

The Curious Case of the Phoenix Columns in Smithfield General Market

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BRITAIN'S HERITAGE

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Front cover image: The Phoenix Columns in the General Market showing plain and foliated capitals. *SAVE Britain's Heritage*

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THE GENERAL MARKET UNDER THREAT

Smithfield's General Market in the City of London was the subject of a public inquiry early in 2014 over a proposal by Henderson Global Investments for extensive demolition. This would have allowed tall office buildings to be slotted within the partially retained facades of the Market. Similarly, its neighbour known as the Annexe was to be reconfigured with a tall new tower inserted behind its altered facade and partly demolished interior. Both buildings stand within Smithfield Conservation Area and, together with the famous listed Meat Market, are the work of Victorian architect, Sir Horace Jones (1805-1887). Jones was Architect/Surveyor to the Corporation of London from 1864 until his death in 1887.



An early view of the General Market, looking north east. *National Monuments Record*

The scheme was refused permission by the Secretary of State, Rt Hon Eric Pickles M.P., following a public inquiry and new proposals for re-using the two long derelict Jones' Markets are now being drawn up.

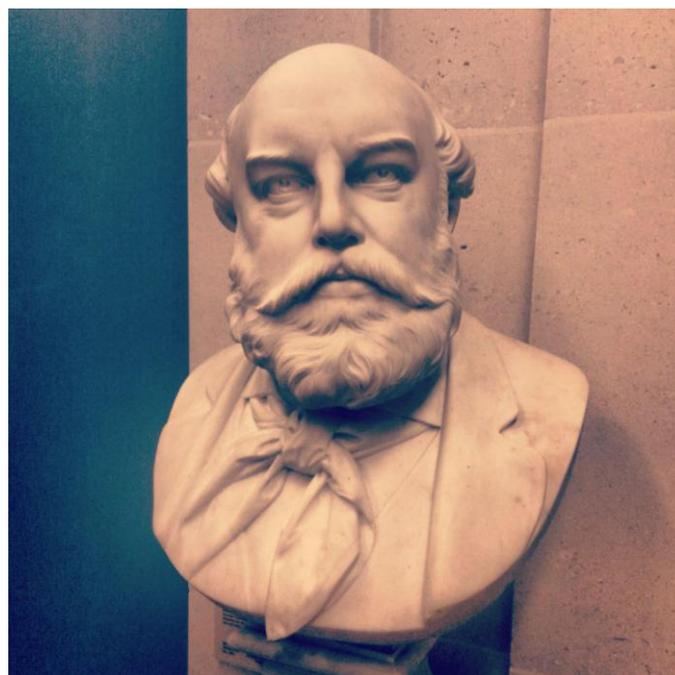
This report sets out to reinforce the significance of the General Market and to suggest how Phoenix Columns, uniquely, came to be used there to support the market superstructure.

SMITHFIELD MARKETS

The creation of new metropolitan markets at Smithfield had been agreed by the City Corporation in the 1860s. It was an immense, complex piece of planning beginning with the construction of the well known Grade II* listed Meat Market at the eastern end of the site, followed by the Poultry Market to the west of 1873-5, then the General Market further west, completed in 1883 facing Farringdon Road. The Annexe, off-axis from the three earlier Jones' markets, was built in 1887 to his design after his death by his assistant, Andrew Murray. A small, later, triangular lavatory block of one storey survives, in altered form. Jones' Poultry Market was burnt down in 1958 and replaced by a new building to the designs of T.P. Bennett and Sons, with a striking shell concrete dome of 1962-3, listed Grade II in 2000.



External view of the General Market. The central dome/lantern and south-west turret had yet to be designed. The Annexe is to the right. London Metropolitan Archives



Bust of Sir Horace Jones. Guildhall Art Gallery Mike Fox

THE PLANNING OF THE GENERAL MARKET

The constraints that Jones faced in planning the General Market were multitudinous. Though links by road and rail were potentially good, the surrounding pattern of narrow roads had to be remodelled to accommodate the planned increased market uses, necessitating the demolition of mediaeval streets. The London, Dover and Chatham railway ran slantwise under the General Market site at its south-east corner, posing access and constructional problems.

There is also a marked fall in the land towards Farringdon Road, although to work well the markets needed to connect through at roughly the same levels. Farringdon Road defined the site boundary along the west side; it was aligned south-west to north-east, and thus precluded the building of a rectangular structure like the earlier Meat and Poultry Markets. The urban setting was tight, with many interests at stake.

Jones decided therefore to create a huge basement at railway level that provided sidings and useful spaces in below-ground vaults. Access to the railway and sidings was achieved by a steeply sloping roadway from the south-west corner of the market close to Farringdon Road.

The square market hall above was constructed on a different alignment, oriented to Farringdon Road and the newly created streets. It was raised up on the east side to link easily with other market buildings.



Aerial View of Smithfield Market in 1947 including the General Market, bottom right, complete with central dome/lantern and south-west turret. Harts Corner destroyed. *Historic England*

Facing Farringdon Road Jones designed a long 'arm' of shops. He incorporated offices, refreshment areas and other amenity spaces for the market workers at upper levels. Shops were introduced all around the facade with more office, administrative and storage rooms above and in the basement.

The central market hall was reached at three points from internal avenues on the north, south and east sides, this last running through to the Poultry and Meat markets. At the north-east and south-west corners were pedestrian entrances. The construction of the hall was an impressive visual and technical feat, unencumbered by the forest of columns usually found in large halls.

Landmark features of the architecture were the eye-catching north-west Harts Corner with its tall towers and twin turrets; the tall octagonal turret at the south-west corner, and a dramatic central dome/lantern set over the market hall.



Harts Corner in 1895. London Metropolitan Archives

The means by which Jones reconciled the differing functional demands of a ground-floor market hall with those of a subterranean railway goods station are extraordinarily intelligent and imaginative. Taken as a whole, Smithfield Market is brilliantly functional and cohesive, yet executed with a flair and light-hearted swagger that belies its innovative character. Some of the building technology employed is explained below, with particular reference to the choice of Phoenix Columns to support the market.



Interior of the General Market hall after replacement of the dome/lantern in 1953.

JONES AS INNOVATOR

Jones was always abreast of technical developments and clearly interested in drawing new ideas into his practice. He had been articled to John Wallen, an architect and quantity surveyor for whom he designed large warehouses in the 1830s. He qualified as a district surveyor in 1849. Surveying, master planning and designing a wide range of buildings were all part of his experience. He was well travelled in Europe, often with architectural contemporaries. He designed houses, shops, offices, agricultural buildings and police stations together with country houses and large public buildings. Unlike a number of his contemporaries, Jones worked collaboratively with engineers, surveyors and other professionals.

Some of his very early drawings for dovecotes and lodges, for example, look to have inspired the louvred dormers and finials that decorate Smithfield market.' Architectural

effect' (*The Builder*, January 17, 1880, p.74) as he described the adornment of buildings, was important to him and he often expressed that publicly.

It is for this reason that the Twentieth Century probably lost sight of his achievements during a time when it was held that structural components were, or should be, sufficiently expressive on their own, without embellishments.



The General Market in *The Builder*, January 17, 1880. The 'embellishment' was a little less elaborate at completion.

PHOENIX COLUMNS AT SMITHFIELD

It has never been satisfactorily explained how Jones came to use the American Phoenix Column system at Smithfield General Market in 1881. Jonathan Clarke, in his recent book on Structural Steel (see Bibliography), considers their use to have been 'anomalous'.

Although Phoenix columns were exported from the U.S. all over the world and used extensively, there is only one other recorded example in the U.K. - very short columns at Redhill railway station in Surrey. Phoenix-type columns were made by various manufacturers in the U.S. and may have been licensed abroad, but Phoenix Columns made by the Phoenix Iron Company in Pennsylvania for the most part reigned supreme, renowned for their strength, achievable heights and wind-resistance in exposed situations.

Jones used the type for the first and only time at Smithfield where they were introduced into the General Market. But how did he come by the idea, with no British precedents? Information is spread among many documents and international sources and is, to an extent, circumstantial, but by grasping the extent of Jones' professional knowledge, his willingness to experiment and breadth of endeavour, compelling answers emerge.

CAST AND WROUGHT IRON COLUMNS

In the history of nineteenth century civil engineering the wrought-iron Phoenix column played an intermediary role in the transition from the use of cast-iron to the employment of steel. Jones, for example, turned to steel for the structure of Tower Bridge at the end of his career.

Cast-iron and wrought-iron have distinct strengths and react differently under different types of strain.

Cast-iron has the advantage of being strong in compression, and is thus useful for structural columns, though it is brittle and liable to gross distortion in heat and fire. Moreover it is subject to wear, oxidation, water damage and sudden collapses under strain. Cast-iron cylinders sometimes cracked or split when used in bridges, especially in severe cold weather. Cast-iron is rigid and inflexible; it cannot be welded or altered except by re-casting.

The American Society of Civil Engineers, whose affairs were frequently reported in the *Building News*, was asking for precise calculations of crushing strengths and breaking weights by 1873, rather than relying on rule of thumb and questionable theories.

At the same time the use of wrought iron was growing, following the establishment of large rolling mills, whereas before wrought-iron was limited to smaller decorative pieces, often with handmade input.

Its strength was being noted. On January 8, 1875, an article in the *Building News* on iron columns noted that, 'We have hitherto confined our attention to columns of cast-iron, as by far the greater number are made of that material; occasionally, however, wrought iron is employed for the purpose especially where the length is very great as compared with the diameter, in which case strength is much greater than if cast iron is used'. The article goes on, 'The reasons why long columns of wrought iron are so much stronger than those of cast iron is that the resistance to flexure is so much greater in the former than in the latter, which is the force chiefly brought into play. In shorter ones, however, the resistance to crushing having to be considered, the superiority of cast iron in that element of strength manifests itself.'

