Sutherland History Lecture

given before a meeting of the Institution of Structural Engineers on 19 March 1998, with Dr S. Thorburn, OBE, FEng (then President), in the chair.

An iron lineage

B. L. Hurst, BSc, ACGI, CEng, FIStructE, FICE

Background

I will, by your leave, start with some recent history, which I think is worth putting on record – the formation of the Institution's History Study Group, which celebrates its silver jubilee this month.

In October 1972, at the suggestion of Cyril Morgan – then Secretary of the Institution and prompted by the President, George Geddes – James Sutherland set up a study group called 'Archaeology of Structures'[1], but, after a few months, it became apparent that history was more important than simple recording, as implied by archaeology, and the group was reformed in March 1973, just 25 years ago this month, under the title 'History of Structural Engineering' with the aim of 'promoting the study of the development of structural theory, materials and construction, not just for its own interest, but also as part of engineering education and as an aid to practising engineers in comprehending present techniques and future trends'[2].

I am perhaps too close to, and involved in, history to know how far this aim has been achieved in the last 25 years, because the activities of the group tend to be devoted more to research and the promulgation of research to members, as an aid to understanding old buildings and structures, and how they work, and hence to appreciating the care and maintenance they need, the *status quo* which must be preserved when contemplating alterations, and the guidance they can give for solving today's problems.

Personally, I have gained a great deal from membership of the Group and the lively and informed forum for discussion that most meetings develop into, but the rock on which we all keep foundering is how to generate a more general interest, particularly in younger engineers, because we all do feel deeply and sincerely that there is a great deal to be learnt from a study of history.

It would be invidious to single out particular meetings, because they are all interesting and stimulating, and are even sometimes useful! I could, however, perhaps just mention the personal reminiscences of Frank Newby on Samuely, to be repeated and expanded this time next year; Ove Arup on his own early years; Bernard Stone on consulting between the wars; and Peter Dunican on the early years of the Ove Arup Partnership.

The aim of the History Group, as part of engineering education, was taken up, in his presidential year, by Keith White, who suggested an annual lecture, but it was over a year after Keith handed on the baton until Dr Euan Corbett delivered the first Star History Lecture, on 'The rise and fall of iron ship construction', on 9 November 1989[3]. That was followed, 16 months later, in the March slot which has now become a regular feature of the Institution calendar, by Dr Norman Smith on 'The Roman bridge-builder' (14 March 1991[4]), Prof. Jacques Heyman on 'The structure of Gothic' (26 March 1992[5]), and Roland Paxton on 'The works of Robert Stevenson' (25 March 1993[6]).

In October 1992 James handed over convenorship of the Group to Frank Newby. As an enduring mark of appreciation for his energy and enthusiasm in forming and driving the Group, the annual lecture was titled – I think at Bill Addis' suggestion – the Sutherland History Lecture, and it was fitting that the first should have been delivered by James himself, on 10 March 1994, under the title 'Active engineering history'[7]. James was followed by Dr Roland Mainstone on 'The springs of invention revisited' (23 March 1995[8]), then Derek Sugden spoke on 'People & places – 50 years of recent history' (21 March 1996[9]) and, last year, Prof. Sir Alan Harris gave his memorable *tour de force* on his own personal reminiscences of Eugene Freyssinet (20 March 1997[10]). That brings us up to date. Now perhaps you can understand why I am apprehensive – not just one but eight hard acts to follow!

Introduction

The original suggestion and proposal was that I should talk about fireproof floors and fireproof construction – a subject which, as many of you know, is close to my heart – but I soon realised that, although the first and important innovations are fascinating, my talk would develop into a catalogue of the systems used in the second half of the 19th century: very important, but excessively boring. I promise I will catalogue them one day, but not today.

So my 'iron lineage' will start with the first fireproof flooring systems employing iron, which lead directly to the first rolled iron joists, I shall then say a few words about the development and use of rolled iron joists and then the first rolled steel joists, which would have still been novel when young Bertram Hurst, my father, started his pupillage with Joseph Westwood at his ironworks on the Isle of Dogs.

I will conclude with my father's career – how he progressed from joining Westwood at the age of 15 and developed his education and contacts to set up, 18 years later, as a consulting engineer – and then say some of the things I have been able to learn about his clients, his staff, and his way of working in his first years in practice.

Fireproof construction

Fire has been a threat to buildings for as long as buildings have been built: it has always been needed for warmth and for light; much of the contents has always been combustible; and, for many years, substantial parts of the construction were also combustible. At the beginning of our current legal system in England, in 1189, Fitzalwyn's assize referred to the conflagration of 1136, which broke out at London Bridge and destroyed St Paul's and other buildings as far as St Clement Danes' Church. His assize required a wall 3ft thick and 16ft high to be built on the boundary between adjoining buildings[11]. Fitzalwyn's assize was not only the beginning of our legal system, but also the start of building regulation and the first stage in the legislation relating to party walls which culminated, only last year, in the coming into force of the Party Wall etc. Act 1996, extending to the whole of England and Wales the provisions that, formerly, had applied only to London[12].

Fig 1. Obelisk to commemorate Hartley's fireproof house on Putney Common, close to Tibbet's corner

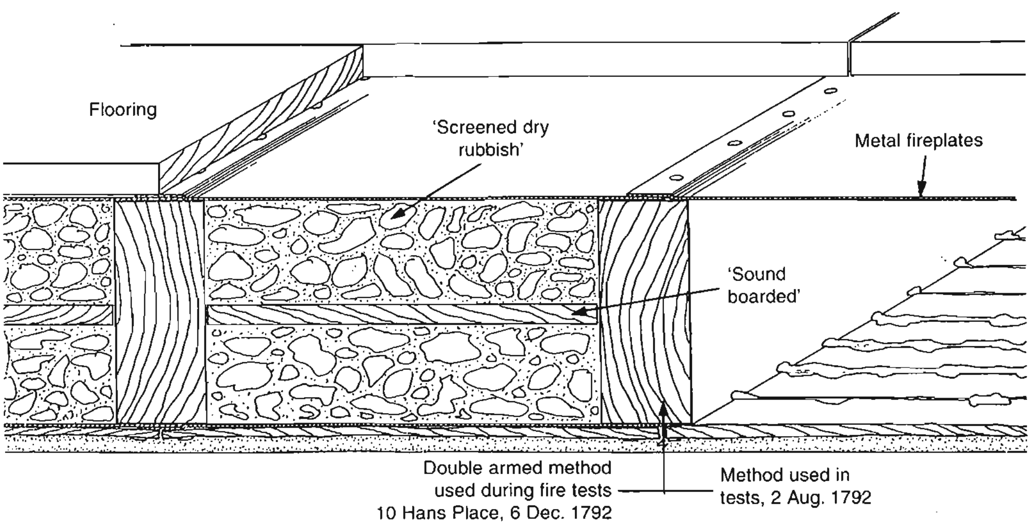


Fig 2. Sections through timber floor fireproofed with Hartley's fire plates, as patented and generally found, and as tested with double plates reinforced by pugging

David Hartley's fire plates

That legislation is no longer concerned with fire separation, which has been covered by other regulations for many years. It was not legislation but an appreciation of the increasing incidences of conflagration and of a need for construction to resist fire that prompted the first two types of fire resisting floor which appeared towards the end of the 18th century – David Hartley's thin wrought-iron plates in timber floors and cast-iron beams in mill construction.

We have yet to discover why David Hartley took up the development of his system, or indeed from whence his ideas came. He trained as a doctor and then as a lawyer and was an intimate friend of Benjamin Franklin,with whom he no doubt had discussions on scientific matters which may have included fireproofing of floors. David Hartley's patent of 1773[13] described his idea of placing a continuous layer of thin wrought-iron plates over timber floor joists immediately beneath the floor boards. David Hartley was 42 years old when he took out this patent, the year before he entered Parliament. His iron plates are about 15in × 18in × 10 thousandths of an inch thick. They are lapped over the top of the joists and clenched together longitudinally so that the boards hold them tightly down and the nails secure them. This produces a non-combustible, impervious layer, thus 'stopping the free supply and current of air, without which, no fire can get to any great height, or make any destructive progress'.

