court and Attingham Park.

Nash's work at the Brighton Pavilion for the Prince Regent which is extensively covered by John Dinkel in his book, *The Royal Pavilion, Brighton*, demonstrates perhaps better than anywhere else the extent to which he adopted new materials and building methods.[38] Nash used a surprising amount of iron within the structure of the building. He also experimented with a patent artificial stucco exterior finish, metallic glazing bars and brick arch floor construction, all relatively new at that time.

The Brighton Pavilion had been transformed by Henry Holland from a small farmhouse into a 'Marine Pavilion' for the Prince Regent in 1787. The central feature of the east elevation was the domed Saloon. With time the Prince desired a grander architectural effect and enlarged accommodation, and in 1801 canted wings were added to the north and south ends of the east elevation, flanking the 'Marine Pavilion'.[39] During 1802 the earliest in a succession of oriental interiors appeared, but in the following year Holland left the Prince's service. The Prince's desire to create an Oriental fantasy was taken up by Porden and Repton, both of whom prepared schemes in exotic Oriental and Hindu styles respectively.[40]

It was not until 1814 that Nash began working at the Pavilion, but within a very short time the appearance of the building was changed. One of the earliest alterations, in September 1815, was the installation of the two famous cast iron 'bamboo' staircases in the spinal corridor of the Pavilion. Cast in London by William Slarke, they were wholly of cast iron — stringers, risers, treads and handrail. The upstairs corridors and ante rooms to which they gave access were lit from roof lights also framed of cast iron.[41]

In 1818 a great transformation of the east front began with the building of the Banqueting and Music Rooms to the north and south of Holland's 'Marine Pavilion', on the site of the canted wings which had been built in 1801. These new rooms, forty feet square, were much grander, and closer in scale to state reception rooms than to those of a seaside villa. They were crowned with concave conical tent roofs which were constructed of twenty concave-arched laminated timber trusses. These were arranged as radial ribs with their bottom ends seated on a flat ring of cast iron to prevent outward thrust[42] (Fig. 13).

The greatest transformation was the erection of a second floor, which included a billiard room enclosed by a great onion dome over the Saloon. This was under construction during the summer in 1818, when the Prince Regent travelled especially from London to see the erection of the structural cast iron work. The concept was bold in proposing a second floor, which, because of its function, needed to carry a considerable load over an existing interior that was not altered in form or appearance. The solution was ingenious. Nash could not support the additional storey and new domed roof on the existing external walls, so he devised a cage of iron columns encircling the walls and rising above the ceiling of the Saloon (Figs. 14 & 15). The second floor was formed on top of a shallow dome of arched cast iron ribs which directed the entire weight of the floor onto the cage of iron columns.

The twelve radial arched cast iron ribs are of 'T' section, with an eleven inch deep web

