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The Development of Steel Framed Buildings in Britain 1880- 1905

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Introduction

Was the Ritz Hotel really the first steel framed building, either in London or in Britain, and were the techniques required imported from America? If we are to understand fully British building construction in the late nineteenth century, these questions demand an answer. Surely British structural engineering could not have fallen so far behind American advances. After all, British engineers had developed the railways, including the Forth Bridge - built of steel and completed in 1890.

Studying existing literature, I was far from convinced by the conclusions reached. The impression held by most people up to now has been that the Ritz Hotel was the first steel framed building in London, because Sven Bylander , a leading steel building designer, had said so in a paper written in 1938[1]. Some authors have gone further. Peter Campbell states – '*the first loadbearing steel framed building of any significance to be built in this country was London's Ritz Hotel (1904), which was followed two years later by the east wing of Selfridges.*'[2] The Ritz was in fact completed in 1906, and Selfridges was completed in 1908. Bylander and others have suggested that these buildings relied heavily on American expertise and experience in both design and construction.

Other important questions follow. Why should it have taken so long to introduce the steel frame in this country, when apparently in America this form of construction began in the early 1880s? Thinking of some of the comments made by Ruskin and his followers, were architects to blame for the delay?

I decided to test the assertions about the Ritz, and to find answers to the other questions. This involved finding the roots of the development of the steel construction industry in Britain, and understanding how this development spread into the building sector. Surprisingly little has been written about this period, and therefore much of what follows is based on my research into documents written during the period in question, 1880 – 1905, and the inspection of buildings of the period in some detail.

There are other themes underlying the information I am presenting. These are important factors that set the context of the buildings - contemporary British building practice, the railway industry, and developments in the Europe and America. The quality, cost and availability of steel are major issues. The philosophy, education and training of architects, the contemporary engineering understanding of materials and structures had a significant effect on how the early steel framed buildings were perceived and designed. From our historical perspective, it is important to think about the challenges that a steel framed building originally presented in terms of design, co-operation between architects and engineers, and construction.

To clarify matters, first of all I need to explain what I mean by a steel framed building. My definition is as follows: "*A steel framed building consists of a framework of primary vertical and horizontal steel members connected to provide full resistance to static, live and dynamic and environmental forces.*" In such a structure the role of masonry can, but does not have to be, reduced to non-loadbearing status. The principal difference from earlier buildings is the use of continuous stanchions for the full height of buildings, butted and spliced as necessary. The connections to the columns should utilise bolts or rivets in shear, either through a seating bracket or directly through a web connection, and should have some moment carrying capacity. With the earlier forms of frame the load from the floor beams was generally carried in bearing. It is difficult to identify in all cases the exact form of the beam to column connection, and so the presence of continuous vertical steel stanchions in or close to the external wall can be taken as one of the key indicators. Detailed investigation may be necessary to analyse a building definitively, and may not always be possible.

Looking briefly at steel frame construction in the America, A.W. Skempton states that the first steel framed building was the Rand McNally in Chicago erected in 1890.[3] Larson and Geraniotis[4] have recently demonstrated that the Home Insurance Building by William Le Baron Jenney, completed in 1885, which is often referred to as the building to use first skeleton frame construction (see for example Shankland[5]), relies on the masonry cladding for its stability. In this case the iron columns are merely embedded in the walls, and their load carrying capacity appears to be secondary to the capacity of the masonry, particularly for wind loads. This example illustrates the need for careful definition of terms and their usage, as well as the reasons for studying the structural function closely.

The paper looks at the early uses of steel and shows how steel framed industrial buildings were developed, influenced by the railways. I then go on to illustrate relevant buildings with a greater architectural input, looking at northern British cities including Manchester and Glasgow. Finally the early steel framed buildings in London are discussed.

The early uses of steel

Although Bessemer patented his process in 1855, the early introduction of steel was a slow process. Serious problems caused by phosphorous in the iron ore were solved eventually by Gilchrist and Thomas in 1879. During 1860s large scale investment in iron production continued particularly in the north-east. Investment in steel production increased as demand for steel began to grow rapidly from 1870 onwards, as shown in Table I. The railway industry pioneered the early use of steel – for rails in the 1860s, for tyres and axles in 1870 and boilers in 1872. In shipping, boilers were introduced in about 1880, and hull plating came into use in about 1885[6]. The steel produced for rails was not suitable for structural uses because although it was significantly stronger it was insufficiently ductile.

Table 1 Production of Iron and Steel 1865-1906, (millions of tons)

Source: Burnham and Hoskins (1943), Tables 2 and 90[7].

Year	UK Pig Iron	UK Wrought Iron	Steel Production – Five Year Averages				
			World	UK	France	Germany	USA
1870-74	6.38	2.60	0.98	0.43	0.13	0.21	0.11
1875-79	6.38	2.27	2.46	0.88	0.25	0.41	0.64
1880-84	8.16	2.01	5.48	1.79	0.45	0.97	1.56
1885-89	7.66	1.91	8.84	2.81	0.53	1.57	2.78
1890-94	7.29	1.93	12.78	3.14	0.76	2.74	4.31
1895-99	8.64	1.15	21.54	4.26	1.24	4.85	7.63
1900-04	8.68	1.16	32.72	4.95	1.67	7.28	13.40
1905-09	9.70	0.94	48.16	5.99	2.60	10.67	20.94

Studying contemporary literature, it would appear that up to 1880 lack of supply and the questionable quality of steel might have precluded its use. Thereafter the discussion focused on permissible stresses related to various uses of the new material. Engineers were by this time willing to build using steel, though exercising care about material quality. Sir Benjamin Baker took a bold decision to use steel for the Forth Bridge, built by Sir William Arrol. An extensive material testing programme for the bridge was conducted. Of the supposed fifty year delay in introducing steel into building construction, exactly half is accounted for by production and quality issues and have nothing to do with architectural issues. It is unreasonable to expect any significant use of steel in construction before 1880. This date can be taken as the start of the mild steel era in Britain, and it is from this point that we should measure any 'delays'.

The architectural debate

The key questions to consider are whether there was a significant delay in introducing steel into the British construction industry and if so, whether it was due, as some have suggested, to the conservative attitude of the architectural profession. I hope to demonstrate that as any delay was small, it is incorrect to hold architects responsible. In this section the debate is summarised. The evidence related to particular buildings then follows.