Furthermore, wrought-iron was proving more fire-resistant than cast-iron, retaining strength even when red hot. Wrought-iron was tough, ductile and flexible. It could be forged in various shapes, rolled or pressed while hot. It might be punched, cut with a chisel, drilled, and filed while cold. Two pieces could be welded together. Wrought iron resisted tensile strain well (*Building News*, April 6 and April 20, 1877).

Wrought iron was suddenly at the forefront of building technology.

Jones made himself adept in the use of both materials during his career, using structural cast-iron columns regularly as one would expect in the 1850s for the frame of Caversham Park near Reading, for example, the country-house of a Welsh ironmaster. Cast-iron columns support Smithfield Meat Market. Their use was universal at the time for heavy-duty purposes.

THE ORIGIN OF PHOENIX COLUMNS

Phoenix Columns were patented by Samuel Reeves of the Phoenix Iron Company of Pennsylvania U.S.A. in 1862.

They were made up of curved circular sections built up of four, six or eight flanged, rolled, wrought-iron sections riveted together. The flanges were then bolted together to form a circle. These columns were immensely strong, and much lighter than cast-iron. In addition, the connections of the columns to beams were capable of being rigid enough to allow buildings and other structures to be wind-braced by relatively simple methods. On the other hand manufacture was complex and the columns were relatively expensive.

Maintenance was relatively easy. Defects in the hollow column interiors could be spotted quickly and were accessible enough to protect from rust by thorough painting; usually they were then filled with cement.

The columns could rise to great heights and carry huge loads. In the U.S. strong, reliable, high-level, wind-resistant supports were essential in the multitude of high buildings, bridges and viaducts proliferating at the time. Phoenix columns filled a need.

Alan Burnham, American architect, historian and scholar (see Bibliography) sets out the column's advantages thus:-

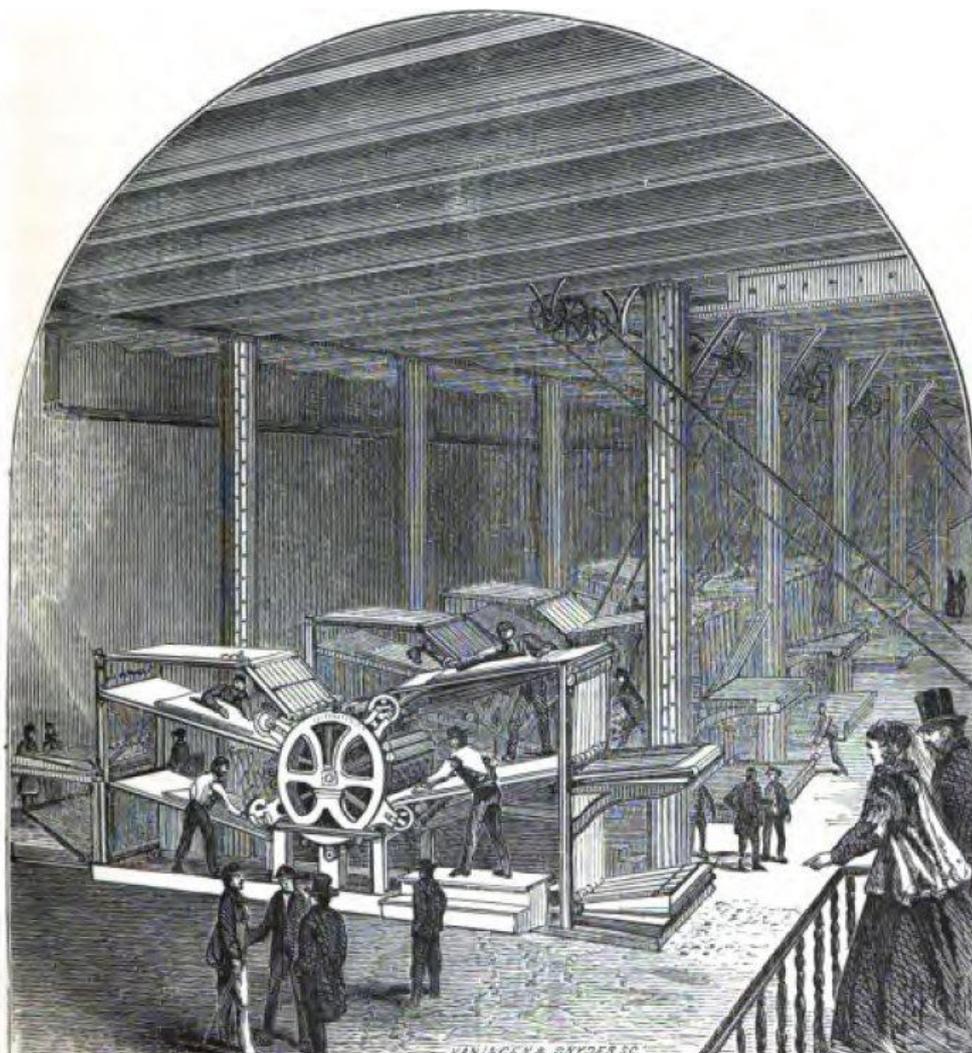
'One advantage of the section was the fact that loads could be applied close to its main axis. If, for example a load were applied to one side only, it would travel down and around the circular section at an angle so that, at some distance beneath the load, it would become more or less evenly distributed over the entire section of the column..... The Phoenix Iron Company also boasted that the column provided a

maximum of strength with a minimum of weight and that, due to the simplicity of its construction, it was the cheapest column on the market.'

Moreover, adding vertical filler pieces between the flanges of the segments increased strength and rigidity. Phoenix columns were famously used in 1867 in Philadelphia in the new Public Ledger Building to support the huge weight of the many printing presses in the Press Room. These Phoenix Columns countered the great weight and vibration of the presses by the introduction of 'full length vertical filler pieces between the flanges of the segments.' The Public Ledger Room was hugely publicised and illustrated in periodicals.

This was the first use of an updated, stronger 'improved Phoenix Column' which was utilised at the General Market. They are still doing their job, even after 135 years and the onslaught of two wars.

As exemplified by the Press Room and later at the General Market, the floor itself had to be enormously strong to bear the columns.



The Press Room in the Public Ledger Building, Philadelphia, U.S.

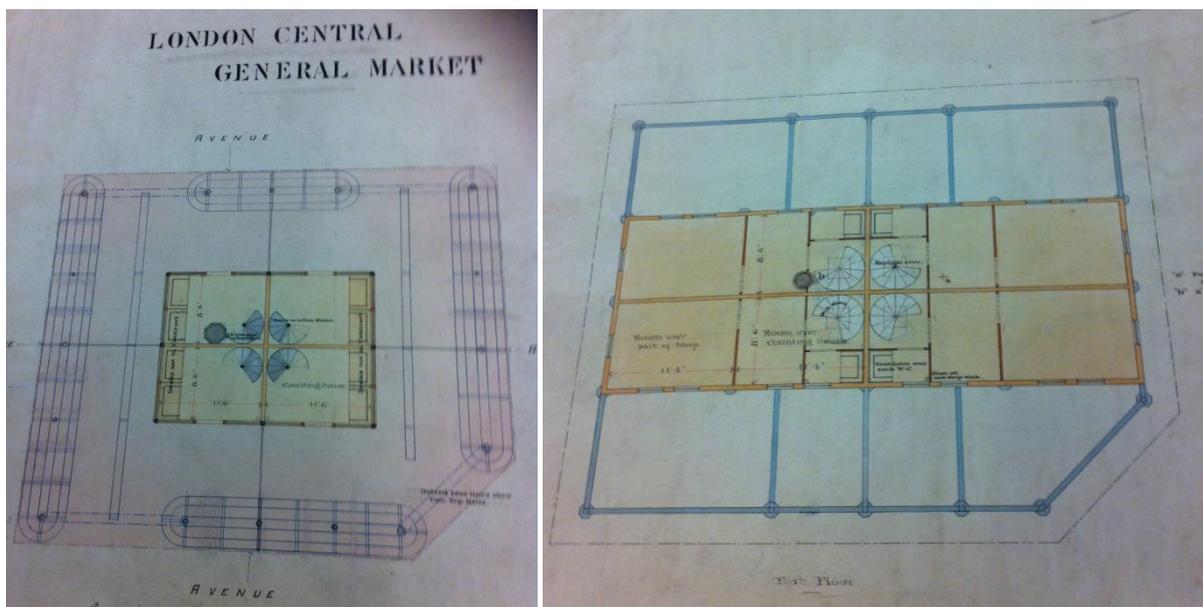
NOT MENTIONED BY NAME

Jones was coy about naming his use of Phoenix Columns at Smithfield, even though he was a well-versed speaker on a wide range of architectural/engineering themes, and a noted public figure;^[1] He never even alluded directly to the method, except briefly to professional audiences, and then only after the columns were secured in place.

There had of course been early problems in the U.S. with columns that were insufficiently strong, and some worried clients, so possibly it looked wise to say little by way of explanation, especially to the City Corporation, his paymaster and employer.

Another reason may have been a reluctance to name the manufacturer, possibly because the columns were imported from Belgium (though there is no evidence for this); that would have made them unpopular and structurally suspect, but maybe they were just too new for acceptance on the London scene.

It is clear from an inspection of the earliest drawings, of 1874/5, for the General Market that he planned to use a small number of columns, only sixteen, to support the General Market's superstructure.