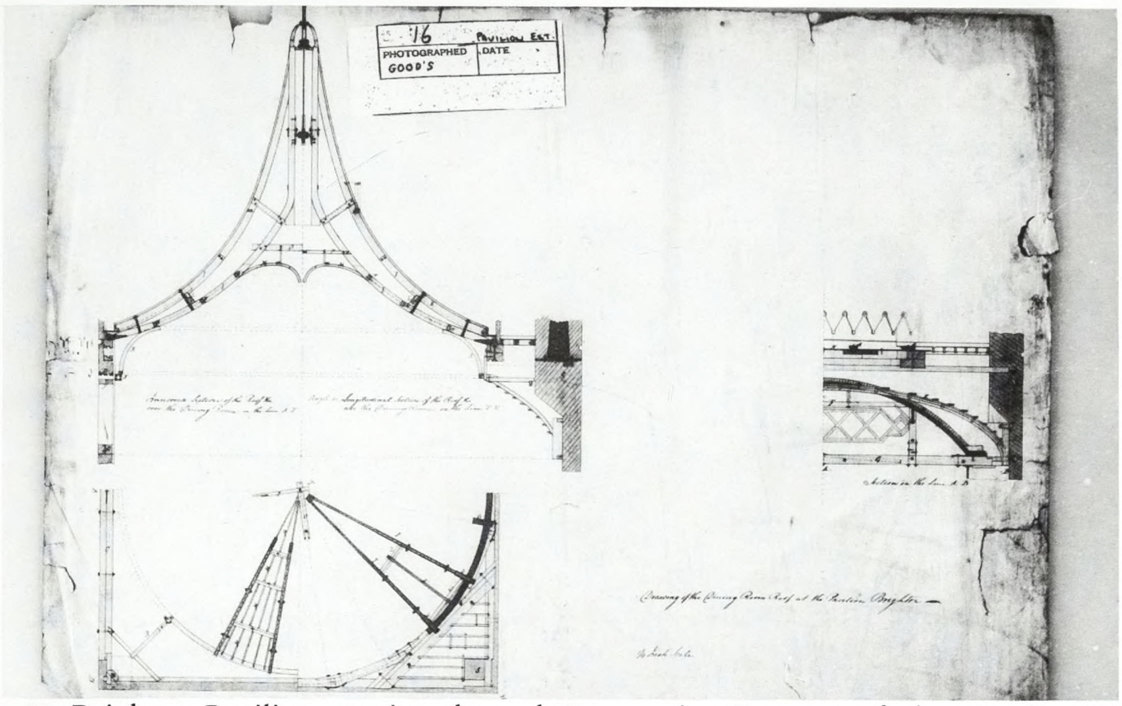


FIG. 13. Brighton Pavilion: section through Banqueting Room roof, drawing by William Nixon, 1827. (Figs. 13, 14, 15 by courtesy of the Keeper of Fine Arts, the Royal Pavilion, Brighton)

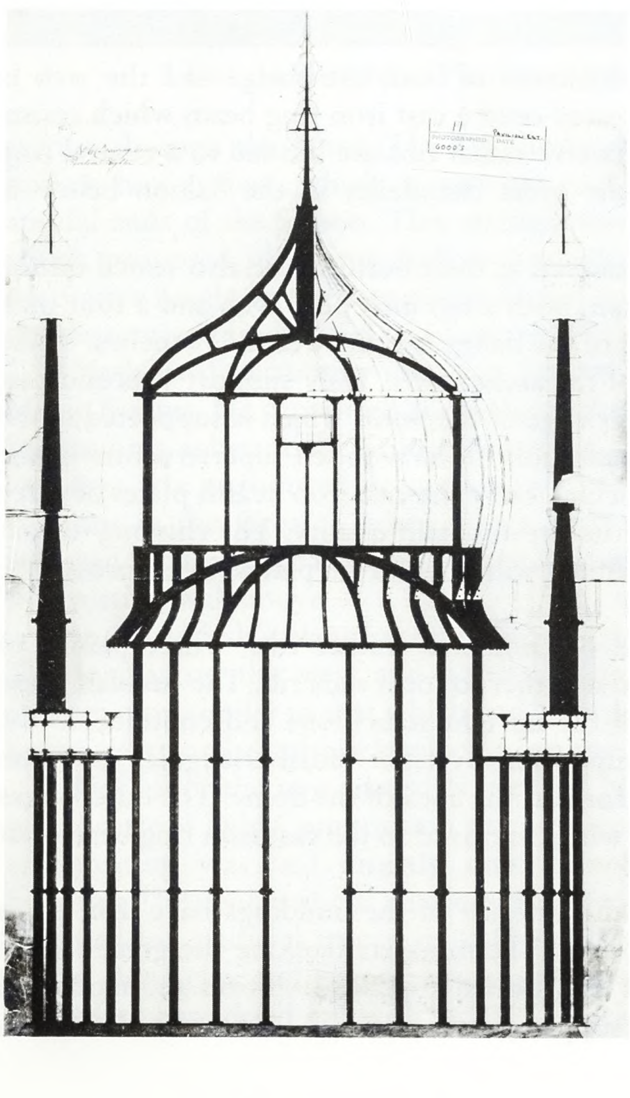


FIG. 14. Brighton Pavilion, section through Saloon, drawing by William Nixon, 1827