The roots of this debate pre-date Bessemer. In 1849 Ruskin had written "*true architecture does not admit iron as a constructive material*".[8] Architects attached importance to truth and morality in their work. It is fair to say this is not a great issue with most engineers, who were not concerned with the conceptual design of ordinary buildings. In 1880 there were two papers about steel at RIBA – by J.A. Picton[9] and Professor A.W.B. Kennedy[10]. These demonstrated that the architecture profession was alive to the issues posed by steel at the earliest stages of its commercial introduction. Picton called for architects to use iron so as to bring out its strength, drawing the aesthetics of architecture into the material. He was condemned by among others William White who called for a new 'tecture', since he believed that construction using iron could never be considered to be archi-'tecture'.

At a further stage in the debate, the design of Tower Bridge, completed in 1894 and still aesthetically controversial today, incensed some of the architectural profesion because of the way its masonry towers conceal steel frame construction. H.H. Statham refused to show it in *The Builder*. Two of the few modern commentators on this debate about the early uses of steel, M. Bowley and F.M. Locker, both write on the erroneous assumption that the Ritz was the first steel framed building in Britain. Bowley holds the design professions responsible[11] for the slow adoption of steel framed construction . Locker states that '*the concept of full load bearing construction confronted the most basic aspects of Victorian and Edwardian architectural logic: truth in construction and stability of form.*'[12] The pragmatists, for example Picton, said at the time that steel construction would happen, and architects should learn how to use the material. In reality, after 1880 engineers became increasingly familiar with designing and fabricating using steel, whereas steel construction presented difficulties to most architects because of their different training. As Hart, Henn and Sontag suggest, iron and steel challenged the traditional concepts of architecture – post and lintel, the arch and proportions of mass and space[13]. The seeds of a revolution were being sown.

We should also recall briefly the state of structural engineering theory in the 1880s[14]. During the period between about 1860 and 1880 there was considerable development of graphical methods of analysis. In parallel, theoretical strain energy methods applied to frame analysis were being formulated; however, these methods were complex and time consuming to apply and required a mathematical understanding that was likely to be make it unworkable in many practices on grounds of cost and ability. There was also inevitably a time lag between the announcement of a theory and its use in the design office. Nevertheless in the late nineteenth century, the theoretical basis for the design of framed structures existed, but empirical methods or simplifying assumptions were needed to be able to design indeterminate frame structures.

Industrial Buildings

Industrial and railway buildings were outside the mainstream of architectural design, and are therefore a good place to start the search for examples of early steel construction. In this section some of the early steelwork contractors are identified together with examples of the types of industrial construction which occurred between 1880 and 1905.

Sir William Arrol completed the Forth Bridge in 1890. By this time his company was operating a construction department, and there was a thriving market for workshops and machine shops. Between 1894 and 1907 Arrol built 143 steel framed workshops of various types, 42 of which were completed by 1900[15]. Other leading contractors also had steel construction departments at this time, including Redpath Brown and Dorman, Long & Co.

The new cargo sheds at Cessnock Tidal Dock, Glasgow were completed in 1895 and are an example of Arrol's work. The buildings were described in *The Engineer*[16], and were designed by James Deas, Engineer to the Clyde Trust. The north shed was 1668 ft long by 70 ft wide, and that on the south 1156 ft by 75ft. The main frames were at 32ft centres, with the stanchions designed for loads of up to 255 tons. The rear wall was constructed of load bearing masonry, whereas the front wall was open, the loads being taken directly to the foundations by steel stanchions, fabricated 18ins square sections, having typical plate thicknesses of 1/2ins. The building indicates the scale of Arrol's sheds and workshops, which were successors to many earlier workshops built using masonry, timber, cast and wrought iron in the engineering centres around the country.

There is more evidence of steel construction capability in the early 1890s. Gilbey's Gin Warehouse in Camden was built in 1890-94[17]. William Huck, who apparently combined the posts of head distiller, architect and engineer (an unusual blend), carried out the design. The warehouse has five floors and a basement. Steel stanchions support primary beams spanning front to back and secondary beams carrying filler joist floors. The walls are mass concrete, and are partly reinforced. This interesting building is one of London's early steel buildings.

In 1894 Arthur Dorman reported at his company's Annual General Meeting that there was a desire among leading engineers to adopt RSJs instead of built up girders, and that the trade was developing in London[18]. This was ten years before Ritz! Dorman Long published their first steel section book in 1887: by 1898 the same firm produced 11,000 tons of fabricated steel. This figure increased to 22,000 tons in 1901 (the distribution of this steel between bridges, buildings etc. is not known). In 1900, Dorman Long were awarded one contract for 10,000 tons of steelwork for the Westinghouse factory in Trafford Park, Manchester. This site is being redeveloped at present, and many of the buildings have been demolished. The Dorman Long archive at the British Steel Records Centre in Middlesborough shows the range of their contracts both in Britain and overseas.

An interesting contrast in the use of materials is shown in the late 19th century fashion for towers. Andrew Handysides and Co. based in Derby, constructed the New Brighton Tower in steel in 1900, whereas the earlier Blackpool and Eiffel Towers were in wrought iron.

The Market Street Store, Dublin 1904

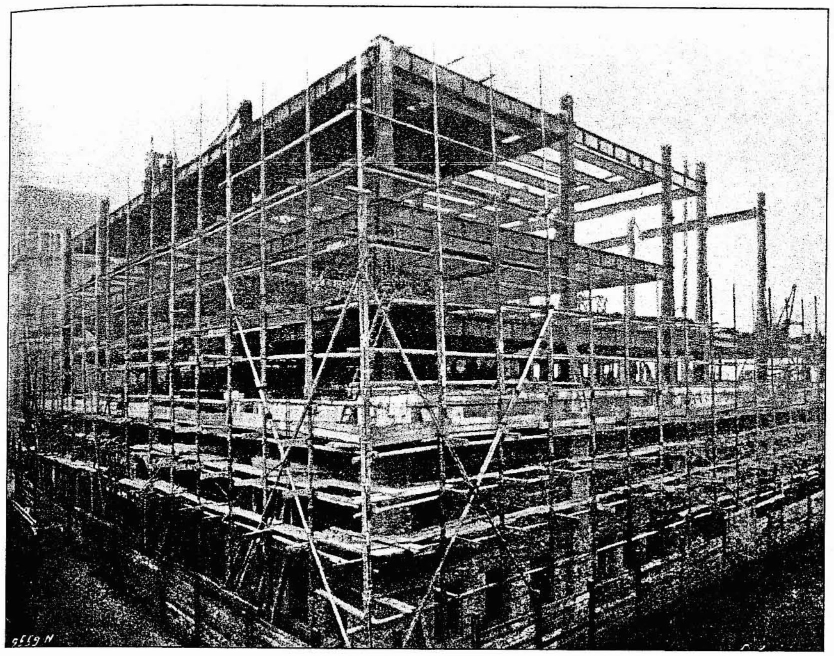

Fig. 1 The Market Street Store, Guinness Brewery, Dublin (1904). The building during erection, showing stanchions in the two external walls, and the steel frame constructed ahead of the masonry cladding (Sir William Arrol Ltd., *Bridges, Structural Steelwork and Mechanical Engineering Productions*, 1909).