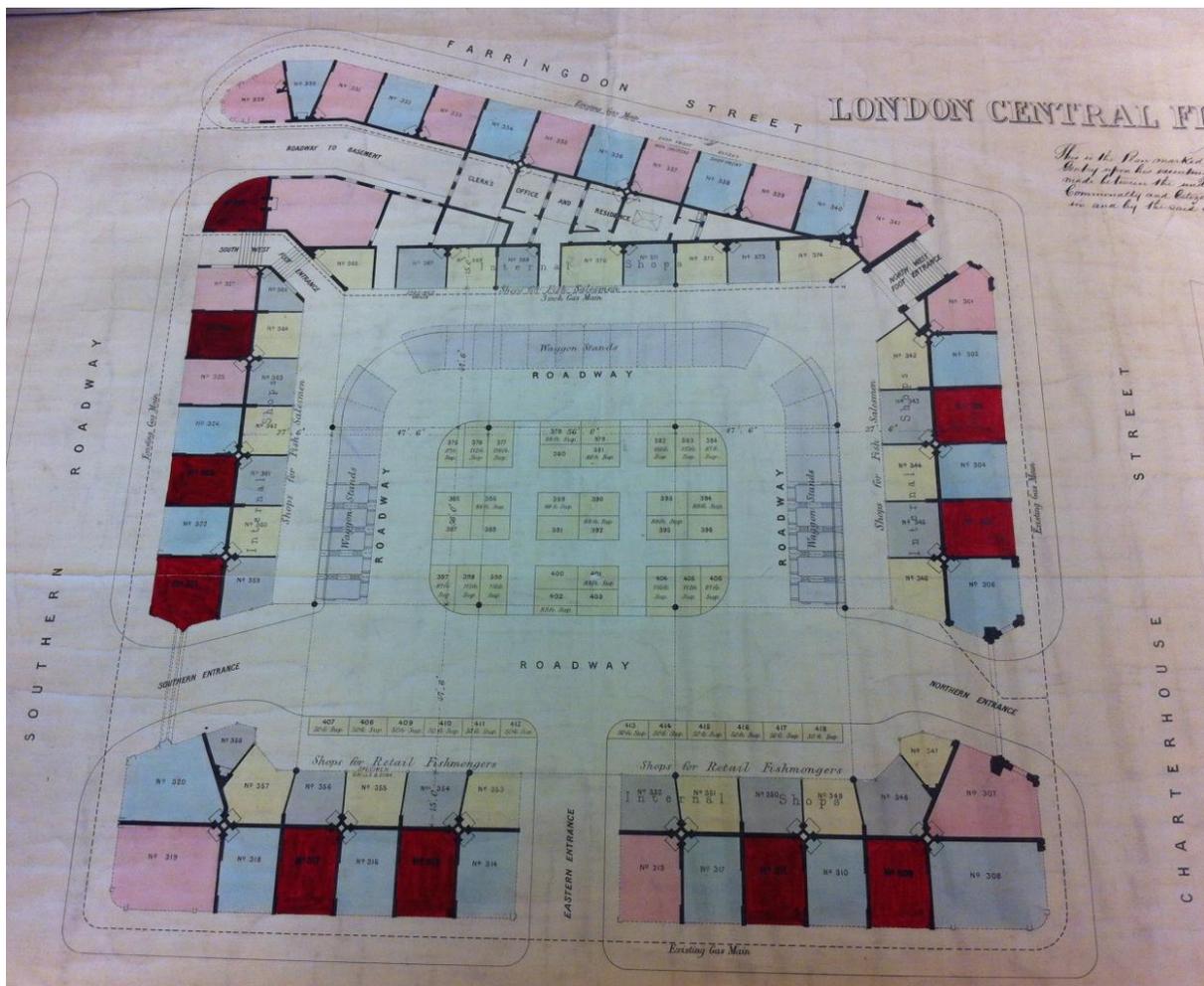
Two early schemes for the layout of the General Market. 16 Phoenix Columns can be counted in each drawing. Harts Corner bottom right. London Metropolitan Archives

But the usual cast-iron columns could not supply the answer. Jones needed tall columns, and wide spacing between them, in order to get the height and space required in the market hall. With cast iron, this would require massive columns of great weight. Jones had to consider weight, and weight distribution, as the uninterrupted floor required in the market hall, with the immovable railway infrastructure underneath, did not allow for numerous supporting columns. Strong wrought-iron columns might not be strong

enough. This factor made Smithfield very different from most other markets which had open, unencumbered basement areas. The decision to use either wrought-iron or Phoenix Columns was made early on, it appears from the drawings.

Rising from the floor in the basement, composite wrought-iron stanchions were used, four of which carried through to the upper market level. Here they supported the four central Phoenix Columns, themselves carrying the colossal weight of the central hall's superstructure. Only one other Phoenix column in the northwest corner of the market bore on a stanchion. The others were carried on the many wrought-iron beams and box girders supporting the market floor, or on the non-combustible strong brick floor of the market itself.

The columns at Smithfield are truly hefty, comprising eight segments, plus additional thickening pieces. They are capable of holding up an enormous weight, yet much lighter than their cast-iron comparators.



**Plan of market as approved - not quite as built (as a Fish market). Harts Corner top right
London Metropolitan Archives**

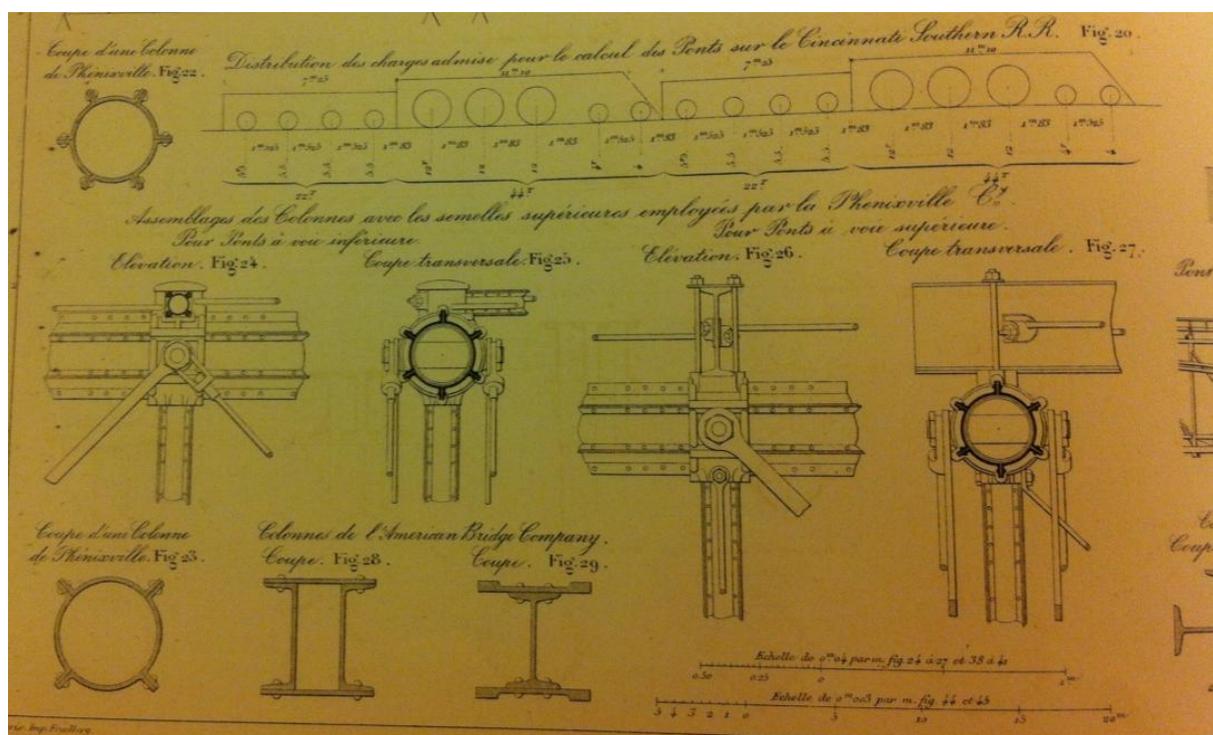
THE IMPACT OF PUBLICATIONS

The speedy dissemination of information across the Atlantic, both by conventional means and the newly-invented telegraph, may be one reason for the confident use of Phoenix Columns at Smithfield.

Detailed drawings of Phoenix Columns were readily available, as was sound, objective information. There were also the well-publicised claims of the Phoenix Company itself in their technical literature, giving relevant loads, crushing strains etc. These claims, and those of other companies, were put to the test by the U.S. government in a series of published experiments from 1875. Phoenix Columns excelled in these trials (see below).