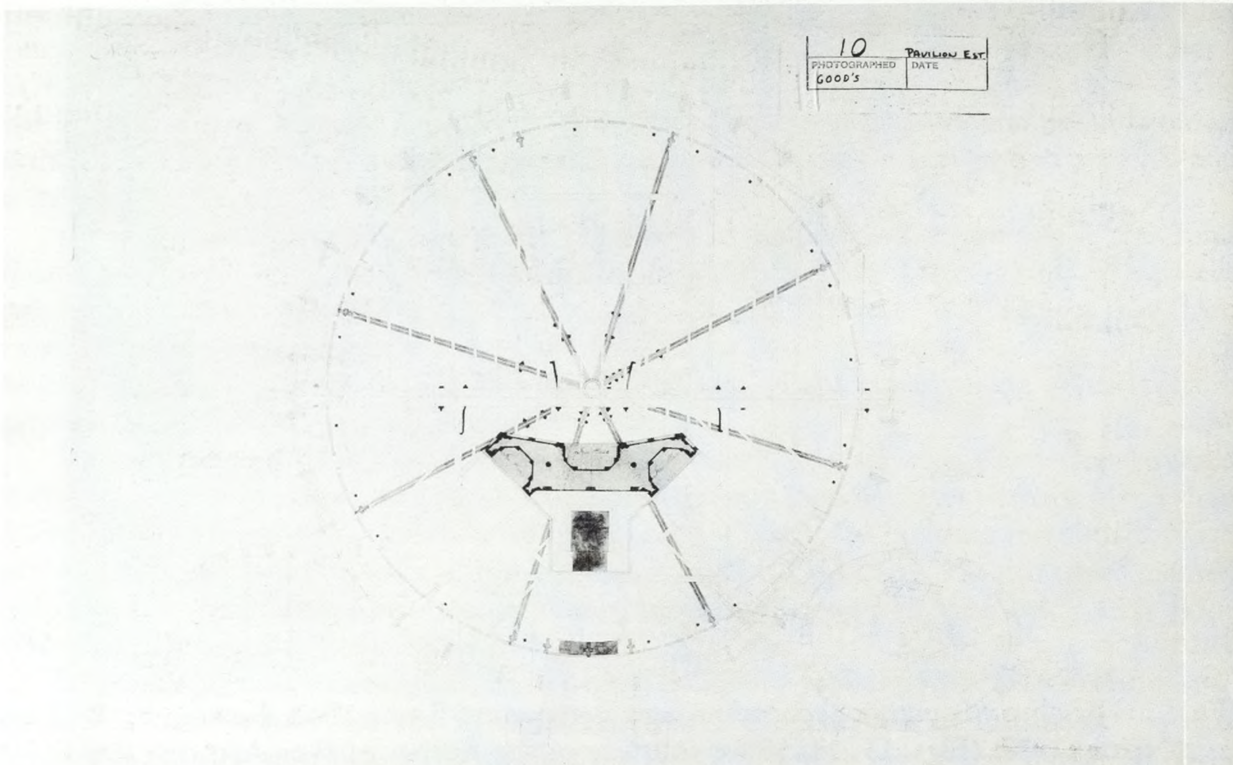


FIG. 15. Brighton Pavilion, plan of second floor above Saloon, drawing by William Nixon, 1827

and a four inch wide flange (Fig. 16). The thickness of both the flange and the web is 1⅜ inches. The ends of the cast iron ribs are seated onto a cast iron ring beam which resists outward thrust. At the apex of the dome the twelve radial ribs are bottled to a central ring which also provides a 'fixing' from which the great chandelier in the Saloon below is suspended.

Thirty-two upright cast iron stanchions, curved at their bottom, are also seated on the cast iron ring beam. They are also of 'T' section, with a ten inch deep web and a four inch wide flange. Like the arched ribs, the thickness of the flange and the web is 1⅜ inches. These stanchions rise to the same height as the top of the arched ribs. They support a second cast iron ring beam that acts as a bearer for the outer edge of the floor, which is supported in the centre by the apex of the segmental dome. In addition to the wooden superstructure of the floor, the radial ribs also support iron bearers which carry the cast iron hearth plates of three fireplaces. No doubt cast iron was chosen for its fire-resistant quality. The chimney throat and breast surrounding the grate are also lined with cast iron plates to improve the fire-resistant character.

The great onion-shaped dome is formed of laminated timber ribs. Three planks of timber approximately one inch thick are bolted together to form each rib. The bases of these ribs spring from approximately mid-height of the upright stanchions and continue to the apex of the dome. The top of the dome is supported by eight radial triangular cast iron trusses, their top members curved to the same form as the apex of the dome. The outer edges of the trusses are carried on cast iron columns which are fixed to the cast iron ring beam that carries the second floor.

