James W.P. Campbell

Introduction

This is a seventh volume in the series of books published by the Construction History Society containing the proceedings of the conferences held at Queens' College, Cambridge in April each year. This was the year, 2020, which was sadly disrupted by the global pandemic called at the time COVID-19. What had been intended to be happy social event, bringing academics together from across the globe, has been forced online. However by the time the disease appeared we had already received the papers and thus we have decided to proceed both with the event (in a new form) and the book. The previous volume contained a series of chapters on the relating to Water infrastructure. This volume contains 16 papers on Iron and Steel in Construction History. These form section one and are arranged chronologically. The second section contains 37 papers that resulted from a general call for papers on all aspects of the history of construction. This is sub-divided into period, with each period being arranged alphabetically by author, following the practice of the previous volumes in this series.

Section One: Iron and Steel

The first paper looks at the use of iron in timber roofs in the Middle Ages. Medieval roof carpentry is generally associated with carefully-crafted wooden joints. These have been the subject of many studies. However surviving Medieval roofs often contain a bewildering array of iron straps and attachments, some of which were original and many of which were clearly later reinforcements. These have largely been overlooked and this is what Christophe Maggi's paper seeks to remedy, starting with a study of such iron reinforcements in Belgium. Iron is too often associated with the 19th century. Aleksandra Kosykh's paper in this volume continues her work on iron roofs in Russia showcased in the last volume. These studies are revolutionizing our understanding of the early use of iron in roofs in Russia. The paper looks at the roofs of the Nikiolas-Zaretsjij Church in Tula. The existing church had wooden roofs which had rotted and in 1773 these were replaced by the current iron structures. Peter the Great had visited Tula in 1712 and challenged the Demidov blacksmiths to build the first armaments factory in Russia and as a result in the 18th century it became centre of iron founding. The church roof is extraordinary for the delicacy of its ironwork, which Aleksandra's paper explores in detail.

The French were barely behind the Russians in iron roofing technology, as is shown in Katerina Maria Chalvatzi's paper on the Théâtre du Palais-Royal in Paris built in 1785 which has a striking arch-braced iron roof and vaults constructed using clay hollow pots very similar to those John Soane used to build the domes of the Bank of England. Tom F. Peter's article is also on a Parisian theme, this time the work of the French architect and engineer Louis Bruyère (1758-1831). Between 1799 and 1820 Bruyère taught at the distinguished École de Ponts et Chaussées and in 1808 he built what Tom describes as "the first modern wrought iron bridge". As well as describing it in detail, he places it deftly in its wider context.

From France and keeping on the subject of bridges, we move North to Belgium, where Bernard Espion describes the development of iron bridges in Belgium before 1853. These are presented in three categories: suspension bridges, arched bridges and trussed bridges, but it is definitely the suspension bridges that steal the show, with their intricate and often playful details.

Introduction

The use of iron and steel in modern construction is associated with detailed mathematical calculations, but as Dermot O'Dywer's paper describes in detail, the early structures were generally constructed by testing and rules of thumb and there was initially considerable confusion over the proper mathematical methods for modeling the structures. The paper deals with the discussions and disagreements in Britain in the period 1820-1860 both in the Institution of Civil Engineers and in publications in the period and shows both their confusion and their pragmatism.

Stéphane Sire and Muriel Ragueneau's paper looks at an wrought iron bridge built between 1851 and 1861, however its main focus is actually on the repairs to this bridge carried out between 1927 and 1936 and the problems these involved in joining steel members to strengthen the existing wrought iron structure. The sections that made up the original bridge were I-beams. Today steel I-beams are so common whenever steel structures are mentioned it is grid work of I-beams we imagine. Rolled iron I-beams first appeared in the 1840s in France and Britain in the 1850s. Sara Wermiel's paper discusses the first introduction of the I-beam to the USA in the 1850s and the involvement of the two rival companies (Phoenix and Trenton) in this process.

The next papers look at two very different roofs. Iva Stoyanova's paper looks at the famous glazed roof of Gallery Vittorio Emanuele II in Milan built completed in 1867 and the 1980s restoration of the same. Kilian Wolf's paper examines the cold pressed steel rhombic lamella roofs (so called *Rautennetz Bauweise*) designed and built by the Austrian engineer Emil Mauritz Hünnebeck (1891-1968). The paper is richly illustrated with contemporary photographs and neatly drawn illustrations giving a very clear idea of the form of the system, which was used to create a series of roofs between 1927 and 1932. It is not clear exactly how many were built but readers of this paper will now know what to look out for.