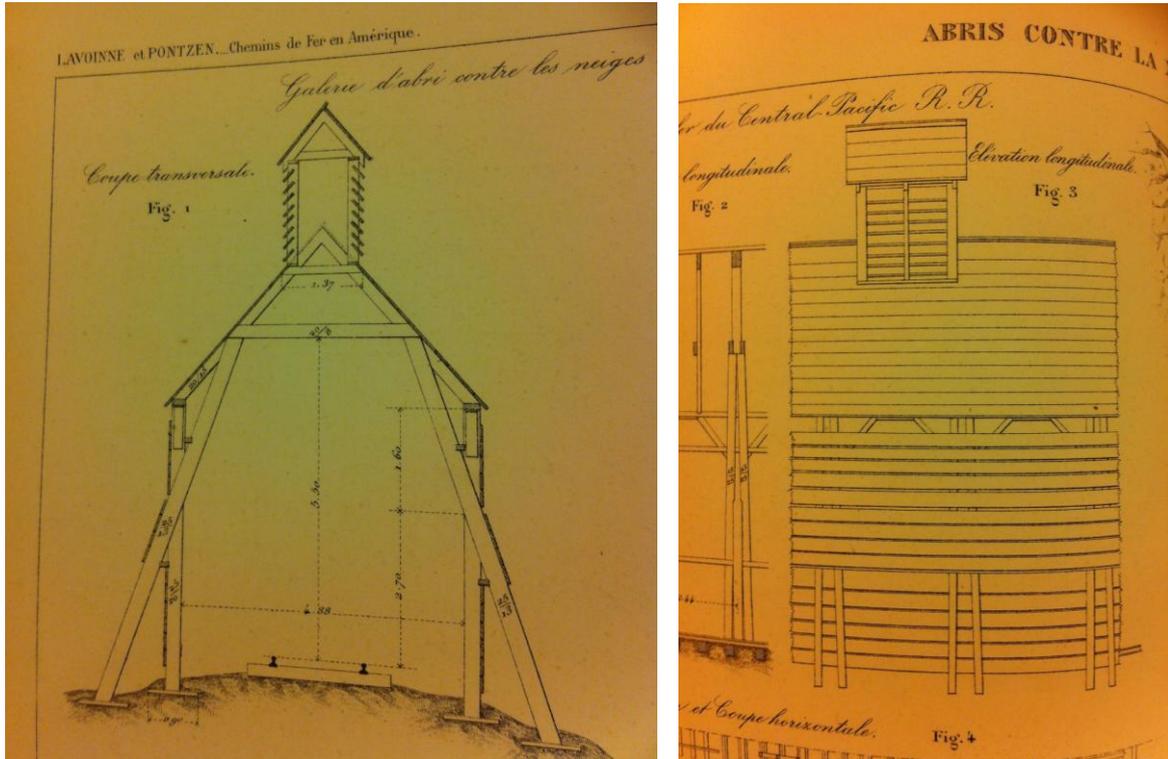
In 1880/82, Edouard Lavionne and Edouard Pontzen, two French engineers, published their volumes *Les Chemins de Fer en Amerique* that were compiled for the use of 'engineers, architects and others'.

Volume 1, of 1880, deals with Construction. Phoenix Columns are described as suitable 'to carry heavy loads' such as railways and bridges. Plate V illustrates Phoenix columns, drawn both in detailed elevation and transversely, attributed to the Phoenixville Company, and described as 'a building system well-used in America'.



Drawing of Phoenix Column in *Les Chemins de Fer en Amerique*

There are drawings, too, for louvred shelters to shed snow, not unlike those Jones used on the General Market and Annexe to prevent ingress of snow and rain.

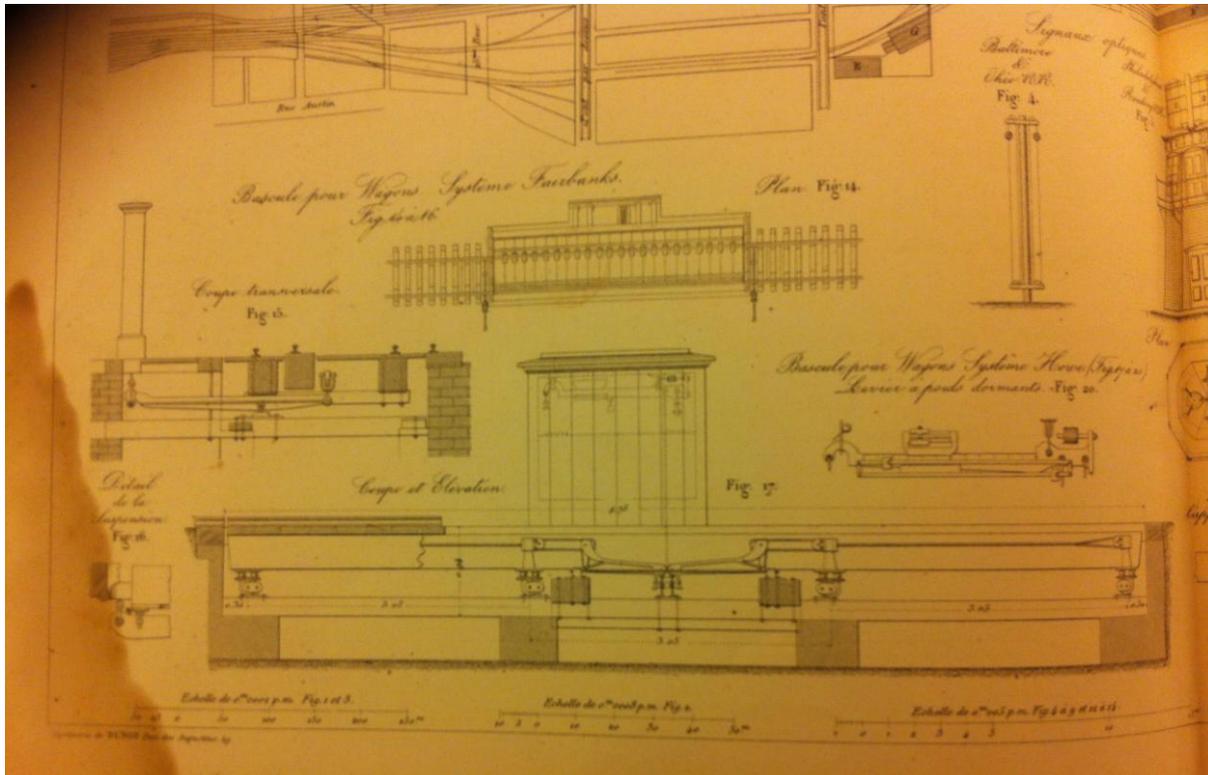


Two drawings of snow shelters in *Les Chemins de Fer en Amerique*



Photo of typical 'dormer' on Annexe, to deflect snow and rain. *Jenny Freeman*

There is a design (unbuilt) for a large bascule bridge at St Louis for carrying the railroad over the Mississippi/Missouri River, where bascules could be raised to allow shipping to pass underneath. Did this anticipate the concept of Tower Bridge? Earlier examples of bascule bridges in Europe were much smaller, spanning canals and rivers at low level.



Drawing of Bascule Bridge in *Les Chemins de Fer en Amerique*

Volume 11, of 1882, shows a Plan of the New York City's Elevated Railroad's extension along Second Avenue, of which more below.

The books achieved French, British and American circulation with original copies still to be found in the Library of Congress, British Library and Bibliotheque Nationale.

In 1880, W.H. Burr (1851-1934) published his *Course on the Stresses in Bridge and Roof Trusses, Arched ribs and Suspension Bridges*, prepared for the Department of Civil Engineering of the U.S. Rensselaer Polytechnic Institute in New York. The Course, originally designed for the use of engineers and students, illustrates 'systems of vertical and diagonal bracing' with diagrams showing the effect of stresses such as wind pressure. There is reference to the work of the British Institute of Civil Engineers on these topics, reflecting the speed, ease and closeness of transatlantic communication.

These matters were of vital interest to Sir Horace Jones whose 80' high General Market (from the pavement to the top of the Charterhouse Street elevation) would be subject to extremes of weather, high winds and a requirement to retain equable temperatures for

people and produce. His design incorporates arched ribs, and carefully considered roof trusses (which amazingly survived World War II, see below).

It is inconceivable that this kind of information would not have influenced Jones directly, or indirectly through periodicals such as *The Builder* and *Building News* that reported these topics assiduously.

THE IMPACT OF THE TELEGRAPH

Although Jones did not seemingly visit the United States, the exchange of new technologies, engineering and scientific research between the U.S., Britain and Europe was a feature of professional life in the mid-nineteenth century, aided by the growth of speedy communication across countries from the 1840s and 50s. Using the telegraph for printing had been accepted worldwide in the 1850s. By the 1870s the telegraph was the important medium for the transmission of news, used by the news media to deliver items of key interest. Presses such as those introduced in Philadelphia were a vital part of this. Articles were often quoted verbatim 'across the pond'.

The American magnate, Cyrus Field (see below), had formed the Atlantic Telegraph Company in London in 1856. The first transatlantic cable was successfully laid in 1858 and the flow of information thereafter rose dramatically.

Horace Jones was himself architect of the English and Irish Magnetic Telegraph Company's elaborate new offices in Threadneedle Street in the City of London in 1859, whence the public could send messages . The 'Building News' commented that this presaged, 'correspondence westward with our transatlantic cousins'. Telegraphic engineering continued to improve over time. There was enormous public interest in the development.

The telegraph system followed the growth of the railways with telegraph offices often being located at railway stations and cabling routed, by agreement, alongside the lines. A close relationship often existed between the two types of company, with crossover in the names in the lists of shareholders and directors. This was true, for example, of Cyrus Field who later (see below) funded the New York Elevated Railroad and telegraph ventures in the U.S.

These links to the U.S. may well have alerted Jones to the potential for Phoenix Columns. Their use in railroads, bridges and elevated locations had become, by the 1870s, a standard component in the repertoire of architects, surveyors and engineers delivering mighty infrastructure across the U.S. Today, those examples that remain are highly regarded. Some 35 examples are currently listed and illustrated in the Historic American Engineering Record.