The Guinness Brewery in Dublin has an important example of a fully framed multi-storey steel structure known as the Market Street Store, completed in 1904. Arrol supplied the steelwork for the building. Judging from surviving correspondence I believe the engineer was Tuit of Arrol's. The building has eight floors giving a height of 116 ft. In plan the dimensions are 165 ft by 146 ft. It is constructed using box columns supporting plate girders and joists and has a masonry outer skin. The original structural drawings have been lost, but a photograph taken during construction by Arrol clearly shows stanchions erected on two sides of the building ahead of the masonry (Fig. 1). This was sometimes referred to in Britain as the 'American' system, but in fact it is an entirely logical way to build a steel framed structure having continuous stanchions. The beams in the west wall are visible from within the building, but this is not the case on the other three sides (Fig. 2).

The evidence strongly suggests that the frame carries the entire load, and that the masonry, though of load bearing thickness on three walls, at most carries only its self weight. The girder connections are site riveted down the full depth of the web, and will resist bending moments (Fig. 3). In plan view, the frame has corner braces to provide resistance to differential horizontal loading, further evidence that the frame was designed to work in three planes.

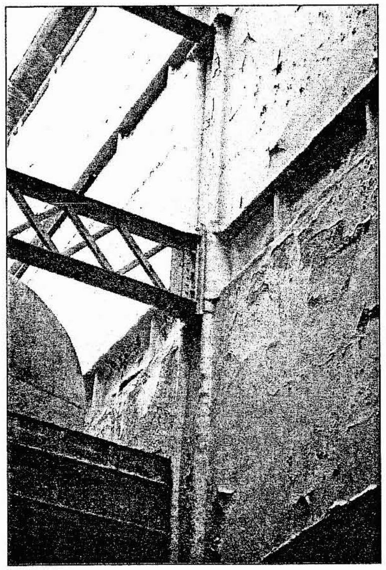

Fig. 2 The Market Street Store, Guinness Brewery, Dublin (1904). Interior view of the west wall showing framework supporting masonry wall panels (Alastair Jackson).

The significance of the Market Street Store is that it is one of the earliest examples of a fully framed multi-storey steel building, and most importantly it appears not to have been altered and so remains in its original structural form. Moreover, this form is fully exposed. The connection details, which have moment carrying capacity, may have been designed specifically for the project, or they may be standard Arrol details. I believe this is one of the earliest surviving buildings in the British Isles showing fully riveted construction. The building is at present unused, and it is to be hoped that forthcoming conversion work will respect its structural importance of the building and its structural framework.

Railway Buildings

As indicated earlier, the development of the railways was one of the main driving forces behind the introduction of steel, in various forms. There were strong links between the railway and steel construction industries, not only in the demand for steel, for rails and locomotives, but also in infrastructure development – particularly bridges, stations and warehouses. W.T. Foxlee, an engineer, designed the Great Northern Warehouse, constructed in Manchester between 1895 and 1899.[19] The building is a unique triple interchange – connecting road, rail and canal. The frame uses steel stanchions with cast iron inserts at each floor level to connect the steel floor beams (Fig. 4). This appears to be an unusual detail which I have not found in any other structure. There is a brick façade. In all, 12,000 tons of steel were used for the warehouse and the approach ramps, with the stanchions being designed for loads of 650 tons. Arrol and Heenan & Froude (who also built the Blackpool Tower) supplied the steelwork. The rolling marks on the joists indicate that they were manufactured by Dorman Long and Leeds Steelwork. At present the building is under threat of alteration in response to which the conservation argument has tended to focus its the transportation role, rather than its structural importance; it is now listed Grade II*.

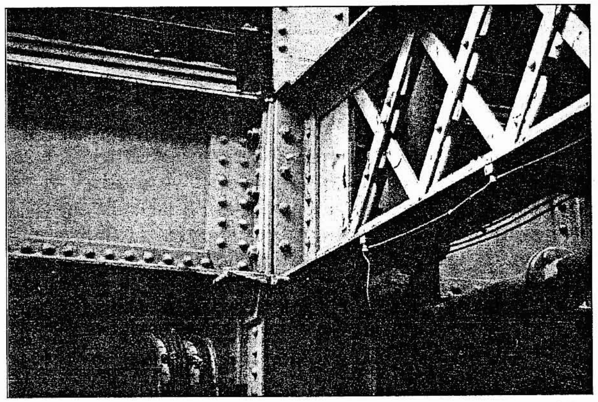

Fig. 3 The Market Street Store, Guinness Brewery, Dublin (1904). Detail of the beam-girder connections within the volume of the girders (Alastair Jackson).

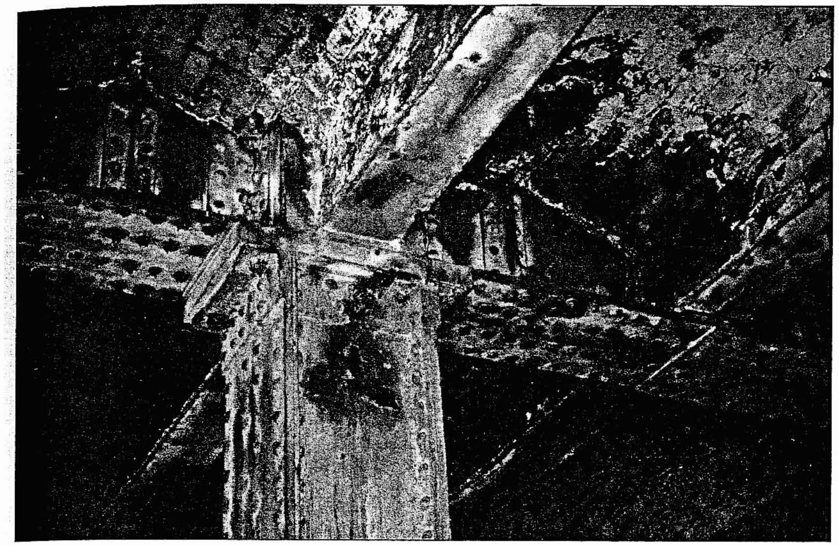

Fig. 4 The Great Northern Warehouse, Manchester (1895-99). Compound steel stanchion supporting steel girders, showing stanchion break at floor level and cast iron seating for floor girder (Alastair Jackson).