While lamella roofs are comparatively easy to identify if you know what to look for, you would be hard-pressed to identify buildings built using the subject of the next paper: iron-mounted stonework facades. As Valentin Gillet shows, at the beginning of the 20th century architect Charles Klein (1873-?) employed Hennibique to build a six-storey concrete framed apartment building in Rue Claude-Chahu in Paris. Photographs of it going up show the exciting concrete structure before it was hidden under what appeared to be a conservative load-bearing stone façade. In fact, as this paper shows it is constructed using a it is thin skin of stoneware with a 100mm void behind and then an inner wall of brick and plaster. The stoneware was held together and back to the brickwork using an armature of iron.

This series of volumes has had a long tradition of articles on nails provided by Chris How. It is good to see this mantle being taken up in the present volume by Jørgen Burchardt, who tells the story of wire-drawn nails. Although the title suggests that the paper covers the period 1898-2000, the paper also includes a longer history of wire nails back to the first machines in 1851 in the US. Its main focus, however, is on Europe in the later period.

The last four papers in this section on iron and steel all look at housing. John Guiness's paper gives a brief survey of numerous systems of lightweight steel framed housing used in England between 1900 and about 1960. Stefania Mornati's paper looks at Post WWII Italy and particularly the work of FEAL *(Fonderie Elettriche Alluminio e Leghe)*, a company specifically set up in Milan to carry out research into experimental building methods, which built high rise buildings of various types including blocks of flats in the period 1945-70. Francesco Spada's paper is also set in Italy in the same period and covers the work of another company, this time the Società Generale Immobiliare (SGI) based in Turin. Elke Nagel's paper returns to system building and covers very similar ground to John Guiness's paper, but concentrates on the designs of one particular manufacturer, Maschinenfabrik Augsburg Nürnberg (abbreviated MAN), working in 1950s Germany.

Section Two: General Studies in Construction History

As in the previous volumes, second half of this book is devoted to studies in the general field of construction history. They are arranged for simplicity, roughly chronologically although inevitably some papers span large period and cross over with others. Just as in previous volumes in this series, the papers cover a very board range of subjects covered under the umbrella of "Construction History". The first section covers the period from the Romans to the end of the seventeenth century. The only reason for covering such a large period is simply that disappointingly few papers were submitted for period before the eighteenth century and this seems to be a genuine problem in the field, where most of the studies are concentrated on the period when science took over, presumably because more buildings survive from this period and more are studied for conservation. There is also a certain appeal in studying buildings where the records survive and the builder's names are known. If this early period is somewhat under represented, this is made up for in the sections that follow and the overall distribution is roughly as follows:

Time Period	**Section 1**	**Section 2**	**Total**	
Classical Period	--	2 papers*	2 papers	(4%)
Medieval Period	1 Paper	3 papers	4 papers	(7%)
Sixteenth century	--	2 papers*	2 papers	(4%)
Seventeenth Century	--	1 paper*	1 paper	(2%)
Eighteenth Century	2 Papers	6 papers	8 papers	(15%)
Nineteenth Century	7 Papers	3 papers	10 papers	(19%)
Twentieth century	6 papers	21 papers*	27 papers	(51%)

Table. 1 Table showing distribution of papers in this volume by period (those marked with an asterisk note that some papers are counted twice as they cover two periods)

From this it is clear that a disproportionate number of papers concentrate on the 20th century. This era no doubt carries a particular fascination because much of the construction has direct relevance today. This partly because many of the materials used and processes discussed are still in use but also because increasingly we are being challenged to extend or preseve these structures and a knowledge of how they are built is becoming increasingly vital. While we always careful to distinguish construction history from conservation, knowledge of construction history is essential to help inform any conservation project that inevitably seeks to understand the fabric and predict what problems may arise when things are opened up. With these general observations in mind, it is now worth examining what the papers were about.

Before the Eighteenth Century

The first paper in this section, by John Gelder, builds on his paper in the last volume and looks at the fascinating subject of Roman pipework. He covers not only pipes, but also aqueducts, tunnels and siphons. Contrary to popular belief, aqueducts are not piped (except when they reach siphons) but consists of open channels and thus, like streams, they flow, rather than build up pressure. However as John shows, the Romans did use timber, terracotta and lead pipes for various purposes.

Arturs Lapins also looks at water management, in this case at how the inhabitants got fresh water in castles in Latvia. As in Artur's previous papers, this one is again lavishly illustrated with his own wonderful drawings. He details the various ways of making wells and the lifting devices used to raise the water up into the castles. Cristianna Veloudaki and Dimitris Theodossopoulos also look at castles, but this time in the western Cyclades in the Byzantine period concentrating in a particular site, Oria Kastro on Kythnos. The stone remains have remarkable rubble vaults. These seem very crude when compared to the very sophisticated masonry of the vaults in the next paper, by Mauel Maissen. This describes the elaborate late Gothic vaulting in the Collegiate Church of San Vittore Mauro in Poschiavo in Switzerland.