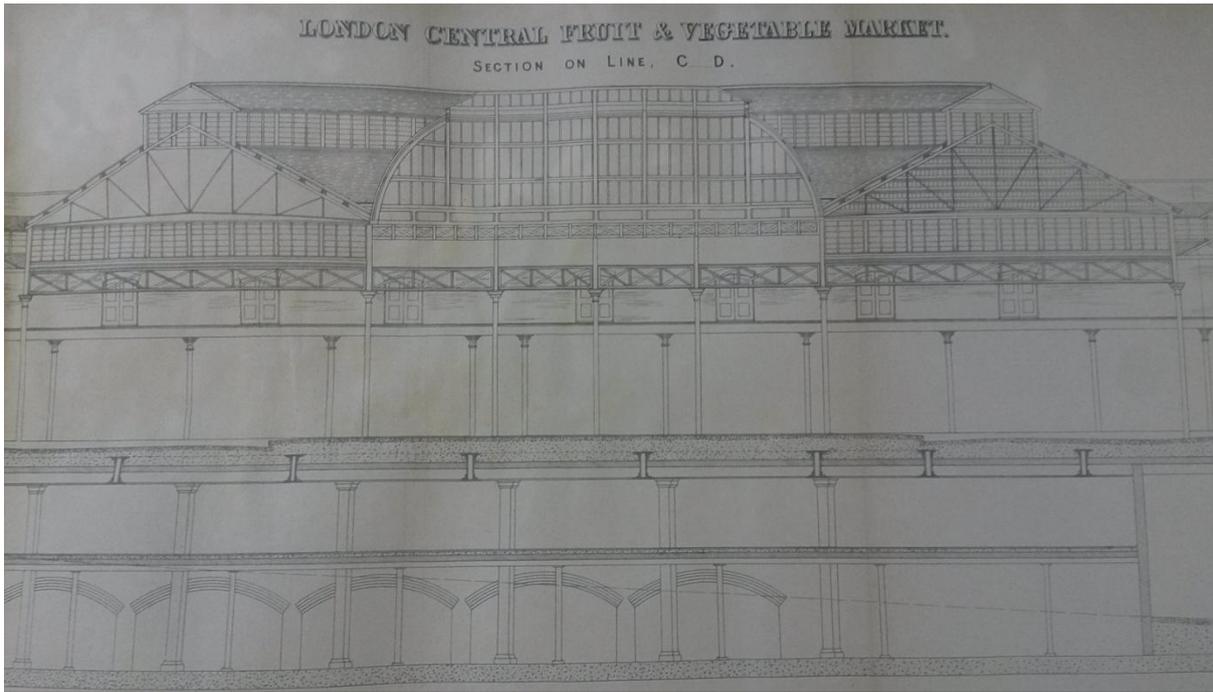


Offices of English and Irish Magnetic Telegraph, Threadneedle Street, City of London. *Illustrated London News* April 2, 1859. pp 329.337. Also in *The Builder*, July 19, 1856. Drawn by Horace Jones.
 Note cables and ships laying them in margins

PROGRESS ON THE GENERAL MARKET

Jones was given authority to proceed with the General Market in 1875, following the passing of the Act of Parliament, and to create the roadway to the basement linking with the railway in May, 1875. It was expected to be a Fruit and Vegetable Market (and duly authorised as such in July, 1879).

Given the complexity of the planning it is remarkable that the overall layout of the Market remained relatively unchanged throughout the planning stage. Jones drawings of 1874/5 show a somewhat more complex roof structure than was eventually built, but the overall concept of the scheme held good for the duration of the contracts.



Early sectional drawing of the General Market, 1875. The roof was less elaborate. Shorter, wrought-iron columns are identical to those built. Phoenix Columns are not indicated. *London Metropolitan Archive.*

In the newly concrete-floored basement of 1876, stout wrought-iron columns support large-span, wrought-iron girders like Jones had, he states, pioneered years earlier (see below). Good column, girder and beam connections were vital to the stability of the structure, given the vibration from the trains below and various vehicular movements inside. Phoenix Columns were ideal because they could be welded, bolted and soundly riveted, making one unit.

The columns and capitals of the shorter columns are depicted in early drawings just as they were built. Phoenix columns are not shown on any plans. It is probable that Jones thought of wrought-iron columns first but soon changed his mind owing to the exigencies of the location, for the reasons given above. But there is no mention of Phoenix columns, nor any descriptions of them in Jones' Report to the Court of Common Council of May 1879, or in subsequent reports.

(Just before its completion the General Market was re-designated as a Fish Market, and opened as such in May, 1883. It may be that the absence of the delightful wrought-iron foliate decoration from some of the capitals of the Phoenix Columns is due to this change of use, because the stylised fruit and vegetable design was no longer appropriate for fish, and there was an obvious, welcome, saving of money- see below.)

These foliated capitals making them resemble classical capitals, that were popular in cast ironwork of the period, are used, uniquely it would appear, at Smithfield.



Photo of Phoenix Column (this example without foliated capital) with shorter column in General Market.
SAVE Britain's Heritage.

The Common Council meeting of May 1879 approved the plans for the New Fruit and Vegetable Market, then estimated to cost £115,000. The site had already been excavated. The floor of the Market would be level, with a gradient necessary at the entrance taking up the ten feet difference in levels across the site. The forty-one shops 'for retail or other purposes' and three main entrances are described. In roofing the Market 'the floor has been kept as clear and open as possible, the detached main roof supports or columns being thirty-seven in number, and the clear span of the roofs is forty-five feet'. The roofs shown are of 'a light-iron construction, with a range of glass louvres at the plate and ridge levels, affording an ample amount of light and air... The height of this roof will be twenty-eight feet to the level of plate, and to the ridge of the louvres forty-five feet.' The height of the structure from the basement was to be a lofty eighty feet.

The plans were approved in July, though the 'light-iron' proposed for the roof was changed to laminated wood (see below).



W H E T H A M, *Mayor.*

A Common Council holden in the Chamber of the Guildhall of the City of *London*, on *Thursday*, the 8th day of *May*, 1879.

THE Markets Committee did this day deliver into this Court a Report in writing under their hands, submitting for the approval of the Court Plans for the New Fruit and Vegetable Market, at an estimated cost of 115,000*l.*; which was read.

Report to the Court of Common Council, 8th May, 1879.

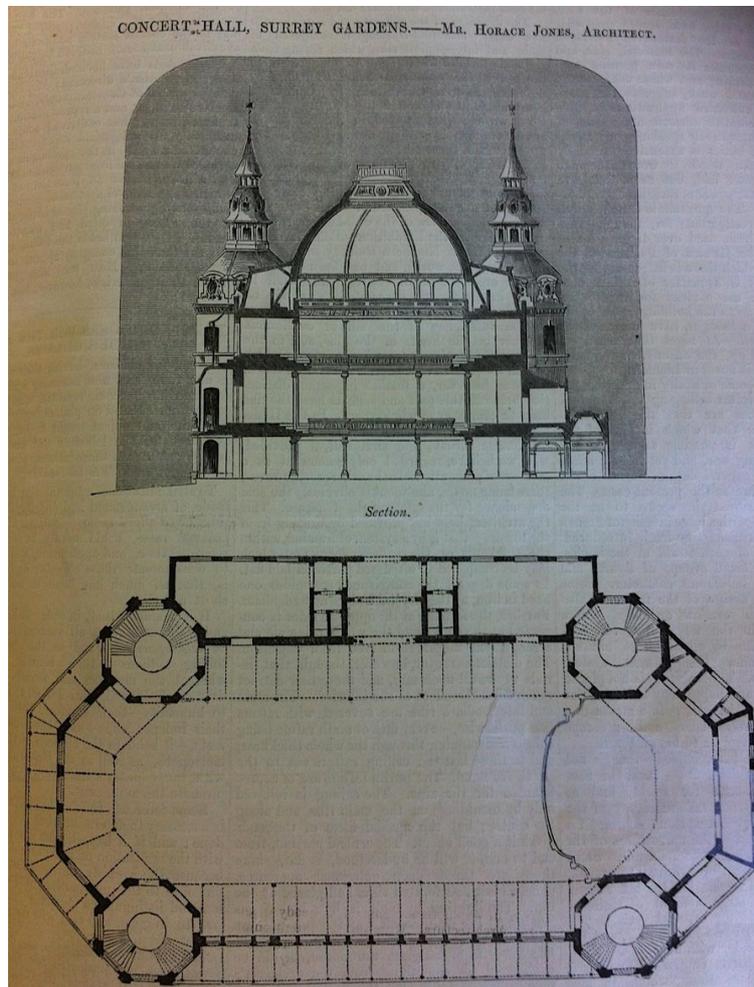
On November 8, 1879 the *American Architect and Building News*, in an article dated October 16th, reported that the contract for the market was signed. In a description taken directly from the Report to the Court of Common Council the item describes, 'a roof seventy feet high at the centre, forty-five feet to the ridge, and twenty-eight feet to the plate, supported on only sixteen columns, so as to leave the area as clear as possible.' The phrase 'only sixteen columns' may suggest the journalist was unfamiliar with the load-bearing capacities of the Phoenix Column. Jones was right to be cautious about acceptance of his idea.

The Builder of January 17, 1880 also covered the proposals in detail, based on the Report to the City Corporation. The cost of the scheme was by now put at £300,000 - an astonishing increase, nearly three-fold in nine months. In the writer's view, this reflects not only Jones' adoption of the expensive but provenly safer Phoenix Column system, but the willingness of the City Corporation to pay for it.

In the same issue the *American Architect* reported the continuing construction of the Tay Bridge, designed by engineer Sir Thomas Bouch. Late in 1879 the new bridge, built on cast-iron columns, was to collapse with tragic loss of life. The disaster was attributed, among other reasons, to inadequate wind-bracing and false calculations of wind pressure on the columns. Cast-iron had clearly shown itself to be unsuitable in this type of location, while the wrought iron components survived better and, furthermore, were proving their worth in the U.S. The City Corporation could not countenance a similar tragedy at Smithfield and may have accepted the cost increase for this reason.

The General Market took shape through 1880 with contractors, J. Mowlem and Company on site and Rownson, Drew and Company supplying the 'ironwork'. The foundation stone was laid on March 19th, 1880. Foundations were in place shortly after and the vaults made ready for letting. The brick jack-arch construction of the basement roof was made exceptionally strong. The basement floor was of concrete.