At Marylebone there is a similar warehouse constructed at the same time as the Great Northern Warehouse.[20] The four floor building was designed in 1896 and completed in 1899. Structurally the building was a significant advance in that the stanchions are continuous for its full height, and the building as a whole utilised 7000 tons of steel: the walls remain load-bearing. Riveted brackets support the main floor beams. These warehouses were designed for enormous loads – in this case 22,000 tons. The mass of the building was no longer the dominant load, and high point loads from the stanchions presented challenges for the foundation design. Such buildings as remain are still very useful and strong buildings.

Moving to Glasgow, early work at the Central Station in 1876-8 gave Arrols some of their early experience which led to the Forth Bridge.[21] The station was enlarged between 1901 and 1906 using steel for the construction. The work also involved a new steel bridge over the Clyde. The constraints in planning the station were resolved by arranging the platforms in echelon. The new station roof, which still survives, has a clear span of 140 feet and is about 900 feet in length. The main roof trusses have a semi-elliptical bottom flange and are built in steel. The roof is supported by steel columns, octagonal in cross-section, built of specially pressed plates. The columns are filled with concrete to reduce corrosion.

The Victoria Station, Nottingham, built for the Great Central Railway in 1901, illustrates the confidence with which structural steel was being used by the turn of the century. The roof consisted of steel arched trusses supported on steel box columns rising 43 feet above the platforms. Such columns were built into the outer masonry walls of the station. The description given in *The Engineer* demonstrates the depth of thought given to the detailing of the roof, but provides little insight related to loads, stresses or analysis.[22]

These examples strongly suggest that steel had completely superseded wrought and cast iron in station construction by the turn of the century. The conclusion from this outline of the steel construction industry in Britain around the turn of the century is that British engineers emphatically did not need lessons in steel design from the US. Now we must consider how and when the architects of the day began to incorporate steel into building construction.

Early uses of steel in buildings

Buildings by Sir Alfred Waterhouse

There are claims that steel was introduced into buildings at a very early date. Whilst some members of the architectural profession were debating the subject of steel, one of their number, the highly respected Sir Alfred Waterhouse (1830-1905) was already quietly using steel in his buildings. The main evidence for this is contained in his biography by Cunningham & Waterhouse (referred to here as Cunningham for clarity).[23] Cunningham and also J. Mordaunt Crook ascribe very early dates to the use of steel by Waterhouse, prompting the question as to whether the material was steel or iron. Cunningham includes a summary of all buildings designed by Waterhouse, including details of the various contractors, the steelwork contractors among them. The first reference to steel in the list is 1869, where J S Bergheim are reported to be the structural steelwork contractors for Owens College, Oxford Road, Manchester.[24] If true this would be remarkable. The first building for Prudential Assurance designed by Waterhouse in 1876-9 is also said to contain steel. Crook also states that the Natural History Museum has a steel frame – constructed in 1873-81.[25] On this evidence perhaps the Americans learnt the secrets from British engineers! Again, I have tried to cross-check this information against sources from the time of construction.

A contemporary article in 1879 about opening the Prudential building in Holborn refers to iron beams supporting the ceiling being encased in cement. The *Survey of London* states that all the iron for Natural History Museum came from Belgium[26] On the basis of this evidence and the state of development of the steel industry at the time, it seems most unlikely that Waterhouse was using steel as early as the 1870s. The confusion may arise from the loose and mixed use of the terms 'iron' and 'steel' in the early days.

The results of my research suggest that the first major building in London to make extensive use of steel and for which there is good evidence is the National Liberal Club, which was completed in 1887, some twenty years before the Ritz Hotel (Fig. 5). This is a grand and opulent building which retains its style and character more than one hundred years after its construction, a testimony to the quality of the materials and workmanship that Waterhouse must have demanded. I have examined the original specification for the building which is archived at the Club. The specification clearly distinguishes between iron and steel. Large built up columns and girders, both of steel, were used. Waterhouse used a separate contract for the supply and erection of the steelwork, which accounts for the difficulty in tracing steel details when looking at architectural archives. Cunningham records the W.H. Lindsay as steelwork contractor and the value of their contract as £165,950. The specification calls for the use of 12 No. steel stanchions under the Gladstone Library, 6 No. under the Grill room and 8 No. under the Dining Room. These stanchions take the form of detached columns situated about four feet inside the line of the outer walls (quasi-framing), and thus reduce the loads on the walls significantly (Fig 6). The result is a

Fig. 5 The National Liberal Club, Westminster (1885-7).

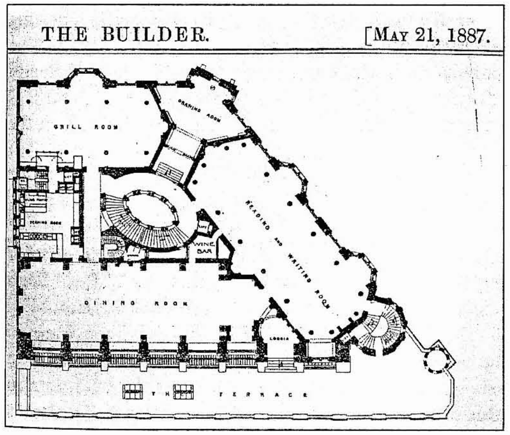

Fig. 6 The National Liberal Club: plan of the upper ground floor (*Builder*, May 21st. 1887, p782).

grandiose and impressive building for an early steel structure. *The Builder* also gave a long description of the building.[27] We should not underestimate the achievement – this building was completed before the Forth Bridge.

There is other evidence of Waterhouse using steel. In 1892 the Liverpool Royal Infirmary was completed using steel floor joists. In the same year, the National Provincial Bank, Piccadilly incorporated cruciform built up steel columns with steel floor girders, supplied by Handysides. Records I have reviewed at the RIBA indicate that some iron was also used in the building, showing that a conscious process of material selection was going on. There was no opposition from the architectural establishment to such uses. As President of the RIBA 1888-91, Waterhouse was a leader of the architectural establishment, and he was also a leader in the use of steel. The evidence of Waterhouse puts the arguments from Locker and Bowley into perspective, and shows that steel was quickly adopted by forward thinking British architects at a much earlier date than has been recognised hitherto.