Some of Nash's decorative elements on the exterior of the buildings have iron cores around which stonework is either sleeved or set.[43] The minarets flanking the great central dome have iron cores, cast in three sections and bolted together to form the elongated vertical spires. Originally stone sleeves were slipped down over the iron cores. The cross

FIG. 16. Brighton Pavilion: cast iron dome above Saloon ceiling

section through the dome (Fig. 14) shows the bases of the minarets fixed onto plate iron hollow box girders, which in turn are anchored to the cast iron columns encircling the apsidal ends of the Saloon. This arrangement is perhaps related to his patent bridge design which proposed plate iron hollow box voussoirs, bolted together to form an arch. The decorative finials on the tops of the domes and concave tent roofs also have iron cores, as do the decorative Hindu oriel windows on the west elevation.

Nash used decorative cast iron brackets to support the eaves of the Banqueting and Music Rooms. He supported a large bank of chimney flues between the Music Room and the Saloon on a substantial cast iron bearer at roof level. The decorative chimney pots are also cast iron. He introduced decorative cast iron columns inside the Pavilion. The 'palm tree' columns in the Great Kitchen which carry the central lantern are well known. He also enlarged the Entrance Hall by moving the west wall and inserting cast iron columns to carry the existing wall above.

In 1819 Nash's plans for extending the private apartments to the north were carried out. The loggias on the west and north elevations are interesting as they are of brick arch construction similar to that which had been developed by mill owners in the 1790s. Cast iron beams carry arches of brick which form the first floor level of the loggia.

Not all of the new materials used by Nash were successful. One unfortunate mistake was the use of Dihl Composition patent stucco on the roof, domes and tent roofs. The patent composition was laid directly onto tinned iron sheets which were nailed to timber boarding.[44] Patent artificial stuccoes had been popular from the mid eighteenth century. Dihl patented his artificial stucco in 1815 and again in 1816.[45] It consisted of linseed oil, lead oxide, china clay and ground brick, which was thinned by turpentine. The turpentine and linseed oil base dried out with time and cracks in the surface of the stucco formed which let in water. This problem was particularly serious on the tent roofs and they were re-roofed in copper as early as 1827. Nevertheless, most of the new materials and building methods used by Nash at the Brighton Pavilion were successful in their application. Several of the complicated design solutions were made possible by them. In particular, the exotic oriental character of the building is due in part to their use.

Building technology during the decades between 1790 and 1830 was very experimental. Many new ideas were explored. These paved the way for later developments which realised more fully the potential of iron. The 1830s and 1840s were decades of greater achievement which saw much wider use of cast iron beams, columns and arches in buildings of all kinds, from commercial to industrial, both residential and public. Notable examples of this more widespread use of iron by architects include Charles Fowler's Hungerford Fish Market (1835), Sir Charles Barry's Houses of Parliament (erected 1840–56), Sidney Smirke's General Post Office, London (1845), Barry's Bridgewater House (designed 1845 and erected 1847–57), Sir James Pennethorne's Museum of Economic Geology, London (1847–48), J. B. Bunning's Coal Exchange, London (1847–49), and Pennethorne's Public Record Office (1850–58). During this time the potential of wrought iron was recognised, as in Burton and Turner's Kew Palm House (1844–48), as well as the inherent limitations of cast iron.[46]

The new technology between 1790 and 1830 introduced into structures a new lightness of effect which Repton advocated as early as 1803. Devices such as roof lights, shallow hollow-pot vaulted spaces, and thin iron supports were used in conjunction with the accepted architectural styles of the day. In some instances they added a certain piquant element by their juxtaposition. Cast iron beams and hollow-pot vaults also made possible architectural interiors on a grand scale such as those by Soane at the Bank of England and the King's Library by Smirke at the British Museum. One of the finest vaulted spaces constructed in hollow pots and spanning eighty feet was H. L. Elmes's Great Hall of St. George's Hall, Liverpool, erected during the mid 1840s.

With more developed application of new materials, particularly iron and plate glass, expression of architectural style began to alter from the earlier part of the century. Technology became more evident on elevations of commercial and industrial buildings. Particularly in the classical style, a new arrangement and a sense of debasement can be recognised during the 1840s and 1850s. As structure became the dominant feature so architectural style was adapted to suit.