Potential collapses were not the only worry. Fire safety was an issue. Cast-iron had been wrongly thought to be fireproof. *The Building News* of 14 May, 1880 reported that filling columns with concrete added to fire resistance, as it was then more realistically called. Jones would have long held in his mind the loss of his own Royal Surrey Music Hall to fire in 1861. Its cast iron columns had crumpled in half an hour. Concrete protection of the Smithfield columns was Jones' approach, although casing columns in terra-cotta also proved popular in London (architect Alfred Waterhouse was a proponent).



Section and plan of the Royal Surrey Music Hall. *The Builder* July 19, 1856

The *Building News* on May 27, 1881 reported on a visit by the Architectural Association. Mr Gosling from the City Architect's office showed the visitors over.

There had been a change to the method of roof construction. 'The roofs are of a laminated rib construction, with a range of glass and louvres affording ventilation and light, but guarding against direct sunlight, and the intrusion of rain and snow (see above). The height of the roofs will be twenty-eight feet to plate level and forty feet to ridge of the louvres. The centre domed roof will have a clear span of fifty-six feet, and will rise to a height of over seventy feet. At the junction of Farringdon Road and Charterhouse Street is a domical tower now being covered in, rising to the same height, eighty feet above roadway levels as the intended dome'. (This refers to the central domed lantern, demolished in the 1950s. See below).

The article continues, 'The floor of the upper market is carried by iron stanchions, forty-five feet and twenty feet apart respectively with wrought- iron girders of similar spans. The stanchions are divided into four classes severally, calculated to bear maximum loads of 170, 240, 285, and 350 tons each. The main girders resting upon these stanchions vary in weight from 15 to 32 tons, the largest being no 71, the fourth from the south end, which stretches across the London, Chatham and Dover Railway and under the main entrance in the southern roadway.... All the girders were rolled and built up in Staffordshire, and brought, ready for fixing, by rail.....The construction of the roof columns, which are all of equal size, is somewhat novel, being sections of rolled channel iron, riveted together with attached moulded bases.... Special precautions have been taken to guard against the possibility of an engine getting off the metals and striking one of the columns which carry the upper market.... a solid pier of brick is set around the stanchions, which here and at other exposed points are doubled, either stanchion being calculated to carry the entire superposed weight. As the lines of the upper market do not follow those of the substructure, the arrangement of plan has been a work of considerable intricacy, further complicated by the necessity to suit the railway requirements.'

Several matters spring out of this account:- the change of roof material; the care for public safety, as noted elsewhere; the unambiguous description of the Phoenix Columns, though without naming them as such; the scientific calculations of their bearing loads, and a vagueness about the supplier, Rowson Drew being credited with making the girders only. The dimensions remained the same.

CALCULATING THE BEARING LOADS OF PHOENIX COLUMNS

A series of tests had been under way in the U.S. since 1875, following industry demand, just as Jones was beginning to work up his designs, but long after Phoenix Columns had achieved widespread use in the U.S. and elsewhere. No comparable research was undertaken in the U.K. because Phoenix Columns were not used here.

Testing in the U.K., notably at the Kirkaldy Testing Works in Southwark (now a museum), was based on David Kirkaldy's exhaustive comparative testing programme

with iron and steel. He published internationally in 1863 his *Experiments On Wrought Iron And Steel*. But Kirkaldy did not test Phoenix Columns and the maximum length he could test metals in compression was 20 feet i.e. a shorter length than Jones used at the General Market.

Load testing was a serious matter for the success of Jones' plans.

The *Building News* of March 18, 1881 printed a short article on 'The Strength of Wrought-Iron Columns', stating that, 'The number and magnitude of the iron bridges and viaducts constructed in America have given the engineers in that country a wider scope for experimental investigations than can be afforded to our own engineers'. The article was referring to a report submitted to the American Society of Civil Engineers. The experiments had tested columns, including Phoenix Columns, and compression members. The results placed emphasis both on the quality of construction and the careful bolting and riveting of component parts. Phoenix Columns had the advantage because, 'the parts being thoroughly united together, the large factor due to defective construction and workmanship may be considered eliminated in great measure'. The importance of bolting securely together the several segments of built columns, 'so that the parts may act as one continuous column is insisted upon; lateral flexure, or buckling, being specifically guarded against, as well as longitudinal relative motion'.

Under the heading the 'Strength of Wrought-Iron Columns,' the *Building News* of June 24, 1881 reported the contents of a technical paper, previously published in *The Proceedings of the Engineers Club of Philadelphia*, by Thomas Cleemann. This concluded that, 'the Phoenix Iron Company's columns' were 'the strongest of those noted'. The conclusion was reached following trials with similar products produced by other manufacturers. Tables and calculations were produced.

In the *Building News* of September 16, 1881, under the heading 'Testing full-sized Bridge Columns', a series of experiments is reported, 'to determine the strength of wrought-iron columns manufactured by the Phoenix, Penn. Iron Company and known as Phoenix Columns'. These tests were conducted in the 'government machine' at U.S. Arsenal, in Watertown, Massachusetts, and upon full-sized columns of twelve to eighteen and a half inches in section and twenty-eight feet in length. 'The loads sustained at various states of deflection were also tabulated'.

These above sizes were exactly the dimensions of the longest Smithfield columns, and the tallest, thickest, tested in the U.S.

The elastic limit and deflection and the total compression, it is reported, are, 'given in a table published by the American Society of Civil Engineers' in which Phoenix columns emerge stronger than anyone had suggested before. 'It is a new and important departure from old methods to test full-sized, complete members of engineering

structures, in lieu of small samples of the material proposed for their construction - the only available way before this enormous machine was built by the United States Government', concludes the article approvingly.

On April 7, 1882 the *Building News* was covering, 'a valuable series of experiments upon the breaking strength, elastic limit, etc, of columns' which had been made by the American Society of Civil Engineers and recently published in their *Transactions*. The reader is referred to Clarke, Reeves and Company's Report (the Phoenix Company's newer name). The columns were 'full-size Phoenix columns, used on bridges', and the experiments were conducted on the Watertown machine at the expense of the U.S. government. Calculations are described, the general conclusion being that the Phoenix Columns performed much better than lattice columns, after deflection.... 'The behaviour of the columns under these tests is of value, as showing engineers the rigidity and bearing-power of iron columns in four segments, and the detailed data furnished of each experiment throw much light on the subject of the strength of columns.'

Phoenix Columns had been vindicated by the tests, and though some of the tests took place, or were reported, after Jones introduced them at Smithfield, the results may have been known, or anticipated, before they were fully tabulated. The *Building News* of March 18, 1881 furthermore noted that large bridge builders often carried out tests using their own 'ample means and facilities for conducting experiments'.

THE GENERAL MARKET COMPLETED

The Builder of February 4, 1882 reported on the City markets in detail, commenting that the General Market 'is now roofed in and a very pleasant and well-lighted space it forms. It is nearly square in plan, and forms a continuation westward of the group formed by the new Poultry and Central Meat Markets'. It is stated that the ironwork has been 'supplied by Messrs Rowson, Drew and Co'.

A recent meeting of the R.I.B.A. is reported (probably the one held on January 23rd, 1882), where Jones had presided as Vice-President, and, 'spoke of a method which he had adopted, and with success, of building-up circular columns of eight lengths of rolled iron of curved section, and having flanges which are bolted together. By this means longer and stronger supports are obtained than would be possible by means of casting, and the effect obtained, that of a column with wide shallow flutings, is by no means unsatisfactory, as can be seen in the new market, where four of such supports are used to carry the large central dome or lantern'. The plans of the market, prepared two years before and published in *The Builder* are referenced by the journalist.

The article goes on, 'The floor of the upper market is carried by iron stanchions, forty-five feet and twenty feet apart respectively, with wrought-iron girders of similar spans. The stanchions are divided into four classes severally, calculated to bear maximum

loads of 170, 240, 285, and 350 tons each'. These calculations could have only one source - the United States.

As before, Jones is reluctant to mention Phoenix Columns by name, or to suggest an American origin, but the description of them could not be clearer. Might it be that Rowson, Drew had simply gone ahead, using published drawings, to manufacture the columns themselves at Jones' request, and that Jones' wanted to protect them from potential lawsuits? Phoenix Columns were patented. Or perhaps the firm had the right licence but was reluctant to publicise the fact early on?

The writer has established that the columns were not American products of the Phoenix Company. Their archives have been searched and there are no references (see Bibliography). Phoenix-type columns manufactured by others would not have passed the stringent strength tests Jones had to rely on.

Belgium has been suggested as the source of the columns, for cheaper Belgian iron had been flooding the British market for years, to the consternation of British manufacturers.^[2] In the late 1850s the first cast-iron columns had been imported to Belgium from England and used with timber beams, but Belgian cast-iron fell in price in the 1870s/80s due to lower wage rates, and the trade reversed. Yet an investigation of Belgian products has not turned up any Phoenix-type products either used domestically there or exported. The jump was made from cast-iron to steel for the most part, where strength in compression was essential.

And would Jones, with his public safety concerns uppermost, have risked a Belgian product that was then held to be of inferior quality owing to a lack of rigorous product testing and the questionable strength of its wrought-iron? Probably not.

As Jonathan Clarke observes, professional specifiers, 'tended to endorse and specify only ironwork manufactured and fabricated in Britain, valuing safety and durability above cost.'^[3]

And costly it certainly was! The staggering completion bill of £430,000 for the General Market, recorded in *The Builder* of May 12, 1883, suggests Jones had sought the most expensive but safest option, probably in the knowledge that the City Corporation could well afford to meet the financial obligation!

In an intriguing sidelight, Jones' remarks about the attractiveness of his columns to the R.I.B.A., above, faintly echo comments by the owners of the Philadelphia Press Room on their Phoenix Columns, thus:- 'the effect produced by the projecting flanges and filling pieces is somewhat similar to that of large fluted columns and is quite ornamental'. Jones refers to 'the wide shallow flutings' as 'being by no means unsatisfactory.' Phoenix

Columns were thought by some to be ugly. Would Jones have read and retained this opinion? It is possible, given his adoption of the columns.