Royal Insurance Building, Liverpool (1895 – 1903)

In 1895-6, J. F. Doyle and Richard Norman Shaw completed the design for the Royal Insurance Building in Liverpool. This is the earliest design of a steel framed building in Britain that I have identified. The building was partially occupied in 1900, and was not opened until 1903. It is one of the pioneer steel framed buildings in Britain, having a main building height of 119ft. The ground floor is a vast and impressive space – I suggest it could not have been created without steel (Fig. 7).

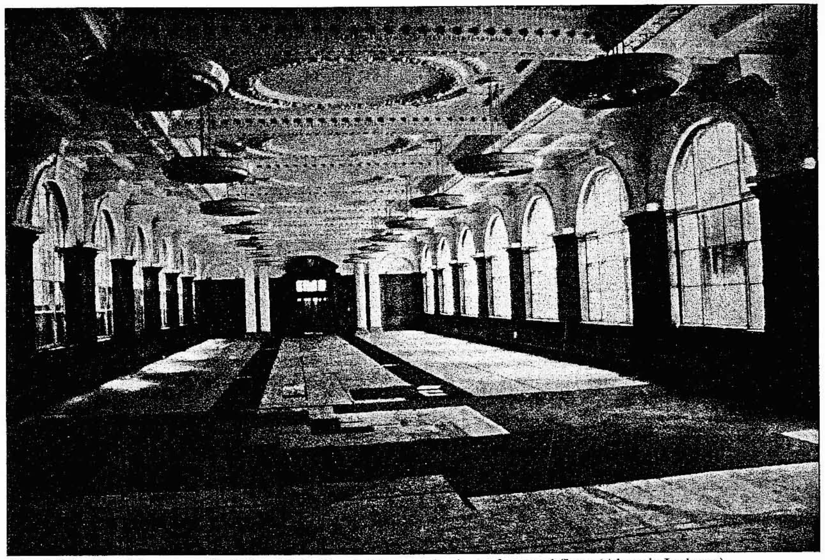

Fig. 7 The Royal Insurance Building, Dale Street, Liverpool: view of ground floor (Alastair Jackson).

A contemporary description states that the 'steel framework is virtually self-supporting and does not depend for support merely on the masonry of the external walls'.[28] The drawing, (Fig. 8), shows the general arrangement of the frame, evidence of which is clearly visible within the building. The building is a bold and confident design statement, and it is interesting to speculate about the source of the experience in steel frames manifest in the drawing.

Claims by Basil Scott

The purpose of this paper is to present the early history of the steel framed building rather than to simply identify the first of the type. However, the statements made by W Basil Scott need to be discussed, for he actually claimed that his design for a furniture warehouse in West Hartlepool in about 1895 was the first steel framed building.[29] Scott was consistent in his claim about being first, but not the place or the date, for in 1930 he wrote that the first recorded example (again one of his designs) was in Stockton on Tees in 1898.[30] It is also odd that Scott was eager to publicise his claim, but never gave clear details of the structures themselves. As to 'first', much depends on precise definitions, and whether one considers completion of design or of construction as the criterion.

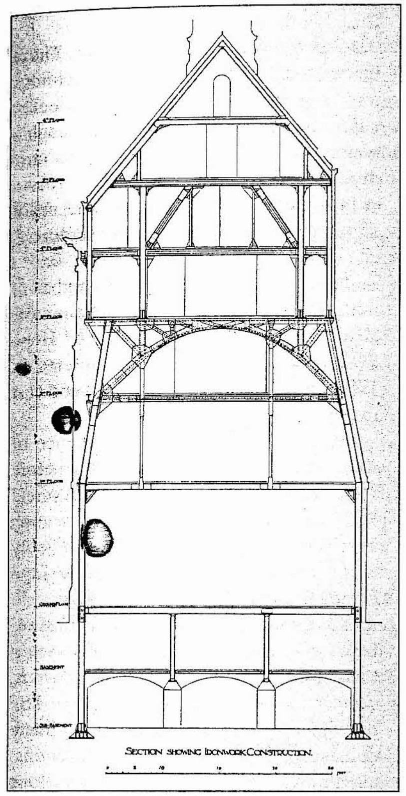

Fig. 8 The Royal Insurance Building, Liverpool. Cross-section of the building showing structural steel frame (J.N. Hetherington, *The Royal Insurance Company's Building, Liverpool,* 1904, courtesy of Andrew Saint)

Robinson's, the major store owner in Hartlepool, had a series of stores in West Hartlepool, whose history was summarised in 1907 in a local newspaper.[31] It is clear from this history that none of the dates of construction of Robinson's Lynn Street stores match Scott's date of 1895. The possibility remains that Robinson had other property, a warehouse as well as a shop in West Hartlepool or that Scott was working for another client. My conclusion is that I have found no evidence to corroborate Scott's claim about an 1895 steel framed building in West Hartlepool. In any case the claim may be considered irrelevant because the design for the Royal Insurance building can be documented to 1895, and is clearly a far more substantial building.

A newspaper report of the opening of the Mathias Robinson store in Stockton in May 1901, states that the building '*is of steel skeleton type, of girders and stanchions encased in plaster*'.[32] The architects Barnes and Coates of Sunderland designed it. The building is listed, having been refurbished in 1936, and is now a Debenhams store. The form and detailing of the frame require further research, but this building remains one of the early steel frame buildings, though not on the scale of others described here. By 1901 other steel frame buildings were under construction: Scott was therefore only one of a number of engineers involved with steel frame construction prior to the Ritz Hotel.

Early steel framed buildings in Scotland

J. J. Burnet has been credited with the first steel framed buildings in Scotland[33] and there is reference to 'occasional steel framing' in Glasgow after 1895.[34] If this is the case, then the influence of Arrols, based in Glasgow, would seen to have spread to building industry and given the city a lead in steel frame design. Burnet's Kodak building in London (1911) is well known. What did he do earlier? Where did John A. Campbell, a former partner of Burnet's, fit in?