In appreciation of the need for such a system and in confirmation of appreciation of Hartley's efforts, Parliament voted him a sum of £2500 to develop the system[14] and also agreed an Act to extend the protection provided by his patent from 15 to 31 years[15]. The Act limits the price to a maximum of 6d/ ft^2 for iron plates not exceeding 10oz/ft^2, which equates to a thickness of 0.4mm or a cost of nearly £90/t. Whilst Hartley's system does not appear to have had wide use, it has been found in a number of buildings; its efficacy was proved in the test house he built on Putney Common where he invited the King and the Prime Minister to dine safely with him upstairs whilst a fire raged in the lower storey. The commemorative obelisk on Putney Common, designed by George Dance and erected by the City of London, confirms the success of his experiment; his head over Traitors' Gate might have been the result had he failed. You can see Hartley's obelisk today, just southwest of the Tibbets Corner roundabout on the A3 (Fig 1).

The Association of Architects tested Hartley's system in a house in Hans Town (an area then in the course of development just south of Knightsbridge) in 1792. The report of the tests[16] shows the success of the system in controlling small domestic fires and also demonstrates knowledge of the control of fires by controlling ventilation – an aspect of the subject which has recently once again come to be appreciated. Fig 2 is a section through Hartley's floor, as patented and generally found and as tested with the plates reinforced by pugging.

Hartley's system was not only to be found in domestic buildings in London and in country houses, but was also used in mills in Derbyshire, Yorkshire, and Cheshire. His idea of inserting a non-combustible, impervious layer in timber flooring was perpetuated by Robert Smirke in the King's Library at the British Museum in 1824[17] and in the London Custom House[18] 2 years later, where Smirke used ceilings of cast- and of wrought-iron arched plates either between main cast-iron beams carrying the timber floor or on a series of secondary cast-iron beams spanning between the main beams (Fig 3). These arches were either an exposed false ceiling, as in the King's Warehouse at Custom House, or a fireproof layer within the construction, as at the British Museum.

Barrie, at the Palace of Westminster, and Salvin in the Waterloo Building at the Tower of London used a similar principle but with arches of tile creasing – i.e. three layers of ordinary clay roof tiles bedded in mortar, resting on, and spanning between, the bottom flanges of the cast-iron beams carrying the timber floor.

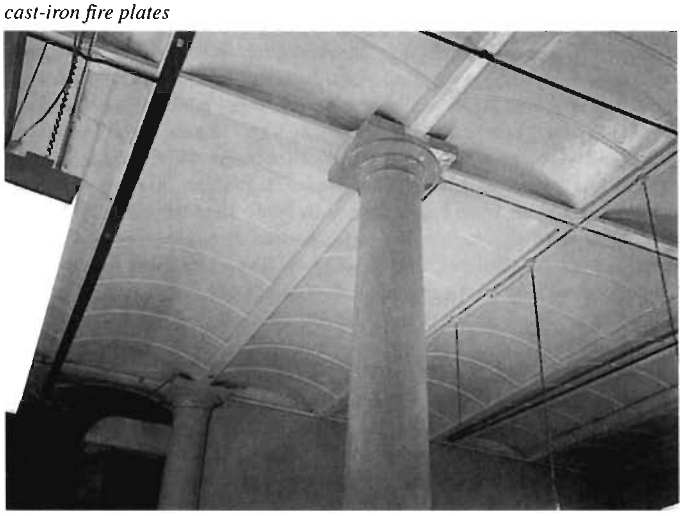
The development of the fireproof mill by Bage and Strutt, incorporating brick arch floors on cast-iron beams and columns, started about 20 years after Hartley's patent; it was prompted by disastrous fires, notably that of the Albion Mills near Blackfriars Bridge in 1791.

The development of fireproof mill construction, mainly in the north of England, of brick jack arch floors on cast-iron beams, which continued until the third quarter of the 19th century, is well documented, as is the use of the same system for other buildings, e.g. by Barry at the Reform Club and in the Palace of Westminster; the contemporary fireproof floor of stone landings on cast-iron Ts is, however, less well known, though more widespread than is generally appreciated. The earliest example of this form of floor discovered is at Armley Mills near Leeds, in part of the complex that was being reconstructed for the wool trade in about 1810[19]. I have also seen stone landings on cast-iron Ts in Smirke's building on the west side of Trafalgar Square, now Canada House.

These floors of stone flags on cast-iron T-section bridging joists spanning between cast-iron main beams were similar to the more developed and elegant form of flooring using by M. I. Brunel for the sawmill at Chatham in 1811, perpetuated by Edmund Holl in dockyard buildings at Sheerness, Plymouth, and no doubt elsewhere, but generally with inverted Ts.

I suspect that it was sight of Holl's fireproof construction in Plymouth that gave John Foulston the idea for the fireproof flooring he used in 1818 at

Fig 3. Sir Robert Smirke's floor at the London Custom House with arched cast-iron fire plates



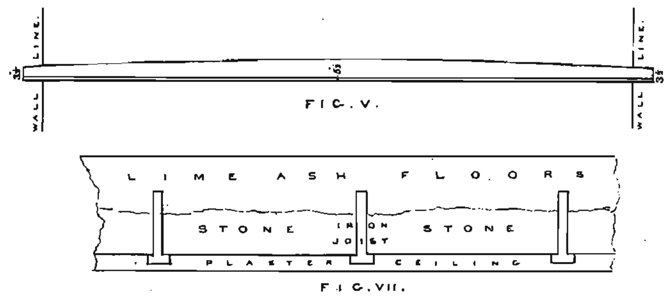


Fig 4. Floor used by John Foulston at Bodmin Asylum

Bodmin Asylum[20] (Fig 4). I have not researched the treatment or behaviour of the insane during the 19th century, but it does appear that a prime desideratum for asylum buildings was that they should be fireproof, and the most important developments of non-industrial fireproof construction in the first half of the 19th century came via that route.

Fox & Barrett flooring

Dr Henry Hawes Fox, whose family practised in lunacy and whose father built a private asylum in about 1804 at Brislington, with iron staircases, doors, joists, and window frames[21], would no doubt have known John Foulston and visited the new asylum at Bodmin where part of the floor had a lime mortar, trowelled surface on stone flags sitting on the projecting flanges of inverted-T cast-iron joists; it would have been a short step from there to the floor Dr Fox used for the private asylum he built in 1833 at Northwoods, near Bristol, when he was at a loose end following the death of his wife.

His floor also incorporated cast-iron inverted-Ts, but used them to support stout timber laths, about 1in square and 1in apart, on which a layer of coarse mortar was spread and pushed down between to act as a key for the plaster ceiling and as formwork for the 1:1:8 concrete filling (one of lime, one of sieved ashes, and eight of clean rubbish – this was not the contents of the dustbin but was, at that date, a technical term for the arisings from demolished buildings and other similar granular material). The surface of Fox's floor was fine lime mortar trowelled smooth and finished with two coats of hot raw linseed oil, so that water on it formed drops like mercury on polished mahogany (Fig 5).

The joists at Northwoods, as reported in *The Builder*, are surprisingly shallow[22]. They are hog-backed 3in–5½in deep for 18ft bearing and 2½in–3¼in deep for 10ft bearing (L/D = 40 and 37). The flange of the inverted-T is turned up at the bearings to anchor the joist into the walls.

Much of Northwoods survives, having been divided and altered as a terrace of houses, and Fox's floor continues in satisfactory use. If you wish, you can buy and live in a piece of this history. Further confirmation that Fox's inspiration came from Foulston at Bodmin is shown by the dovetail joints at the ends of hearth trimmers in joists reused over part of the basement at Northwoods, these being similar to Foulston's dovetail bearings used at Plymouth Theatre[23].

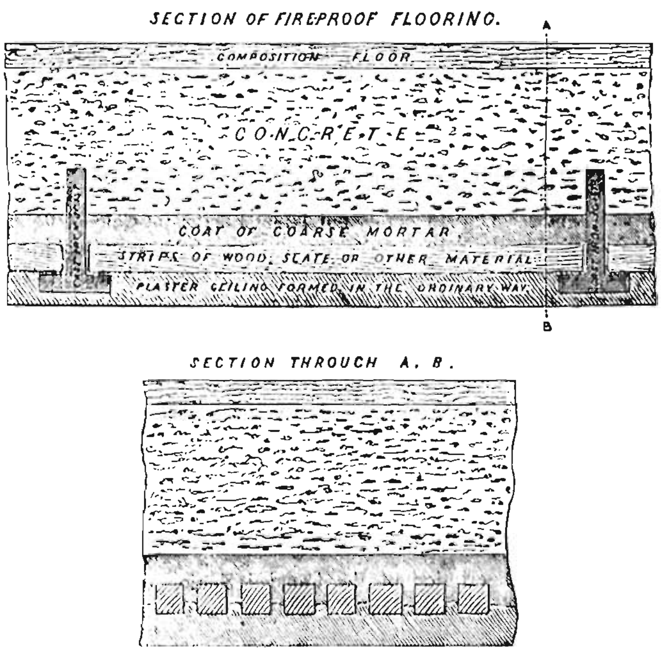


Fig 5. Early Fox & Barrett flooring with cast-iron joists

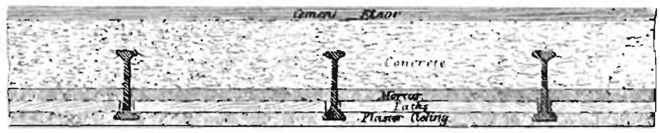


Fig 6. Fox & Barrett flooring with rolled iron joists

Fig 7. Fox & Barrett flooring at Finsbury Barracks

The asylum was extended in 1840 and, in 1844, a builder inmate persuaded Dr Fox to patent his floor[24].