THE NEW YORK CITY ELEVATED RAILWAY

The decision to create an elevated railroad in New York City had been made in 1875. An iron skeleton structure, 25 feet high, was envisaged and described in the *Building News* of June 4, 1875, quoting the American Society of Civil Engineers. The system became famous.

Though the experiments being undertaken in the U.S. probably came to Jones' attention and strengthened his resolve, he had the example of the working success of the New York Elevated Railroad in employing Phoenix Columns to persuade him, and moreover the timing of part of its construction, just ahead of the General Market, was apposite.

Phoenix Columns were used to support both the 2nd Avenue line and the New York Metropolitan Elevated West Side extension from 83rd to 159th Street. The columns' capacity to take heavy loads and their ability to flex were key attributes in choosing them. Their vertiginous viaducts were a wonder of the time, and were reported, with drawings and photographs, in many publications in the U.K. At the junction of 110th Street and 8th Avenue the huge height of the railroad, fifty-seven feet above Manhattan's streets, borne aloft on Phoenix Columns, was a source of amazement. Moreover the columns clearly resisted high winds, all weathers and constant vibration. Both these stretches of railroad had been erected in 1878/79, just before the General Market went up. Jones could hardly have avoided reading all about it in various publications.

Much of the system relied on 'Warren's Lattice girders' to link the columns successfully and to distribute the weight of the railroad cars. It was this type of girder that Jones used at the General Market (see below), though differently deployed. Diagrams and drawings showed the construction methods, as was usual, and of course they were on view to every beholder rather than hidden away inside buildings. Two-way transverse girders were employed, with the wrought-iron Warren lattice girders usually employed for the longest spans.

After much earlier weaknesses had been identified and eliminated (by strengthening the Phoenix Columns with braces) the railroad system performed well.



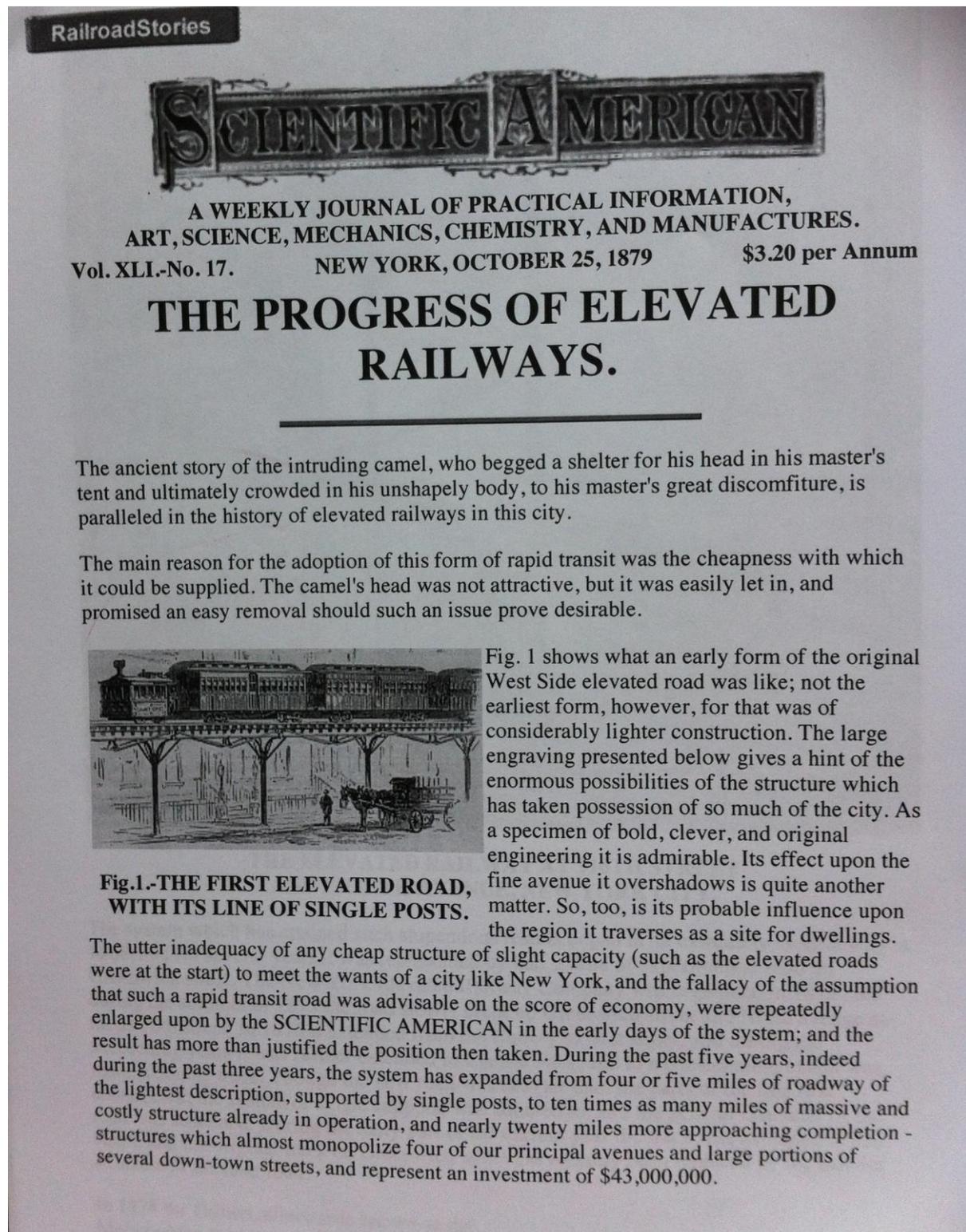
Print of New York Elevated Railroad at 110th Street, 8th Avenue, from *Scientific American*, Oct 25, 1879

Cyrus Field (see above), of the Atlantic cable venture, 'invested heavily in the New York Elevated, using much of his fortune to purchase control of the system. His reputation and monies gave a great stimulus to the whole undertaking and did much to assure the success of the company and promote its expansion'.^[4] Among the contractors were of course Clark, Reeves and Company of Phoenixville, Pennsylvania - the makers of the Phoenix Columns.

The column exteriors were painted, as at the General Market (see below). The column bases were given cast-iron fenders filled with cement to protect them from passing vehicles. Protection was given to column bases at Smithfield. As followed at Smithfield, cement was used to fill the hollow Phoenix columns to lessen corrosion and deaden noise.

On April 20, 1881, Thomas Hall read a paper to the American Society of Civil Engineers synthesising the works in detail, and with illustrations of the various types and sizes of piers i.e. Phoenix Columns - employed. 'The iron structure is composed of Warren's

longitudinal girders of the deck system whose upper chords rest upon the top chords of a transverse girder of a similar character, supported by six segment wrought-iron columns of the Phoenix pattern'. Explicit construction details, information about the project organisation and relevant costings are all provided to the reader.



RailroadStories

SCIENTIFIC AMERICAN

A WEEKLY JOURNAL OF PRACTICAL INFORMATION,
ART, SCIENCE, MECHANICS, CHEMISTRY, AND MANUFACTURES.

Vol. XLI.-No. 17. NEW YORK, OCTOBER 25, 1879 \$3.20 per Annum

THE PROGRESS OF ELEVATED RAILWAYS.

The ancient story of the intruding camel, who begged a shelter for his head in his master's tent and ultimately crowded in his unshapely body, to his master's great discomfiture, is paralleled in the history of elevated railways in this city.

The main reason for the adoption of this form of rapid transit was the cheapness with which it could be supplied. The camel's head was not attractive, but it was easily let in, and promised an easy removal should such an issue prove desirable.

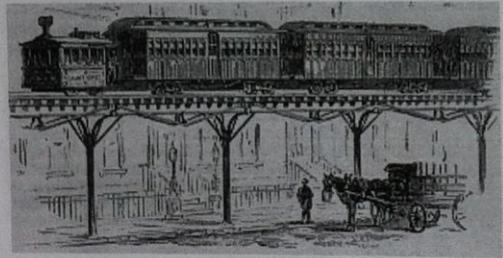


Fig. 1 shows what an early form of the original West Side elevated road was like; not the earliest form, however, for that was of considerably lighter construction. The large engraving presented below gives a hint of the enormous possibilities of the structure which has taken possession of so much of the city. As a specimen of bold, clever, and original engineering it is admirable. Its effect upon the fine avenue it overshadows is quite another matter. So, too, is its probable influence upon the region it traverses as a site for dwellings.

Fig.1.-THE FIRST ELEVATED ROAD, WITH ITS LINE OF SINGLE POSTS.

The utter inadequacy of any cheap structure of slight capacity (such as the elevated roads were at the start) to meet the wants of a city like New York, and the fallacy of the assumption that such a rapid transit road was advisable on the score of economy, were repeatedly enlarged upon by the SCIENTIFIC AMERICAN in the early days of the system; and the result has more than justified the position then taken. During the past five years, indeed during the past three years, the system has expanded from four or five miles of roadway of the lightest description, supported by single posts, to ten times as many miles of massive and costly structure already in operation, and nearly twenty miles more approaching completion - structures which almost monopolize four of our principal avenues and large portions of several down-town streets, and represent an investment of \$43,000,000.

Photo of headline article on New York Elevated Railroad, *Scientific American*, 25 October, 1879

It thus seems most likely that the practical model for Smithfield's General Market was the New York Elevated Railroad. The decision had been boosted by the copious amount of information available at the right time and Jones' own wide-ranging technical knowledge.

But Jones was taking no chances. His columns consist of a formidable eight segments!