To answer these questions I carried out extensive research into the records of important buildings in Glasgow using the excellent and efficient system of Dean of Guild Court records. Burnet's first large building was Atlantic Chambers. The drawings were signed and dated on 30th April 1898, and the building was completed in 1900. The drawings show

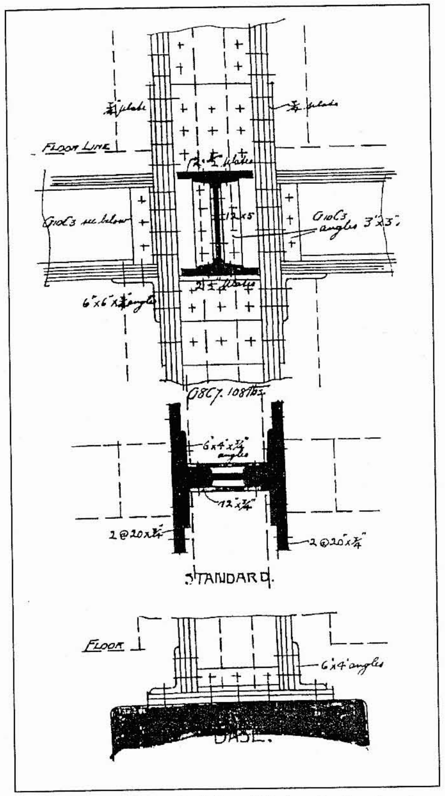

Fig. 9 The Scotsman Building, Edinburgh, showing stanchions over the engine room (drawing dated 27th October 1898, in Edinburgh City Archives).

clearly that the floor loads are carried to the load bearing side walls by transversely spanning steel beams. These beams slot through the cast iron columns and are supported but not directly connected to them. The later McGeogh's warehouse (completed in 1906 and now demolished) also had steel joists supporting the floors, with the main support provided by cast iron columns encased in concrete.

It is a similar story with Campbell – both at Dundas House in Buchanan St, also designed in 1898 and 157-167 Hope St, designed in 1902 and completed in 1903. Both use steel floor beams and cast iron columns.

Surprisingly, I found no evidence of steel framed buildings in Glasgow before 1905, and did not look at later ones. Steel construction design and fabrication expertise must have been more profitably employed in the shipyards and bridge companies than in the building trade.

I believe that Burnet's first steel framed building was R. W. Forsyth's (now Burtons) in Edinburgh – where construction started in 1906. The drawings show that the main floor girders consist of 19in. built up beam sections, assumed to be steel. The main floor beams are carried on stanchions built into the outer walls. My brief inspection of the building revealed one stanchion on the fifth floor with a flat flange. I concluded that Burnet was not the pioneer of steel framed buildings that I had anticipated.

By contrast my research in Edinburgh has revealed that the Scotsman building, designed by architects Dunn and Findlay in 1899 and completed in 1902 has full steel framing. The building has several floors, and is a vast building on a steeply sloping site in a prominent position in on the west side of North Bridge. I have not discovered the name of the contractor. The scale of the construction again suggests confidence in the use of the material. The Dean of Guild drawings (Fig. 9) show that the building has a steel frame, and most importantly has continuous stanchions.[35]

The building has six floors plus two basements, and the plan of the first floor below Market Street shows stanchions in the external walls of the building. These drawings are the only source of information found during this study, and more work is required to establish the exact form of the structure. The heavy stanchions are quite different to Burnet's buildings in 1900 and 1902, and the building demonstrates that Burnet was not in forefront of structural design at all. Perhaps the economics of construction meant that for speculatively built offices the steel frame was not competitive at the turn of the century.

The Midland Hotel, Manchester

Having already discussed Trafford Park and Great Northern Warehouse, we now consider another important building in Manchester, the Midland Hotel, which continues the railway influence again. The hotel occupies a prominent site in the heart of Manchester near to the former Central Station. It was here in May 1904 that C S Rolls and Henry Royce agreed to form the illustrious company named after them.

Charles Trubshaw, who was architect to the Midland Railway Company, designed the hotel. Construction started in 1900, so the design must have been completed earlier when there were few steel frame examples from which to learn.

Anticipating the ideas that Bylander claimed to have introduced at the Ritz and Selfridges about five years later, the *Builders Journal and Architectural Record (BJ&AR)* explained that:

> *'the speedy erection of the buildings has resulted more from foresight, close direction of the work and good wages.... The contractors know what they want and carry out their work in a systematic way – that is the pith of the matter.'*[36]

These methods had been developed at the Westinghouse project at nearby Trafford Park. The main contractor was the Manchester firm of W. Brown & Co and the contractor for the steelwork were Messrs. E. Wood & Co of Manchester. *BJ&AR* gave credit to a Mr. J.C. Stewart for the erection of the hotel, but does not indicate the company for which he worked. The steel was supplied by Dorman Long, who were also involved at British Westinghouse. This establishes at an early date the direct connection between the engineering of industrial development and the introduction of steel into the commercial sector of building construction. The Midland Railway were aware of the pioneering nature of the hotel, for a representative is quoted as saying that it would, '*it is confidently expected, influence the future of all English hotels both from a structural and managerial point of view*'.

The erection included 2000 tons of constructional iron and steelwork, chiefly built up stanchions and girders, some of the latter weighing 30 tons.[37] *The Builder* gives a good indication of the scale of the operation, and clear evidence of the existence of the steel frame:

> *'and then was seen the erection of a framework of girders – a skeleton of steel – going up apparently to a sixth storey. This steelwork cost £200,000. The contractors, who have never during the last six months had less than 1,000 men engaged on the job at once...'*[38]

The illustration (Fig. 10) confirms that the stanchions were continuous over more than one storey, and indicates the scale of the workforce employed. Here is indisputable evidence of an established British steel frame building construction industry operating in 1900.