In 1847 Dr Fox's son, H. H. Fox, went into partnership with James Barrett, who took the idea up to London and set out to publicise it. James Barrett had previously worked for Price & Manby, the heating contractor, so it is possible they met through the building industry. Nothing further is heard of the son except that his partnership with Barrett was dissolved in 1851, but James Barrett clearly worked very hard on publicity in the latter months of 1848 and succeeding years.

Barrett persuaded the builders of an extension to the Middlesex Hospital to use his floor; he advertised in *The Builder*[25] and persuaded J. C. Christopher, an architect and Metropolitan District Surveyor, to visit Northwoods and to write a long letter about it to *The Builder. The Builder* declined to publish the letter but did devote its editorial in the issue for 11 November 1848 to Northwoods, with a detailed description of the flooring system and dimensions of the joists; this must have been provided by Barrett, as the information does not appear elsewhere. Barrett published Christopher's letter as a pamphlet[26] and also a brochure, describing the system in detail and setting out its merits, and he presented a paper to the RIBA on 18 December 1848[27]. He took the opportunity to tell the Institution of Civil Engineers about it when, on 27 February 1849[28], he participated in the discussion following Braidwood's paper on fireproofing; he reiterated it again in his paper to the Royal Society of Arts in December 1849[29], so, by that time, there was little excuse in the building world in London for not knowing about Fox & Barrett flooring, as it had by then become known. Lest people had forgotten, he reminded them with his paper to the Civils in January 1853[30]; it is therefore not surprising that, by early 1854, over 1Mft² of the system had been used by many of the leading architects in at least 30 – and probably more than 100 – buildings[31].

In about 1850 prejudice against cast-iron joists induced Barrett to turn his attention to wrought iron, and he persuaded ironmakers to roll wrought-iron joists, which almost immediately replaced the cast-iron Ts (Fig 6).

His flooring system continued in use until at least the 1870s, because it was simple to build and, once the patent had lapsed, anyone could use it. It was adaptable for all shapes and sizes of building, unlike later systems which could be used only with parallel joists and parallel straight bearing walls, and, above all, it used components readily available everywhere – iron joists, timber laths, concrete and plaster – compared with most other systems utilising patented components and specialist or licensed contractors. I have come across it at the Royal Albert Hall, at Finsbury Barracks (Fig 7), and in a number of other buildings.

Very many other systems were proposed, and many were patented, but only a few were used in quantity. Amongst the most popular were Dennett & Ingles, which consisted of limestone and gypsum or lime concrete arches, and two systems employing fireclay lintols or tubes – Homan & Rogers, with triangular tubes, and Fawcett's with arched top tubes laid diagonally. There was, of course, the ordinary filler joist floor, with which most of you are familiar. This probably first appeared in the 1860s, where it appears to have been described in a patent by Matthew Allen[32] and gradually took over from the other floors until the 1890s, when it was certainly the most common and continued as such until about 1910.

As you know, the ordinary filler joist floor consists of wrought-iron or, later, steel joists at about 3ft centres and unreinforced concrete usually made with coke breeze aggregate. It can be recognised by the cracks or signs of irregularity in the soffit on the lines of the joists, as can be seen at Northwoods,and a strength in excess of any that you can show by calculation. It is difficult to believe the composite action that does really come from the very weak, usually no-fines, concrete, but that is perhaps even less surprising than the fourfold increase in strength reported by Barrett compared with naked joists[33], which is perhaps even more surprising when one considers that his 'concrete' was only 8.1.1. I think the statement in Christopher's letter[34], which must have come from Dr Fox, was the first published appreciation of composite action between iron beams and concrete flooring. Barrett also reported the increase of strength found when the joists were built into the supporting walls compared with just bearing on them[35]. This composite action was graphically described by Piper in 1854 as a 'good brotherhood between the concrete and the iron, the whole forming a trustworthy mass'[36] and by Barrett himself as 'one large beam with iron ribs'[37]. So far as I know, Fox and Barrett between them were also the first to say they appreciated the need to embed the flanges of the joists within the floor to protect them from fire below.

Rolled iron & steel joists

As I mentioned earlier, in 1850 or 1851 James Barrett substituted rolled iron beams for the cast-iron inverted-Ts in Fox & Barrett flooring. This change was due to prejudice against cast-iron joists, prompted perhaps by an unreported – or so far undiscovered – collapse or perhaps by failures in the proof load tests to which virtually all cast-iron beams seem to have been subjected. Barrett said, in 1854, that, 3 or 4 years before, he was induced to turn his attention to wrought iron. Here he had to break entirely new ground, institute experiments, and overcome many obstacles from manufacturers, before he had rolls prepared from 4–8in deep of the I-section[38].

To date, no record has been found of the first iron equal-flanged joists rolled in Britain, but it was here in Britain that Kennedy & Vernon took out a patent in 1844[39] for sections for use in shipbuilding. That patent, including a plate illustrating an equal-flanged rolled joist, was referred to in the description of the asymmetrical deck beam section rolled in 1845 by Mallinson for Turner for his Palm House at Kew[40]. These deck beams, so called because that type of bulbed T was used for stiffening decks of ships, were the first use of what was almost a rolled joist section.

Evidence points to the first equal-flanged joist sections being rolled in France in 1846[41] or 1847, but they were not produced in quantity until 1849 by La Providence in Belgium[42]. This was some years after the carpenter's strike, in Paris, in 1845, which is frequently cited as the reason for the introduction of iron joists for floors. References indicate the probability that Butterley was responsible for rolling the first equal-flanged iron joists in Britain, probably no more than 7in or 8in deep and with narrow, thick flanges and a thick web[43].

The amount of power needed to roll a joist section using conventional rolls is not generally appreciated; this, with the difficulty of maintaining the temperature of the metal and moving it out to the toes of the flanges to produce a straight bar of acceptable quality, resulted in only small, heavy joists being available at first. One way of overcoming these difficulties was patented by John Alleyne at Butterley, where he rolled two Ts and riveted them together[44]. A year later he welded them together with a small H-section glut of readily weldable iron, to form a joist, as shown in his patent of 1859[45] (Fig 9).

Larger, wider rolled iron joists gradually became available, but their production was never a priority in the iron industry in Britain, which resulted in the majority of rolled iron joists used here being imported from the Continent. The paucity of published references to the use of rolled iron joists in buildings from their introduction in 1850 to their replacement by steel in the 1880s indicates that they were little used in this country.

On the other side of the Atlantic, the Americans were slow to adopt iron framing and did not start rolling joists until 1855, but there was much more pressure there to provide fireproof construction, particularly in new publicly-funded buildings, so they soon overtook rolling practice in Britain[46].

In 1856 Henry Bessemer invented his steelmaking process, closely followed by the Siemens Martin open-hearth process in 1862, both of which made steel readily available – but, at that time, only acid steel. But steel was desperately needed in this country for other purposes, such as rails, armaments, and shipbuilding, so even though there is a reference to a steel beam section being rolled in Sheffield in 1860[47], and we also know that Bolckow Vaughan was rolling steel joists in Middlesbrough in 1880[48], the structural steel industry in Britain did not really start until 1887 when Dorman, Long substituted open-hearth furnaces for half its puddling hearths[49], opened its Britannia Mill, and published its section tables.Dorman, Long's was the first real handbook: previous leaflets from iron suppliers had just provided safe loads without section properties or other information to enable a beam to be designed or analysed[50,51].