NOTES

1. The Halle au Blé was built 1763–69 to the designs of Le Camus de Mezières. In 1782–83 the building was given a domed roof in wood by Roubo in collaboration with Legrand et Molinos. Bélanger's dome survives beneath large mural paintings which were installed when the building was remodelled internally and externally in 1888.
2. B. Lemoine, *L'Architecture du Fer*, Champ Vallon: Seyssel, 1986, pp. 155–57.
3. T. Ruddock, *Arch Bridges and Their Builders 1735–1835*, Cambridge University Press: Cambridge, 1979, chapters 11, 12 and 13.
4. R. J. M. Sutherland, 'Pioneer British Contributions to Structural Iron and Concrete: 1770–1855', *Building Early America*, ed. C. E. Peterson, Chilton Book Co: Philadelphia, 1976, pp. 96–118.
5. Ruddock, op. cit., pp. 140–41; J. M. Robinson, *The Wyatts, An Architectural Dynasty*, Oxford University Press: Oxford, 1979, p. 50; T. Bannister, 'The First Iron Framed Buildings', *The Architectural Review*, Vol. 107, April 1950, p. 244.
6. Loudon advocated the Curvilinear style for conservatories and glasshouses, see: J. C. Loudon, *Remarks on the Construction of Hothouses*, J. Taylor: London, 1817; *Sketches of Curvilinear Hothouses*, 1 March 1818; 'Letter to the Editor', *New Monthly Magazine*, Vol. 9, May 1818, pp. 313–15; *An Encyclopedia of Gardening*, 1st ed., Longman, Hurst, Rees, Orme and Brown: London, 1822; and *The Greenhouse Companion*, Harding, Triphook and Lepard: London, 1825.
7. H. Repton, *Observations on the Theory and Practice of Landscape Gardening*, J. Taylor: London, 1803, p. 106.
8. A. W. Skempton, 'Samuel Wyatt and the Albion Mill', *Architectural History*, Vol. 14: 1971, pp. 53–73; J. M. Robinson, op. cit., pp. 44–47. The Albion Flour Mill was designed by Samuel Wyatt and