Early steel framed buildings in London

So we must now come back to London and re-examine the cases of the Ritz and Selfridges. We need to remind ourselves of what Bylander said about the Ritz – '*the style, the details ... were the same as were being used at that time in New York Buildings*'.[39] Whilst Bylander was an important figure who left an excellent record of his work and thinking, the evidence is that a steel frame construction industry, was operating in London before construction of

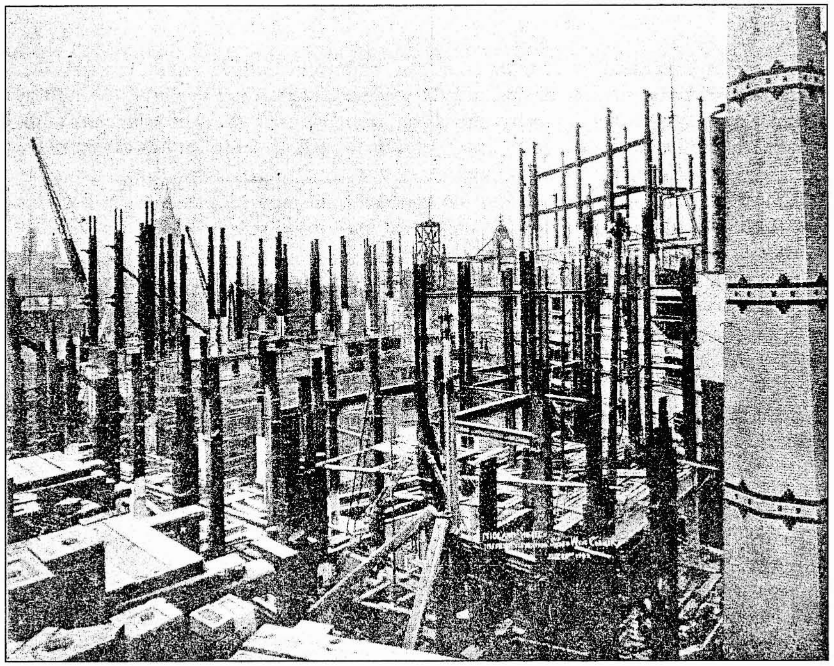

Fig. 10 The Midland Hotel, Manchester. The erection of the steel frame in 1903 (*Builder's Journal and Architectural Record*, May 20th 1903, p204).

the Ritz got under way. As we have seen, it was already well established in other major British cities.

There was, and still is, great rivalry, between the Ritz and the Savoy Hotels. This rivalry extended to construction, for a major steel framed extension to the Savoy was built in 1903-4, ahead of the Ritz. The architect for the work was Thomas E. Collcutt.

British Steel records show that Dorman Long had a contract with James Stewart & Co to supply 2,000 tons of steelwork for the Savoy Hotel extension of the south, east and west wings adjoining the Strand.[40] This is the same James Stewart, described as '*a Scottish building manager having American training*'[41] who was responsible for the Westinghouse works and the Midland Hotel in Manchester. The *BJ&AR* article about the Savoy Hotel extension refers to the work being carried out by Americans (Stewart employed an American site manager to hustle the work along).[42] The *BJ&AR* states in 1904, before the Ritz articles, that skeleton construction was used, and '*it is worth noting that although the steelwork carried all the weight, the London County Council would not allow thinner brick walls.*' (It is interesting to note that *BJ&AR* says Manchester would allow them – does this mean Midland Hotel walls are thinner? – an area for further research). The construction at the Savoy was ahead of the work at the Ritz Hotel. There is likely to have been more than a little competition between the two hotel owners. The cost of work was £1,000,000, a vast sum of money in those times.

There is another earlier commercial building - Harrod's Phase I (1901), which was constructed by the engineering contractors Morelands. There is a photograph in the

Moreland archive at the Institution of Civil Engineers showing part of the Harrod's building under construction. It shows vertical stanchions in the external wall, which based on knowledge of Moreland's work can be assumed to be made of steel.

The Builder describes the new department store for Waring and Gillow, completed in 1906, as having '*the constructional steelwork [is] so arranged that the whole weight of the floor is carried on stanchions, thus relieving the brickwork of any actual weight*'.[43] The architect was R.F. Atkinson who was the designer of steel framed Laurie McConnell (now Habitat) Store in Cambridge, completed in 1903. Atkinson was later involved with Selfridges; the contractors were Waring White, (the same Waring as in the store itself) who also had something of a reputation as hustlers (a word much in vogue during the 1900s). Bylander worked for Waring White and so he was probably also responsible for the design of the steelwork for this building.

The construction of these buildings before the Ritz Hotel puts the arguments over the London Building Regulations into a different perspective, since it shows the London County Council was prepared to sanction steel framed buildings, but not 'thin' walls, well before the Selfridges building.

The effect of the LCC Building Regulations

The London County Council has been blamed, particularly by J.C. Lawrence, for the delay in introducing steel framed buildings in London. I believe the debate was as much to do with volumes and fire regulations as over the design of a steel framed building.

Lawrence states that the two factors in the London Acts that restricted the planning of the Selfridges steel framed building in 1906 were the regulations about building volume, part of the fire protection provisions, and those pertaining to structural stability, principally the requirement for load-bearing external walls.[44] The validity of concern about fire safety expressed by the authorities is demonstrated by the fact that in 1906, within the LCC boundaries there were 112 fires where structural safety was endangered and twenty four lives were lost.[45] Selfridge's team strove to increase the volume of the store, but it is not clear if any additional fire protection safeguards were offered. As Lawrence points out, twelve other petitions to exceed the cubical limit were submitted in 1906, so Selfridges was not an isolated case.[46]

Regarding wall thicknesses, it should be remembered that the regulations were for general use, with a system enabling consideration of specific exceptions. The vast majority of buildings would have been designed with load bearing walls on the conservative basis of previous experience without resort to calculations or engineers.

The very fact that Selfridge got permission for a steel framed building under the 1894 Act demonstrates clearly that the Regulations were not an insurmountable obstacle to progress, which is rarely achieved without struggle. The publicity surrounding the construction of the store undoubtedly helped to launch his business. By their nature, technical regulations tend to follow practice – the progressive designer is always trying to expand the boundaries, and his imagination and ingenuity will be permanently ahead of a set of codified rules written for general use within an industry.

Engineering design considerations

When reading the 1894 Act, the dearth of technical requirements for buildings is striking.

The introduction of steel framed buildings meant that fundamental changes would be needed in both the regulations and the design process. In structural terms, in a traditional building the floors span between the load bearing walls, or to a supporting column, and it had been usual practice to select member sizes empirically. As metal columns and early steel floors were introduced, the situation became more complicated, and guidance relating beam depth to span for a particular building type, and column capacities would have been needed. With a full steel framed building, several important new considerations arise. These may be summarized as:

- The allowable stress for steel had to be defined, and was much debated by the professions; it determined, among other elements, the depth of floor beams.
- Steel stanchions had to be checked for buckling. This can occur both locally, when the flange collapses, or globally when the full column gives way. The integrity of the building also relies on the strength of the joints which needed designing.
- The third important design aspect, and potentially the most difficult to determine, was the overall stability of the building. The structure has to sustain important actions such as windloads and temperature effects, which become more significant as the buildings become higher and less massive.
- Steelwork had to be protected against corrosion.
- New forms of joint detail were needed for the connection between columns and floor beams; during erection of the building, these joints had to be made on site with rivets, a new trade for the building construction industry.