Dorman, Long's first section book, entitled 'Steel and Iron Sections'[52] (Fig 10) (although I think it only ever rolled steel), includes a complete

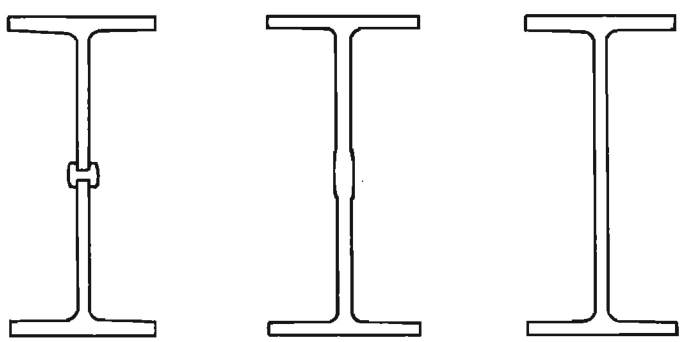
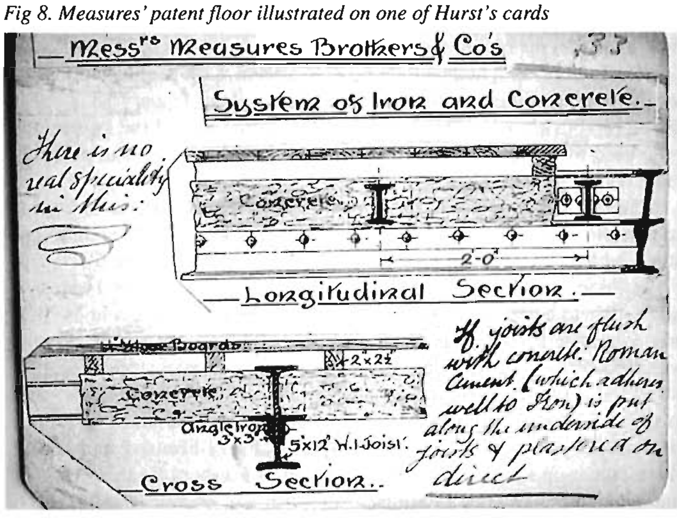
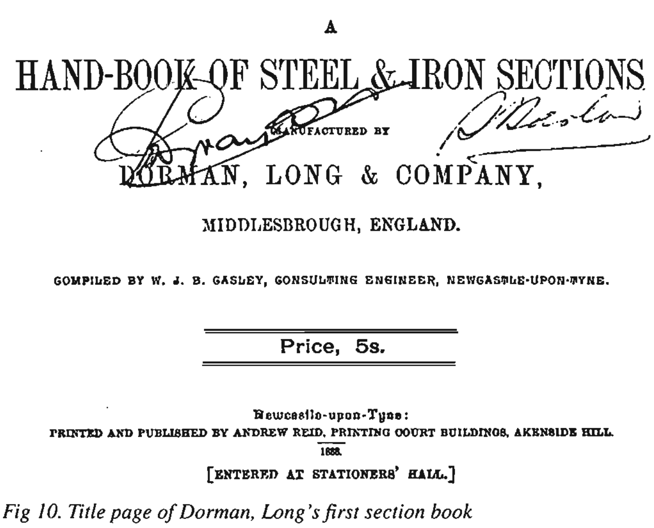


Fig 9. John Alleyne patent method of making up rolled iron joist from two Ts

Fig 8. Measures' patent floor illustrated on one of Hurst's cards





A

HAND-BOOK OF STEEL & IRON SECTIONS

MANUFACTURED BY

DORMAN, LONG & COMPANY,

MIDDLESBROUGH, ENGLAND.

COMPILED BY W. J. B. GASLEY, CONSULTING ENGINEER, NEWCASTLE-UPON-TYNE.

Price, 5s.

Newcastle-upon-Tyne:
PRINTED AND PUBLISHED BY ANDREW REID, PRINTING COURT BUILDINGS, AKENSIDE HILL.
1888.

[ENTERED AT STATIONERS' HALL.]

Fig 10. Title page of Dorman, Long's first section book

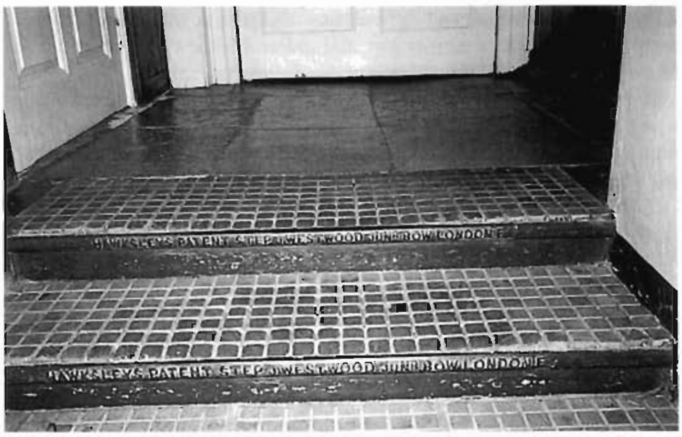


Fig 11. Andrews Hawksley's patent tread

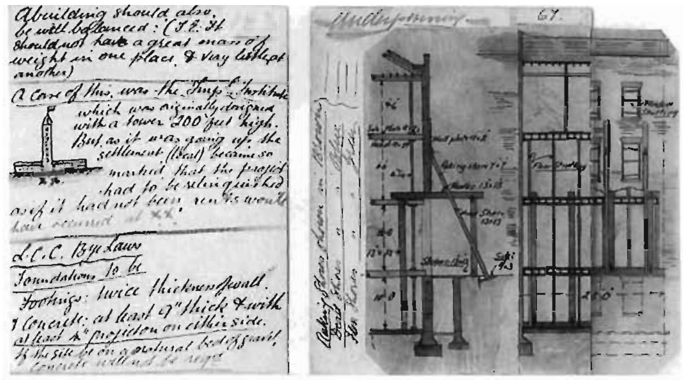


Fig 12. Two of B. L. Hurst's manuscript revision cards

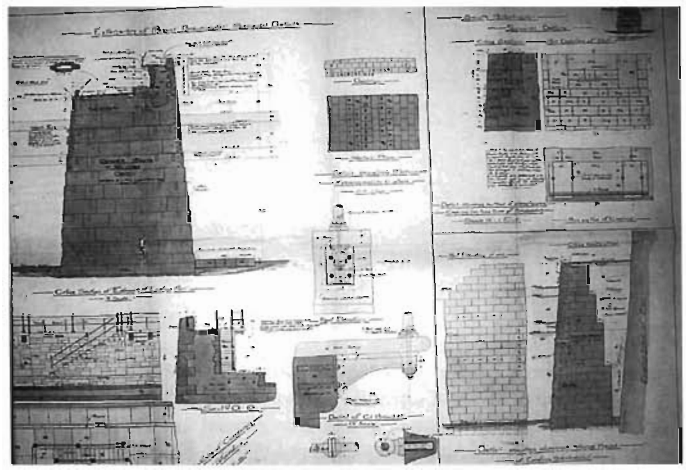


Fig 13. Part of drawing of breakwater in B. L. Hurst's characteristic hand

range, with joists from 3in x 1¼in up to 20in × 8in. The company was keen to increase that range when, in 1894, it sent a representative across the Atlantic to visit Carnegie to obtain information on designing rolls for 24in sections[53].

The fact that Dorman, Long's sections formed the basis for BS 1, BS 4 and BS 6, published by the Engineering Standards Committee, indicates that it was the leader and the source of a substantial proportion of the rolled steel structural sections at that time. We do know, however, from rolling marks, that Leeds Steel, The Earl of Dudley at Round Oak, Colvilles, Dailzell, Glengarnock, and probably others, were also producing steel joist sections.

Shortly after the turn of the century, Henry Gray, an Englishman working for Carnegie in the USA, solved the problem of rolling I-sections with four rolls (two horizontal and two vertical – the universal mill), which opened the way to producing sections with thinner webs and wider, thinner flanges with less taper. His ideas, however. were first applied commercially at Differdange in Luxembourg in 1904[54], followed soon after by Carnegie and Bethlehem Steel in the USA. In this country, we had to wait for native universal sections until Dorman, Long installed a universal mill at Lackenby in 1959[55]; these have now entirely superseded joist sections.

Bertram Hurst's early career

Shortly after Dorman, Long started to roll steel sections, Joseph Westwood – who had bought a constructional ironworks on the Isle of Dogs – was the principal guest for the prize giving, in 1890, at the choir school of St Saviour's Church in Eastbourne and found that several of the prizes for the boys leaving to start their careers were awarded to one B. L. Hurst, to whom he offered a pupillage. That is how my father embarked on his career in this industry.

Joseph Westwood bought Napier Yard in 1883 or 4[56]. It had included, or been adjacent to, Fairbairn's London yard, where model tests for Stephenson's Menai Bridge had been carried out; it was also the site where the Great Eastern was built, and my father met men who had worked on it. The only remains today are timbers of the slipway exposed at low tide[57].