THE LATTICE GIRDERS

At the General Market Jones used, 'a two-way spanning framework, composed entirely of wrought-iron, to carry its roof. This framework was conceived and erected as a self-supporting structure, its strength and stability dependent on the careful engineering of the column-girder connections'. The girders were supported directly upon the Phoenix Columns.^[5]

It was different in New York where six-arc Phoenix Columns supported the Warren girders. These girders carried the rails over which ran the trains. Slimmer girder connections between the lines of Phoenix Columns were erected parallel to the railroad below the Warren girders, with additional girders lower down, bracing and strengthening the whole.

At Smithfield, 'The wrought-iron lattice girders were arranged in a series of contiguous rectangles, supported at their corners by sixteen tall, built-up (Phoenix) columns of the same metal.... The framework of primary girders running in both directions was designed to provide a sufficiently strong foundation for the secondary roofing system, including the ability to withstand wind pressures'.^[6]

Warren trusses had been invented in the U.S. in 1848, as a development from the widely adopted timber lattice, or 'plank' bridge. Thence iron began to be substituted for the timber. Warren-type, wrought-iron lattice girders caught on in England from the 1850s. They were ideally suited to choose for Smithfield because of their high load-bearing capacity (they carried the central dome/lantern), and for offering load-bearing support where floors carried heavy weights, as in the market.

Interestingly, addressing the R.I.B.A (see Bibliography) in January 1882, Jones mentions that he had been using wrought-iron girders early on - 'It is quite, you know, within all our memories: the first use of wrought-iron girders that was executed, I did five or six and thirty years ago.' That puts them around 1846. Jones may have been referring to Caversham Park where of necessity his girders remain unnoticed, being hidden from view in a house. A wealthy ironmaster was his client and, unusually for a residence, Jones had also iron-framed the building.



Photo of Columns, lattice girders and roofing system in General Market. *SAVE Britain's Heritage*

In 1889, after Jones' death, the General Market morphed into a meat market, mainly for chilled and frozen produce. Changes to the fabric were carried out by Jones' successor, his former assistant, Andrew Murray. As English Heritage reports, 'the single-storey extensions to the shops added in c.1889 are supported by built-up beams, ...in some cases resting on shelf brackets riveted to the flanges of the Phoenix Columns'. This technique had been introduced by the Phoenix Company in the U.S. Murray was obviously as attuned to transatlantic ideas as Jones had been.

THE ROOFS OF THE GENERAL MARKET

Another feature of significance is the considered use of laminated timber for the roof trusses in 1881, in preference to the 'light iron' he had originally favoured. Metals tend to absorb heat from the sun. Victor Baltard's Les Halles in Paris had been criticised for their use of iron on these grounds. Jones had lectured on his City Markets, comparing Smithfield favourably with Les Halles from a technical viewpoint (R.I.B.A. Transactions, 1877-8, see Bibliography).

Jones calculated his market hall would be much cooler and better ventilated in summer, to prevent produce from spoiling, and bearable for humans in winter whence his moveable louvred dormers deflected snow, wind and rain. Glass louvres were

introduced at plate and ridge level, 'affording an ample amount of light and air', but excluding direct sun.

Jones' arched ribs were made of light, inexpensive, laminated timber. It had many advantages over solid timber in an application such as this - it can be prefabricated and simply assembled on site; it is strong and not prone to splitting, and, unlike metal, cool, and therefore was a material ideally suited to a market roof. Its use at Smithfield was not only functionally effective but, together with the central lantern/dome (see below), made an arresting architectural statement. Additionally, its louvres assisted upward ventilation. Jones was familiar with the construction of 'arched ribs' which he had used at the Royal Surrey Music Hall, on that occasion using iron.



Interior of General Market. Jenny Freeman

THE SHOPS

Before the General Market was built Smithfield's business was wholesale in character. The General Market was to introduce a retail element in the peripheral shops, some forty-one in number, and thus encourage income from shoppers by mopping up surplus product and small quantities. Non-food trading was possible. The shops potentially had basement storage and upstairs accommodation. There was more shopping provision behind, backing onto these units.

In creating the shops he was doubtless influenced by his work for the Oxford Street, London, store of Marshall and Snelgrove which, in 1851, went by the name of the Royal British Warehouse. Newly fashionable plate glass windows, set in cast-iron frames, as

later at Smithfield, were designed for the ground floor to attract customers inside. Similarly, the shopfronts and goods were shaded by awnings. Retail sales occupied the ground floor of the 'warehouse', with wholesale transactions at first floor level. The rest was used for staff living-in accommodation. This skilful combination of different uses under one roof was to prove a hallmark of Jones' success. The warehouse was partially redeveloped later as a department store.

The wholesale side of the General Market was to be conducted largely inside the huge, open market hall and along the three covered 'malls' that converged on it. There were thirty-three shops planned inside plus pitching stands for goods and wagons. These arrangements altered as the market uses changed through the 1880s (see above).

THE GENERAL MARKET IN THE TWENTIETH AND EARLY TWENTY-FIRST CENTURY

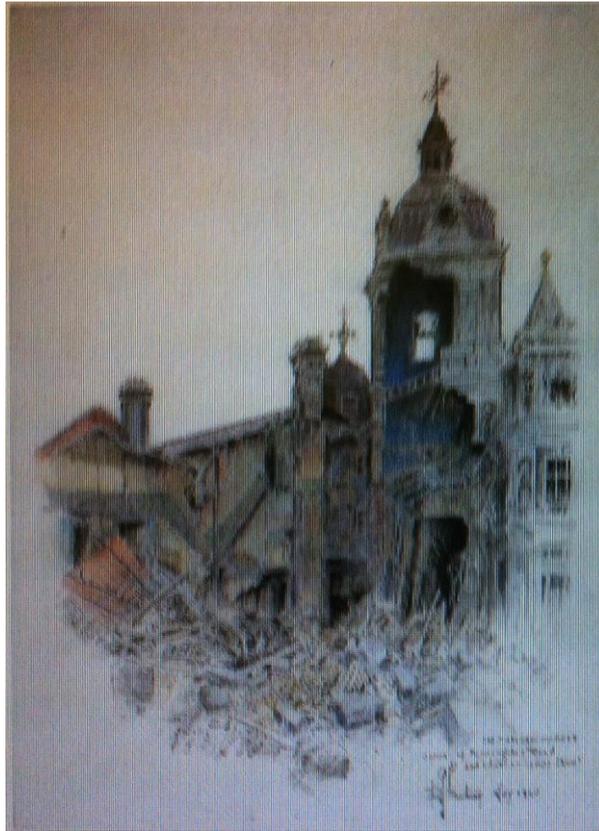
Harts Corner, the flagship of the Market complex facing Farringdon Street, with its prominent tower, flanking turrets and stepped entrance below was severely war-damaged and later demolished. The damage is recorded in photographs and in a watercolour by Richard George Mathews in 1941, now in the Guildhall Museum. It was rebuilt, in a pared-down, inexpensive manner by the City Corporation.

In 1948-53 the central dome/lantern was taken down and replaced by an elegant, shallower concrete dome which rests on the four tallest Phoenix columns and the original lattice girders. This dome was sensitively designed by the City Surveyor, George Halliday (photo, p.8).

The decorative tall slim conical tower that pinpointed the south-west corner of the General Market was removed around this time and not replaced. All these features were major losses to the townscape and diminished the intended impact of the General Market, as the key player in the Smithfield ensemble facing onto Farringdon Road which was then as now, a major thoroughfare (photo, p.4).

As has been noted, Jones' magnificent Poultry Market was burnt down in 1958 and replaced by T.P. Bennett's listed building, of 1962-63 which occupies the same footprint. Its elliptical paraboloid roof forms a visual link with the renewed General Market roof of a decade earlier.

The basement was converted to a carpark in 1970. Gradually the General Market was allowed to fall out of use, though a few outer shops/eating places continue in business and the interior is occupied for storage.



Watercolour by Richard George Mathews, 1941. Guildhall Library

THE FUTURE

The refusal of consent for the Henderson scheme has paved the way for a more sympathetic conservation-based approach. This is being explored by several parties, with the Museum of London officially declaring their intention to move to the General Market by 2021.

Given the planning and technological prowess displayed at Smithfield, it is imperative that the General Market structure is understood, respected and appropriately retained for future generations. Further investigation of this extraordinary structure on site might well answer outstanding queries and theories. At all costs it must be kept from harm.

EUROPEAN INDUSTRIAL AND TECHNICAL HERITAGE YEAR, 2015

This is being co-ordinated by the European Federation of Associations of Industrial and Technical Heritage, known as E-Faith. These rare, unique example of Phoenix Columns in Britain deserve wider recognition than they have hitherto received.

The architect, Sir Horace Jones, deserves to be better known. A moment has arrived to acclaim his achievement.

NOTES

Dr Jennifer M. Freeman OBE, BA Hons, Dipl (Cons) AA, Hon Doct Arts, IHBC, FRSA, FSA was a researcher for the New York City Landmarks Preservation Commission. She wrote her postgraduate thesis on 'Sir Horace Jones; Architect of Landmarks'. A former Secretary of the Victorian Society and Director of the Historic Chapels Trust, she now runs her own company restoring historic buildings at risk. She is a longstanding member of the SAVE Committee.

[1] The Transactions of the R.I.B.A., 1877-8, record Jones' lecture on the New City Markets, p.113

[2] Illustrated London News. April 2nd, 1859, pp. 329,337

[3] Jonathan Clarke, Early Structural Steel in London, pp. 28, 36. (see Bibliog)

[4] Robert Reed, The New York Elevated, p.57. (see Bibliog)

[5] Western Buildings at Smithfield. English Heritage Report, 2003, (see Bibliog)

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