erected in 1783–86.
9. 'Resolutions of the Associated Architects with the Report of a Committee by them appointed To consider the Causes of the frequent Fires, and the best means of Preventing the Like in future', 26 July 1793; T. Bannister, op. cit. pp. 243–44.
10. P. Guedes, ed., *The Macmillan Encyclopedia of Architecture and Technological Change*, Macmillan Press Ltd: London, 1979, pp. 94–95.
11. T. Bannister, 'The First Iron-framed Buildings', *The Architectural Review*, Vol. 107, April 1950, pp. 231–46; H. R. Johnson and A. W. Skempton, 'William Strutt's Cotton Mills, 1793–1812', *Transactions of the Newcomen Society*, Vol. XXX, 1955–56 and 1956–57, pp. 179–205.
12. J. M. Crook and M. H. Port, *The History of the King's Works*, Vol. VI, HMSO, London: 1973, pp. 356–57; J. M. Robinson, op. cit. pp. 50–51; T. Bannister, op. cit., pp. 243–44.
13. J. M. Crook and M. H. Port, op. cit., pp. 416–17; J. Gloag and D. Bridgewater, *A History of Cast Iron in Architecture*, George Allen and Unwin: London, 1948, pp. 198–99.
14. J. M. Crook and M. H. Port, op. cit., pp. 466.
15. Ibid, p. 276.
16. T. Bannister, op. cit., pp. 233–34.
17. D. Dunster, ed., *John Soane*, Academy Editions: London, 1983, pp. 61–74.
18. J. Bottomley, *Windows, skylights and fanlights, balcony railings, Railings*, 42 Wood St, Cheapside: London, December 1793.
19. D. Watkin, 'Soane and his Contemporaries', D. Dunster, ed. *John Soane*, Academy Editions: London, 1983.
20. J. M. Crook and M. H. Port, op. cit., pp. 399–401; Sir Owen Morshead, *George IV and Royal Lodge*: Brighton, 1965; J. Summerson, *John Nash*, London: 1949, pp. 144–45.
21. Jones and Clark became known as Clark and Hope and then as Henry Hope in the mid 19th century. For an account of the Birmingham metallic sash trade see: Roy Anderson, *From Greenhouse to Conservatory*, 4th year dissertation, Birmingham School of Architecture, 1968 (copy in the Birmingham Reference Library).
22. *Jones and Clark Order Books*, Vol. I, Order 293 (summer 1822) and 385 (December 1823). Henry Hope, *Book of Designs of Horticultural Buildings & C*, Birmingham, 1874, plate 36; D. Linstrum, *Sir Jeffry Wyatville*, Oxford: Clarendon Press 1972, pp. 61–67.
23. Anderson, op. cit.
24. J. C. Loudon, *Sketches of Curvilinear Hothouses*, 1 March 1818; and 'Letter to the Editor', *New Monthly Magazine*, Vol. 9, May 1818, pp. 313–15.
25. W. Bailey, 'Windows & C', enrolled 11 July 1818, No. 4277 (London: Patent Office, 1857).
26. T. A. Knight, 'Suggestions for the Improvement of Sir George Steuart MacKenzie's Plan for Forcing-Houses', *Transactions of the Horticultural Society of London*, Vol. 2 (1817), pp. 350–53, and Plate 26; 'Upon the Advantages and Disadvantages of Curvilinear Iron Roofs to Hot Houses', *Transactions of the Horticultural Society of London*, Vol. 5 (1824), pp. 227–232, and Plate 8. [J. C. Loudon] *The Different Modes of Cultivating the Pine-Apple*, (London: 1822) pp. 157–59.
27. His earliest curvilinear designs appeared in : J. C. Loudon, *Remarks on the Construction of Hothouses* (London: 1817) and *Sketches of Curvilinear Hothouses* (London: 1818), but neither was published in large editions. His theory and designs were more widely available through the *Encyclopedia of Gardening*, London: 1822, 1st ed. and 1824, 2nd ed.
28. Webster's drawings are held in the Record Office, County Offices, Kendal, Cumbria.
29. For the Bicton Palm House see: J. Hix, *The Glass House*, Phaidon Press: London, 1974, pp. 24–27; and C. Jones 'Two Glass Houses, Syon and Bicton', *The Architects' Journal*, 29 April 1987, pp. 57–62.
30. J. Harris, 'C. R. Cockerell's "Ichonographica Domestica"', *Architectural History*, Vol. 14 (1971), pp. 19–20; E. J. Diestelkamp, 'Fairyland in London', *Country Life*, 19 May 1983, pp. 1342–44.
31. R. D. Altick, *The Shows of London*, Cambridge, Mass: Harvard University Press, 1978, pp. 141–62; and H. Honour, 'The Regent's Park Colosseum', *Country Life*, 2 Jan. 1953, pp. 22–24.
32. *A Brief Account of the Colosseum, in the Regent's Park, London* (1829).
33. E. J. Diestelkamp, op. cit.
34. Other examples of Jeffry Wyatt's chaste architectural conservatories were erected at Longleat, Wiltshire (c.1814), Bretton Hall, Yorkshire (1815), and the Aroid House, Royal Botanic Gardens, Kew (1836); see D. Linstrum, *Sir Jeffrey Wyatville*, Oxford: Clarendon Press, 1972.
35. C. M'Intosh, *The Book of the Garden*, 1853, p. 368.
36. C. Jones, op. cit., p. 57.
37. 'Calls at Suburban Gardens, 4 December 1826', *The Gardeners' Magazine*, Vol. II, 1827, p. 107; J. C. Loudon, 'Some Account of the Duke of Northumberland's Improvements in the Kitchen Garden and Forcing Department at Syon', *The Gardeners' Magazine*, Vol. V, October 1829, pp. 503–15; 'The Hot Houses at Syon', *The Gardeners' Magazine*, Vol. XIV, No. 102, September 1838, pp. 443.
38. J. Dinkel, *The Royal Pavilion Brighton* (Philip Wilson: London, 1983). I am also very grateful to Corrine Bennett of Purcell, Miller, Triton and Partners for showing and explaining parts of the Pavilion not normally seen by the public.
39. Dinkel, op. cit., pp. 19–25.
40. Ibid, pp. 34–39.
41. Ibid, pp. 54–55.
42. Ibid, pp. 56–58.
43. J. Dinkel, 'Royal Restoration', *The Architects' Journal*, 8 July 1987, pp. 24–27.
This idea was also used by Charles Barry. He used wrought iron cores for the Gothic pinnacles on the Houses of Parliament.
44. J. Dinkel, *The Royal Pavilion, Brighton*, op. cit., pp. 54, 75–77.
45. Ibid, p. 61; P. Guedes, ed. *The Macmillan Encyclopedia of Architecture and Technological Change*, op. cit., p. 251.
46. P. Guedes, op. cit., p. 269–71. R. J. M. Sutherland, op. cit.