At the age of 15 years and 2 weeks Bertram Hurst moved up to London and started work in the drawing office at Napier Yard, Millwall, where for 5½ years he learnt about the detailing, design and construction of iron and steelwork. He worked on a variety of jobs, including the bridge over the Ferro Carril in central Argentine, of which we have a photograph of the trial erection with all the works staff and labour posed on and in front of it. He also worked on several contracts for the GWR and was employed on staircases with Andrews Hawksley patent treads, which many of you may remember walking up and down from the Metropolitan, District and Circle Lines. They had cast-iron steps formed like waffles with square wooden inserts about 1in square, so that you trod on the end grain of the timber (Fig 11). As far as I know they have all been replaced, but their durability is proved because they lasted 70 or 80 years.

He left Westwood for a position in the bridge and ironwork office at Paddington, where he worked for the next 9 months, notably on Reading New Station, and then returned to Westwood as Assistant Chief Draughtsman for the next 9 months; he then went back to Paddington as an assistant in the Chief Engineer's Office for 2¾ years, working on the new stations at Windsor and Plymouth.

Soon after he joined Westwood as a pupil, he enrolled at the City of London College to embark on his technical education under Professor Henry Adams; certificates indicate that this was more mechanical than civil or constructional for the first 5 or 6 years. It is interesting to note that the earlier exam certificates from the Department of Science & Art state the number of candidates and the numbers passing the various grades – in May 1894 26 577 candidates presented themselves for the mathematics exam, of whom nearly 9927 failed; 4 days earlier, on 5 May, 13 472 candidates had presented themselves for the machine construction and drawing exam, and 3678 failed. These large numbers are no doubt the result of the mechanics institutes which had sprung up in the second half of the 19th century to provide technical education for all.

Surviving notebooks indicate that it was during the last years of the 19th century that Bertram Hurst concentrated on construction. As well as upwards of 500 cards, prepared for study and revision on the way to and from work, each covered on both sides with closely written notes on building and engineering topics (Figs 8 & 12), a number of other notebooks survive on other subjects. The most significant are two on permanent way, started just before he left the GWR to join the Admiralty, which are filled with extracts from iron and steel specifications, mostly from railroad companies in Britain and the USA. One intriguing reference, from the Illinois Central RR, gives required properties for 'high steel', 'medium steel', and 'low steel that may be substituted for iron' – a division into categories new to me.

As I mentioned, his notebooks on permanent way were started just before he left the GWR and joined the Admiralty on Christmas Eve 1899 as an Engineering Assistant in the Director of Works Department, where he worked for 3½ years on a variety of projects. During this time with the Admiralty, he continued his study of permanent way and evidently continued his association with the GWR, for which he seems to have continued to work in his spare time, as evidenced by dated drawings in his hand (he was moonlighting!)

His work at the Admiralty included responsibility for overseeing the specification, design and detailing of the new breakwaters for the Grand Harbour in Malta at a cost of £800 000. A recent paper in the ICE Proceedings on the Malta breakwaters praises their design[58], which has certainly stood the test of time.

We also have one drawing of a breakwater in his own characteristic hand (Fig 13), which is now deposited in the Civils' archives with his copies of the drawings of the Malta breakwater.

Whilst at the Admiralty his studies were successfully concluded with the

Fig 14. B. L. Hurst taken at Portsmouth c. 1903

Associate-Membership exam of the ICE in February 1903. The exam included papers on a wide variety of scientific subjects, because the Civils was still the general engineering Institution, and also general knowledge essays. (One of the five subjects was 'Nine-tenths of the noble work done in the world is drudgery'... .) He also became a Chartered Mechanical Engineer in 1903.

In July 1903, he was selected from the head office staff by Lieut. Col. Stuart Davidson, RE, who needed a deputy for his new post as Superintending Engineer at HM Dockyard, Portsmouth. There, Hurst was in charge of all design and estimating works to a value of about £150 000 p.a., with control of a large drawing staff. Fig 14 shows him as he was at Portsmouth.

It seems likely that it was at that time that he made the contacts which were transformed into clients when he set up in practice as a consulting engineer; these included Sir Aston Webb, RA. Sir Aston Webb was architect for Britannia Naval College at Dartmouth, built in 1899–1904, possibly with the assistance of the Assistant Civil Engineer in the Director of Works Dept. at HM Dockyard, Portsmouth, for it was extended in 1915–16 by Aston Webb, with B. L. Hurst as consulting engineer.

Towards the end of 1907 the Admiralty workload decreased, and temporary staff were told that their services were no longer required. For 8 years Hurst's position had been temporary, even though he had been in control of works averaging £150 000 p.a., and he was amongst those discharged. Towards the end of that time his salary had no doubt reached more than the £312 he was paid in 1906.

Gray & Hurst

The next 2 years are something of a mystery, because the only evidence of Hurst's work is in his ICE application form for transfer from Associate-Member to Member; this reads 'Junior Partner in the firm of Messrs Gray & Hurst, Consulting Engineers, Craven House, Kingsway', and lists jobs he worked on.

Directories show that Charles Wesley Gray had been in practice as a consulting engineer at 11 Adam Street, Adelphi, in 1906 and 1907 and that he carried on at Craven House until 1922, but we have yet to discover what he did. Of the clients mentioned in Hurst's Civils form, we do know the source of the Rand Water Board works, because one of Hurst's colleagues at the Admiralty (D. C. Leitch) had gone out to South Africa in 1902 as Chief Engineer to the Rand Water Board, and my brother remembers Peirce saying that the first project he worked on when he joined the staff in April 1910 was the extension to Imperial College, for which Sir Aston Webb was the architect.

We also know that Gray & Hurst was a less than satisfactory partnership because it survived only for 2 years, leaving Hurst very disillusioned with the concept of partnership. He is reputed to have said that choosing a partner was more important and difficult than choosing a wife because it was more difficult to end a partnership, and indeed he knew and worked with Peirce for 20 years before taking him into full partnership.

The other thing we know that Gray & Hurst did together in their office, in one of the first buildings to be completed in Kingsway, was to take out three patents – for sliding door gear, for a non-corroding patent glazing bar, and for a reinforced concrete system[59, 60, 61].

Early years of practice

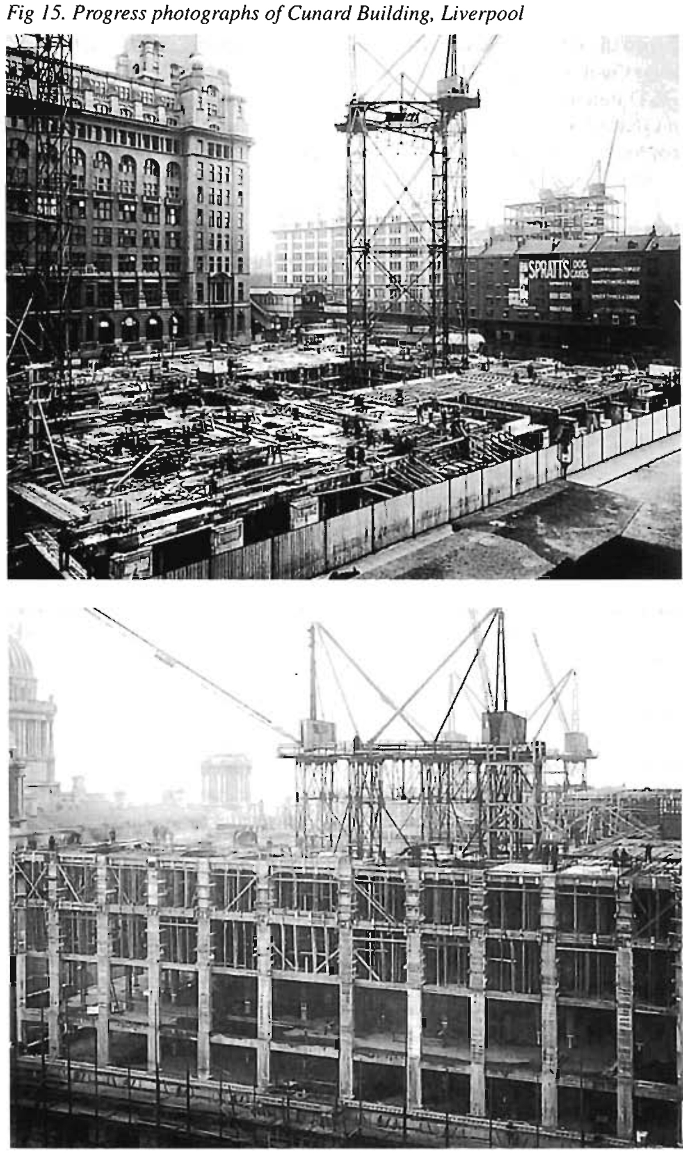
Whatever the rights and wrongs of the matter, Hurst left Gray and started on his own at Craigs Court House, off the top of Whitehall, in January 1910.