Most of these design issues had been already been addressed by engineers in bridge design, and some of them by naval architects (one of White's new 'tectures'!) as the design of steel ships progressed. In America the early skyscraper designers had faced up to these challenges. They were new issues for architects, and emphasised the need progressive thinking and a move towards a much more rational and less pragmatic method of analysis and design. The changes required collaboration between the professions to develop steel framed buildings. It is no coincidence that when architects did begin to explore the new materials, Modernism was one of the fruits.

Conclusions

After Bessemer's invention in 1855, due largely to the difficulties in producing Bessemer steel from basic (alkaline) iron ores, demand for iron-based industrial products for the railway and ship building industries continued to be met primarily by wrought and cast iron until about 1880. By this time the quality of steel had been shown to be acceptable and production levels began to increase. In 1882 the construction of the Forth Bridge was started using steel. It was one of the first major projects in the world to use steel – the scale of the undertaking was and remains dramatic. The bridge was completed in 1890. By that time the contractors, Sir William Arrol & Co. Ltd. were constructing some steel framed workshop buildings and other contractors were moving into the steel construction industry. We have seen how the construction of large goods warehouses and the need to enlarge stations provided further areas in which steel design experience was developed.

Sir Alfred Waterhouse was one of the first British architects to incorporate steel components into his buildings. There is clear evidence that the National Liberal Club in London, completed in 1887, has substantial steel columns, and that some proportion of the floor beams are made of steel. This is a much earlier date than has been hitherto recognised for the use of steel in buildings designed by architects. Waterhouse used separate contracts

for steelwork and general building.

The first all steel building in Chicago appears to have been the Rand McNally Building, erected in 1890[47]. So the construction industry in Britain was not far behind. The expertise in steel construction gained in the railway and industrial sectors was quickly used to design steel framed buildings. Three examples of such buildings designed by different architects and built in different cities between 1895 and 1900 have been documented. The Royal Insurance Building in Liverpool, designed in 1895 by J. F. Doyle and Richard Norman Shaw has a steel frame and is the earliest steel framed building I have so far discovered in this country. The claim by Scott to have built a warehouse in West Hartepool in 1895 looks dubious, and is overshadowed by Doyle and Shaw's building. The Robinson's furniture store at Stockton on Tees, with which Scott was involved, is an early example of a steel framed building. There are numerous other examples of steel framed buildings built around the country between 1900 and 1905. The extension to the Savoy Hotel, built in 1903-4, is steel framed and pre-dates the Ritz Hotel, which thus cannot be considered the first steel framed building in the country, or even in London. I have shown, contrary to some sources, that the buildings by Burnet and Campbell built in Glasgow and Edinburgh before 1905 are not steel framed. I suggest that Scotland's first steel frame building is the Scotsman Building in Edinburgh, completed in 1902, ahead of Forsyths, begun in 1906.

There is overwhelming evidence that there was a steel construction industry in Britain from 1880 onwards, which included commercial building work. There is no strict sequential chronology applicable to the change from cast iron columns and wrought iron girders to steel stanchions and girders and full steel framed buildings. By 1905, the use of steel and the construction of steel framed buildings in Britain was widespread.

Whilst the architectural profession was undoubtedly engaged in a debate about the use of steel in buildings, this was part of a wider debate related to the search for a Victorian style, a debate which went back to Pugin and Ruskin. As with all debates, there were two (or more) sides to the argument. One group was accepting and using the new materials, another group would have nothing to do with them. This is part of the normal process of change: and it takes time for changes to be assimilated and accepted, particularly by those brought up and accustomed to different design philosophies. I have shown that in reality, the perception of a slow or delayed take up of steel construction and steel framing in Britain is mistaken and that Waterhouse was incorporating steel into his buildings by 1887. The development in Britain followed a different path to that in America because the social, economic and cultural conditions in the two countries were quite different.

The development of the steel framed building in this country was not, as some have suggested, reliant on the importation of American construction techniques or American challenges to the building regulations, though in time these had to be revised. The Ritz Hotel and Selfridges were but part, and not the first part, of a wide group of early steel framed buildings, all of which were symbols of new techniques and ideas. The skills and experience and expertise necessary for their construction already existed in Britain.

Although the steel framed building was superficially similar to earlier framed buildings constructed using cast and wrought iron, it was in fact radically different in terms of its structural functioning. Notwithstanding important artistic influences, Modern Movement buildings were dependent on these new technical developments. The fundamental technical change brought about by the introduction of steel into buildings was to use continuous columns, extending for more than one storey. This ended the long tradition of constructing buildings floor by floor. The design of the joints between columns and floors changed significantly as a result.

The design, fabrication and erection of constructional steel was initially undertaken by specialist companies. The design procedures were more complex than for the traditional buildings, and engineers rather than architects possessed the training, the skills and the experience in these matters. It was in the period around 1900 that independent engineers became involved for the first time in the process of building design. It is no coincidence that this change took place concurrently with the construction of the first steel framed buildings. The transition can be viewed as a design revolution, following the interpretation by Addis of Kuhn's theories. There was a crisis in architecture, in part because architects' design skills did not fit them to design steelwork. A rational solution evolved by bringing into the building industry the engineering skills developed in related industries. The new model of architects and engineers co-operating in building design is still functioning well one hundred years later.

Looking back, we can see that though cast and wrought iron had significant influence on the architecture of buildings, the introduction of mild steel has been of even greater long term significance. As a construction material it has lasted already for more than a century and forms the structural heart of a large proportion of modern buildings. The important change at the end of the nineteenth century was the introduction of the continuous stanchions of more than one storey, and changes in connections detail resulting. As a material, steel has proved to be flexible in modes of application and when well detailed, durable. After the pains of the late nineteenth century, due in part to an unfamiliarity with a new material, architects have grown accustomed to using steel, working with their chosen structural engineers.

As Picton foresaw in 1880:

> *"Science has put within our reach a new constructive element so to speak, of which the engineer has hitherto almost enjoyed the monopoly. Let the architect put in his claim. The material is plastic and ready to take any form that genius and taste may suggest, and in this way the motto which should characterize all true architecture, "Strength, commodity and beauty," may be fully realized."*[49]

The early steel frames were but the first steps along this pathway.

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