We have his account-books for his 20 years as a sole practitioner, and I have used these – supplemented by ICE application forms and the limited records of early jobs that have survived – to build up a picture of his clients, his projects, his staff, and of how he made ends meet during his first years[62].

The first fees paid in 1910, evidently for work carried out in the previous partnership, were on 10 January by Sir Aston Webb for alterations to the Conservative Club, on 2 March by the Great Western Railway, on 10 March for work carried out during December 1909 on the Egyptian Government new barracks to accommodate the army of occupation, and on 12 March by the Rand Water Board.

The Great Western Railway (by whom, you will recollect, he had been employed 10 years previously and for whom he had continued to work part-time about 8 years before) provided the new practice with regular commissions and steady income. He was entrusted with the design of 102 different bridges and other structures, at a total cost of nearly £150 000, including the 161ft span × 64ft-wide Ladbroke Bridge at a cost of £15 500, including the abutments and piers. The total fee paid by GWR for these designs was £2617. 9s. 3d. or 1.77% of the total cost.

Fig 15. Progress photographs of Cunard Building, Liverpool



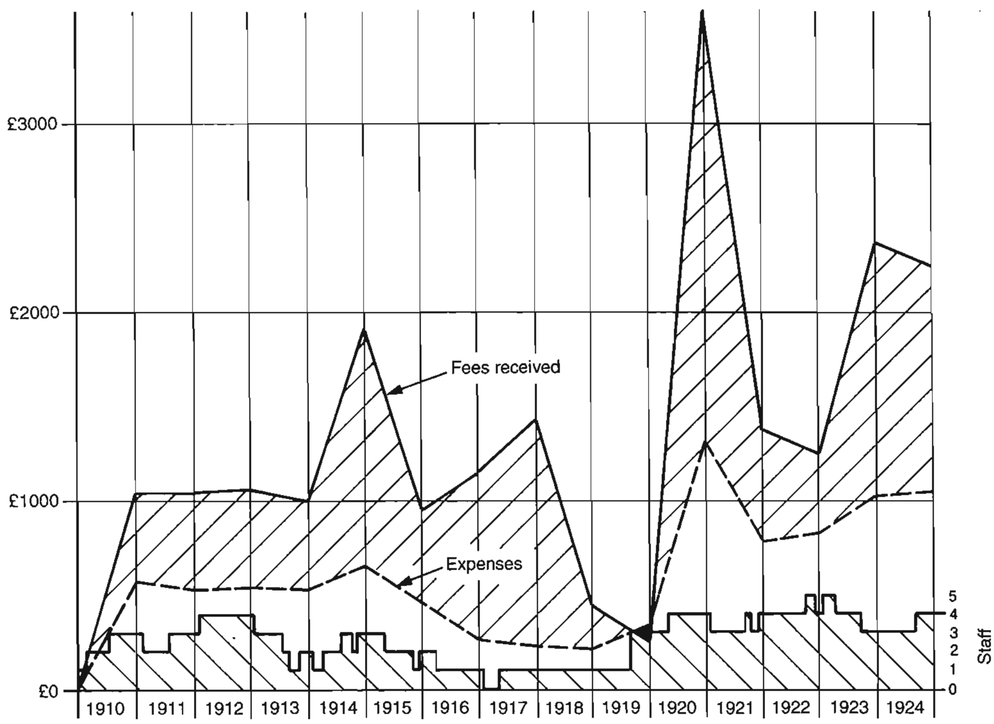


Fig 16. Graph showing staff numbers, expenses, and fees, 1910–1924

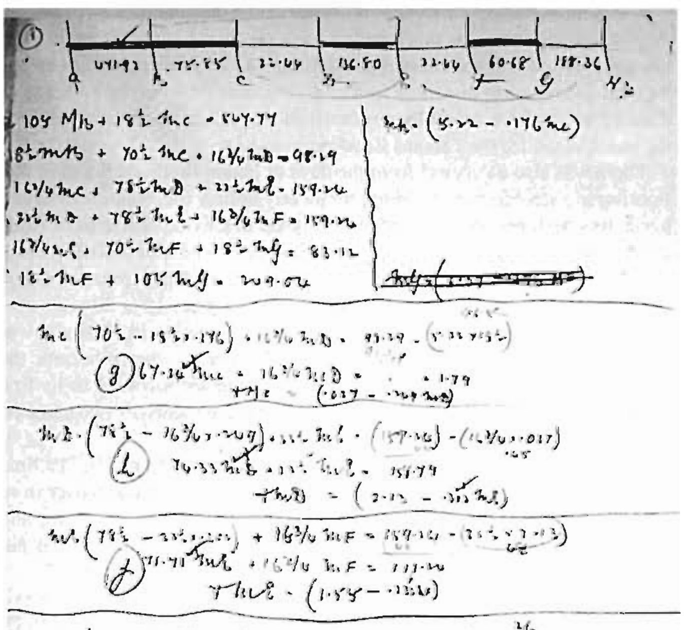


Fig 17. Cunard Building, Liverpool: continuous beam calculations by Hurst

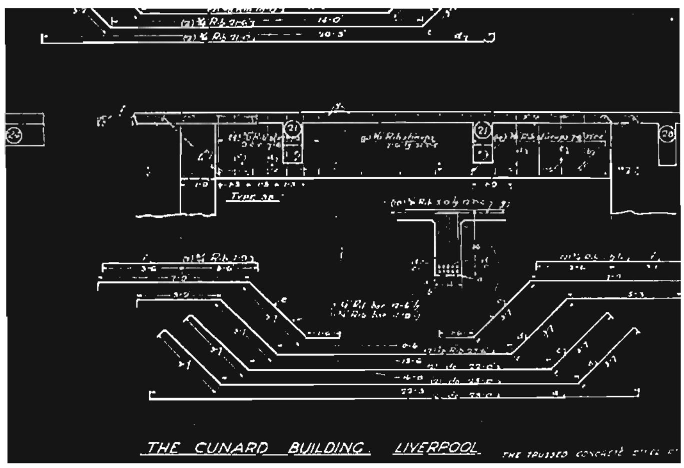


Fig 18. Cunard Building, Liverpool: RC detail drawing by TCS

I recollect my uncle Harry – 5 years younger than my father and also a civil engineer, but who spent his life working for the Admiralty – saying that he had difficulty understanding why his brother had set up as a consulting engineer, as he could see no future in it – that is, until Bertram was appointed to advise on the foundations and structure for the new building in Liverpool for Cunard with a total cost of £256 000, of which £120 000 was structure. The architects were Willink & Thicknesse, in association with Mewes & Davis, and the structure was the responsibility of the Trussed Concrete Steel Company, using the reinforcing bar invented by Julius Kahn in 1902 or 1903[64]. The QS was Thornley and the main contractor Wm Cubitt & Co. Hurst designed the foundations partially in the old St George's Dock on Pierhead, Liverpool, and checked and supervised TCS's work. It is likely that he was involved in the selection of TCS, to whom he appears to have been introduced by Aston Webb, but it is not known why reinforced concrete was chosen for the frame – perhaps because of the Liver Building, by Hennebique, completed recently on the adjoining site.

It was, however, income from work on the Cunard Building which saw the practice through the dark days towards and after the end of World War 1, when not a lot was happening in the building world.

Progress photographs of the construction of the Cunard Building give some idea of the differences with work on site today (Fig 15).

The contact made with Mewes & Davis on the Cunard Building provided the introduction to the London County Westminster & Parr's Bank (now the NatWest Bank), for the former were the architects for the new head office in Lothbury, as well as for the Threadneedle Street branch, which arrived in the office in August 1921. That, together with continuing work for, and with, Sir Aston Webb, provided a sound basis for reestablishment of the practice in the 1920s.

Peirce (who had been a pupil at E. F. Blakeley & Co., a steelwork con-

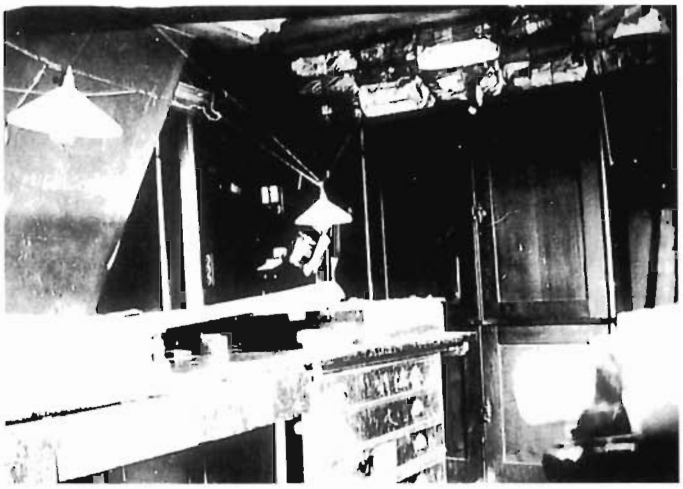


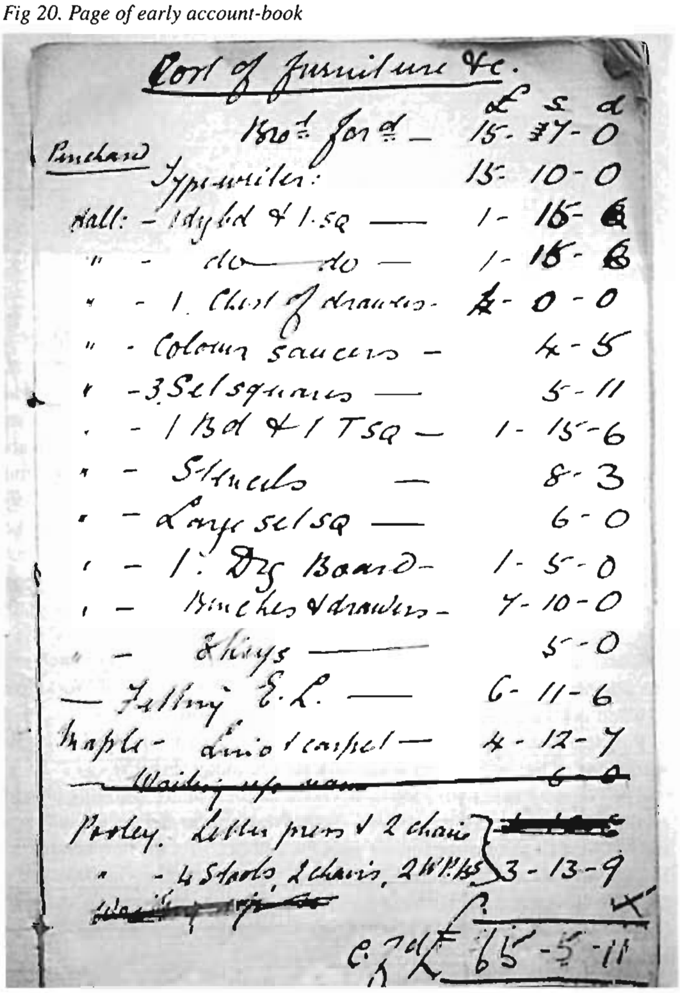
Fig 19. The office c. 1920

tractor in Liverpool) joined the office in July 1910. He was called up into the Royal Engineers in February 1916 and did not return until towards the end of 1919, a year before Jim Malcolm was taken on as an indentured pupil. As can be seen from Fig 16 the office continued with no more than three or four staff until the mid-1920s.

The Cunard Building was, of course, designed before the days of computers and before Hardy Cross had invented moment distribution. The calculations in Fig 17 give some idea of how continuous beams were analysed – and of how they were detailed (Fig18). Our copies of the calculations and TCS drawings, with copies of the progress photos, are now deposited on permanent loan at the ICE as part of its reinforced concrete archive.

There were, of course, also no computers to be paid for in equipping the office which, as you see, looks somewhat dingy (Fig 19); rather, items such as drawing board, typewriter, set squares, lead weights, with bottles and

Fig 20. Page of early account-book



Cost of Furniture &c.

	£	s	d
[illegible]	15	17	0
Purchased Typewriter:	15	10	0
Hall: – [illegible] & 1 SQ	1	15	6
" – do – do	1	15	6
" – 1 Chest of drawers	4	0	0
" – Colour saucers		4	5
" – 3 Set squares		5	11
" – 1 Bd & 1 TSQ	1	15	6
" – [illegible]		8	3
" – Large set SQ		6	0
" – 1 Dg Board	1	5	0
" – Benches & drawers	7	10	0
" – & keys		5	0
– Fitting E.L.	6	11	6
Maple – Lino / carpet	4	12	7
Pooley. Letter press & 2 chairs; " – 4 Stools, 2 chairs, 2 WPBs	3	13	9
	65	5	11

stand and ruling pens, are listed on these first pages of the first account-book (Fig 20). And was it worthwhile? As you see from Fig 16 the profit after 2 years on his own was probably not much more than his pay before he left the Admiralty 4 years earlier.

Now what are the differences and similarities between practice then and practice now as a consulting engineer? One very noticeable absentee from my father's account-books is professional indemnity insurance, which now takes third place in our expenditure, after staff and accommodation costs. Ninety years ago (and indeed until after World War 2), professional people did not need that type of protection, and I think that was perhaps the first sign of erosion of the trust that sadly becomes less and less common in relations between professionals and clients. There is a tendency to treat everybody as a customer and for commercial considerations to take precedence over professional behaviour and integrity.

Then, as now, clients came from the architectural and surveying professions and from the owners and occupiers of buildings and structures and from contractors. One difference, however, was that payment of fees frequently seems to have come via the contractor. This was not for design-and-build or for advice to a contractor, but was provided for in the contract documents, in the same way as the contractor was frequently required to pay the quantity surveyor. Even when I started work, architects' fees were reduced, by, I think, 1%, for parts of the work on which an engineer's fee was payable. This inevitably resulted in architects using and nominating steelwork contractors and reinforcement suppliers for the structural design and detailing, but I do not think that was the reason for making the contractor pay the consultant. I suspect the reason was that clients expected to pay only one professional fee, and the alternatives were therefore for the architect to pay the engineer out of his fee (thus making him look superficially more expensive) or to include it in the contract and hence have his percentage on it too.

Another difference which does not come out in our financial archives, but I know was the case, was that bending schedules were prepared by the contractor. Hence reinforced concrete drawings had to contain enough unambiguous information to enable him to do that and thus needed to be more detailed and to have more dimensions than they do today, as you see from the beam detail for the Cunard Building in Fig 18.

There was also a survival from the days of patent fireproof floors in that flooring in a steel framed building, frequently hollow tile, was tendered and hence was designed and detailed by Diespeker or Caxton or Kleine or Attoc or whoever supplied and constructed the floor, and who also probably cased the steel beams. This, however, is probably more similar to practice today, where the work is divided into packages, than to practice 15 or 20 years ago.

Hurst had joined the Concrete Institute at its inception in 1908 and was a member of Council from 1918–26, during the period when it became the Institution of Structural Engineers. He was evidently involved in its first examinations in 1920 for, at that time, occasional payments of 'two guineas' appear in the accounts as 'Conc. Inst. exam fee'.

My title – 'An iron lineage' – has become somewhat diluted in this final section, for, by the time father started in practice, steel had taken over from iron, reinforced concrete was in general use for building structures, and structural steelwork had effectively reached a mature stage which was not to change, from the constructional viewpoint, until after World War 2.

But to conclude the iron theme, it is worth recording that Hurst was a member of the Steel Structures Research Committee in 1929[65] and, in 1932, of the drafting committee for the first edition of BS 449, which brought the design of structural steelwork out of the dark ages of the 1909 LCC General Powers Act into the form it took until limit state took over.

He also continued his interest in reinforced concrete with membership, in 1931, of the Reinforced Concrete Structures Committee of the Building Research Board, which drafted the first Code (the forerunner of CP 114) and in both materials with his membership of the committees drafting the first LCC Byelaws and the 1939 London Building Acts (Amendment) Act.

Conclusion

I hope that this ramble from fireproofing to joists to the early days of structural consulting has given you some idea why history is so important to me. If you can only discover why – and indeed how – our forefathers worked and built and how they were motivated, and particularly the dates when developments took place or practice changed, your understanding of what they built will be greater and you will be better equipped to work on their buildings. If you understand a building – not just the structure but the whole construction – and are not afraid to date its components, you will be qualified to advise on and work on it. If you are not prepared to try to understand old buildings (and particularly to date the component parts), you should stick to new construction.

References

1. *The Structural Engineer*, **50**, No. 10, October 1972, p404
2. *The Structural Engineer*, **51**, No. 3, March 1973, p110
3. *The Structural Engineer*, **67**, No. 20, 17 October 1989 (p3, 'Structural News')
4. Smith, N. A. F.: 'The Roman bridge-builder: some aspects of his work', *The Structural Engineer*, **71**, No. 9, 4 May 1993, p160
5. *The Structural Engineer*, **70**, No. 6, 17 March 1992 (p3, 'Structural News')
6. *The Structural Engineer*, **71**, No. 6, 16 March 1993 (p3, 'Structural News')
7. Sutherland, R. J. M.: 'Active engineering history', *The Structural Engineer*, **72**, No. 13, 5 July 1994, p205
8. Mainstone, R. J.: 'The springs of invention revisited', *The Structural Engineer*, **74,** No. 22, 2 November 1995, p39
9. *The Structural Engineer*, **74**, No.5, 5 March, 1996, pA4
10. Harris, A. J. : 'Freyssinet: the genius of prestressing', *The Structural Engineer*, **75**, No.12, 17 June,1997, p201
11. Knowles, C. C., Pitt, P. H. : *The history of building regulation in London 1189–1972*, London, Architectural Press, 1972, p6
12. An Act to make provision in respect of party walls, and excavations in proximity to certain buildings or structures; and for connected purposes (Party Wall, etc., Act, 1996), Elizabeth II, 1996.c.40. came into force July to September, 1997
13. Hartley, D.: 'Securing buildings and ships from fire', *Patent No. 1037*, 1773
14. Proceedings of the House of Commons, 16 May, 1774, p756
15. An Act for vesting in David Hartley Esquire, his Executors, Administrators, and Assigns, the sole Use and Property of a certain Method by him invented of securing Buildings against the Calamities of Fire, throughout His Majesty's Dominions, for a limited Time, 17 Geo.III,Cap.VI. (1777)
16. Resolutions of the Associated Architects with the Report of a Committee To consider the Causes of the Frequent Fires, and the best means of preventing the like in future, London, 26 July 1793
17. Slade, R.E., Playle, C.: 'The British Museum: upgrading the floor over the King's Library', *The Structural Engineer*, **73**, No. 12, 20 June 1995, p193
18. Royal Commission on the historical monuments of England: 'The London Custom House', London, 1993
19. Fitzgerald, R. S.: 'The development of the cast-iron frame in textile mills', *Industrial Archaeology Review*, **X**, No.2, Spring 1988, p127
20. Foulston, J.: *The public buildings erected in the west of England as designed by John Foulston, FRIBA*, London, J. Williams, 1838, p75 & pl. 110
21. James, J.G.: manuscript note in his card index now held at the Institution of Civil Engineers, quoting letter published in Monthly Mag., 1 December 1809, p447.
22. *The Builder*, **VI**, 11 November, 1848, p541
23. Foulston: *op. cit.*, p32 & pl.44
24. Fox, H. H.: 'Fireproof roofs, floors, and ceilings', *Patent No. 10 047*, 1844
25. *The Builder*, **VI**, 25 November, 1848
26. Christopher, J.C. : *Notes on a visit to Northwoods, Gloucestershire*, London, Mudie & Sons, 1848
27. Barrett, J.: 'On the construction of buildings fireproof', read to the RIBA, 18 December 1848 (manuscript in RIBA Library)
28. Barrett, J.: discussion to 'On fireproof buildings', by James Braidwood, *Proc. ICE*, **VIII,** 1849, p162
29. Messrs Fox & Barrett: abstract of paper, *Proc. Royal Society of Arts*, 1850, p32
30. Barrett, J.: 'On the construction of fireproof buildings', *Proc. ICE*, **XII**, 1852–3, p244
31. Burnell, H.H. : 'Description of the French method of constructing iron floors', *Trans. Royal Institute of British Architects, 1853–4*, p36. (This total area of Fox & Barrett flooring and number of buildings in which it had been used by that date are deduced from contributions to the discussion to Burnell's paper.)
32. Allen, M.: 'Fireproof buildings', *Patent No.244*, 1862
33. Barrett, J.: *op. cit.*, p251
34. Christopher, J. C.: *op. cit.*, p6
35. Barrett, J.: *op. cit.*, p251
36. Piper in discussion to ref. 31, p40
37. Barrett in discussion to ref.31 , p 40 & 45
38. Barrett in discussion to ref.31, p43
39. Kennedy, J., Vernon, T. : 'Building iron and other vessels', *Patent No. 10 143*, 1844
40. Peterson, C. E.: 'Inventing the I-beam: Richard Turner, Cooper & Hewitt, and others', p63, in *The technology of historic American buildings: studies of the materials, craft processes, and the mechanisation of building construction*, ed. H. Ward Jandl. (On p70 Decimus Burton's letter of 16 June 1845 about the Palm House framing, where he mentions Kennedy & Vernon's patent, is reproduced.)
41. Jolly, C., Joly Fils : 'Etudes pratiques sur la construction des planchers et putres en fer', Paris, Dunod, 1863 (p13, para. 5 reads 'Les premiers fers à double T furent fabriqués en 1846 par M. Laguoutte, maître des batiments de machines fixes du chemin de fer atmosphérique de Saint-Germain.')
42. see also ref. 38, p73
43. Piper in discussion to ref.30, p39
44. Alleyne, J. G. N.: 'Manufacture of wrought-iron beams and girders', *Patent No. 2107*, 1858
45. Alleyne, J. G. N.: 'Manufacture of wrought-iron beams', *Patent No. 2059*, 1859
46. Wermiel, S. W.: personal communication
47. Ravenhill, J. R.: in discussion following Ewing Matheson's paper 'Steel for structures', *Proc. ICE*, **LXIX**, 1881–82, p42
48. Kennedy, Alex B.W.: ' "Mild steel" and its application to building purposes'. *Trans. Royal Institute of British Architects, 1879–80*, p190
49. Malcolm, I. C.: 'Dorman, Long & Co. Ltd, 1889–1967. Notes towards a history', *The Cleveland Industrial Archaeologist*, **20**,1990, p31
50. Phillips, W. & T.: *Architectural iron construction, Part 1 – Beams and girders*, London, 1870
51. Rownson, Drew & Co.: *Illustrated catalogue of constructional ironwork,* London (n.d.) (*c.* 1880s, judging by mention of the Natural History Museum and of Cannon Street Station)
52. Casley, W.J.B.: *Handbook of steel & iron sections manufactured by Dorman, Long & Co., Middlesbrough, England*, Newcastle-upon-Tyne, Andrew Reid, 1887
53. Walker, R.: personal communication about his grandfather's visit to Carnegie in 1894
54. 'History of the Differdange Grey mill'. (Typescript obtained from Arbed, which appears to be a translation of a paper in German by an unknown author *c.*1960.)
55. Barlow, S., Foster, G.: 'Universal beams and their application', *The Structural Engineer*, November 1937, p425, and April 1958, p138
56. *Survey of London*, Vol.XLIII: 'Poplar, Blackwall and the Isle of Dogs', London, Athlone Press, 1994, p470
57. Wilson, A.: *London's industrial heritage*, Newton Abbot, Devon, David & Charles, 1967, p95
58. Soler, W.: 'Grand Harbour breakwater in Malta: 1903-09', *Proc. ICE, Civil Engineering,* **114**, May 1996
59. Gray, C. W., Hurst, B. L.: 'Improvements in hanging gear for horizontal sliding doors, windows and the like', *Patent No. 2278*, 1908
60. Gray, C. W., Hurst, B. L.: 'Improvements in glazing bars or astragals, for skylights, windows and the like', *Patent No. 21 929,* 1908
61. Gray, C.W., Hurst, B. L.: 'Improvements in metal skeletons for the reinforcement of structures of concrete or artificial stone', *Patent No. 27 944*, 1908
62. Hurst, B. L.: information about Hurst's early life and work, and the history of the early years of the practice founded by him, has been gleaned from his application forms for membership of the Institutions of Civil and Mechanical Engineers, from papers in Hurst, Peirce & Malcolm's archives, their account-books 1910-29, their job lists, and from BLH's manuscript notebooks and reference cards
63. Souster, E. G. W.: 'The Cunard Building, Liverpool', *Concrete & Constructional Engineering*, **XII**, No. 11, November 1917, p595
64. *Concrete & Constructional Engineering,* **I**, No. 2, May 1906, p80
65. *Final Report of the Steel Structures Research Committee,* London, HMSO, 1936