The fourth paper in this section returns to the subject of water supply. Continuing from the paper in the last volume, Raimund Mair provides a detailed description of the pumping stations that helped supply water in the city of Augsburg. The city has preserved an incredible collection of original models and drawings showing how these worked.

Valentina Burgassi and Mauro Volpiano explore the construction of the sixteenth and seventeenth century buildings of the Savoy Court in Piedmont. These are well documented, with building accounts and drawings providing valuable insights into the construction process at the time.

The last paper in this section explores the subject of fountains. Maria Grazia D'Amelio and Lorenzo Grieco give a fascinating surviving document which amounts to operating instructions for the complex water garden of the Villa Aldobrandini in Fascati. This provides a fresh look at the wonderful gardens of the villa, which were full of complex water features and devices which thanks to their complexity and the difficulty of maintaining them have long since disappeared.

Eighteenth Century

The first paper in this section, by Walter Richard Wheeler, traces the transmission of Dutch house-framing techniques in the US as a precursor of the later development of the balloon frame. The balloon frame with its small section timbers and nailed joints was the product of newly machine sawn timbers and the production of cheap nails in the 19th century, but as Walter shows, small section timbers had been used in framing much earlier. Giuseppe Mazzone's paper provides an introduction stone and stereotomy in the works of De L'Orme and Guarini, with excellent drawings and complements the existing huge literature on the subject.

The next paper returns to the theme of pumps and fountains explored in the other papers above. In it, I explore the work of John Theophilus Desaguliers, whose publications give the very first description of pumped fountains. Although smaller fountains had sometimes been driven by water pressure from heated vessels, previous large fountains had throughout history had been driven by gravity from tanks or reservoirs mounted. Desaguliers describes the very first fountains driven directly by pumps, in these instances by water wheels driving pistons.

Mike Chrimes's paper examines a new piece of evidence on the life of Jesse Hartley (1780-1860), the engineer of the Liverpool Docks. Hartley's papers were burned after his death but there are a few chance survivals. This paper looks at a diary from 1797, which contains the appointments for the young trainee engineer and gives an idea of his movements. Chrimes compares this to other sources and diaries of the period.

Factories are often overlooked by architectural history and their buildings are not the primary focus of industrial archaeology. They do, however, regularly feature in construction history papers because their long spans and fire proof construction and the comparative economy of their construction often drove innovative solutions to technical problems, particularly in floors and roofs. Estefanía Herrero-García and Ignacio-Javier Gil-Crespo's

paper looks at the Royal Glass Factory in San Ildefonso in Segovia in Spain, a monumental 18th century complex in the grounds of the palace built as a showpiece. As this paper shows, its layout was strongly reminiscent of a monastery with the main space mimicking a church with a central brick dome over the main furnace and glass-making happening in the barrel-vaulted nave-like space off it, all constructed with the aim of being as fire-proof as possible. Fire proofing is also the subject of the following paper by Lia Romano which looks at the contribution of the artist-engineer Jean Far Eustach de Saint-Fer (1746-1828) to the debate on the construction of fire proof floors and the promotion of the use of hollow clay pots of the type similar to those described in Katerina Maria Chalvatzi's paper on the Théâtre du Palais-Royal in Paris built in 1785 in the iron and steel section of this volume.

Nineteenth Century

Although only three papers appear in this section, it is worth noting that a number of 19th century papers are included in the Iron and Steel section above which in any other year would have appeared here.

The first paper, by Stefan Holzer and Clemens Knobling looks at the use of laminated timber arches in wooden bridges in the first half of the 19th century. Timber bridges far outnumbered stone and brick bridges in the late Middle Ages and continued to do so until well into the 19th century but they were never expected to last and had to be frequently replaced. In the late 19th and 20th century they were generally replaced by iron, steel and concrete bridges, so survival of timber bridges is low and their study correspondingly difficult. In the nineteenth century they played a hugely important role in the development of railways. This paper looks at just one form of timber bridge, the laminated arch bridge and traces its types, appearance in literature and development and use in Switzerland which has some charming survivals.

The roles of the various actors (patrons, architects, engineers, contractors etc) in the building world have constantly shifted throughout history and there is enormous variation in practice between different regions, yet these differences are all too easily ignored or overlooked. More puzzling still are those individuals who work across disciplines and contrary to the common practice of the time. Laurens Bulckaen and Rika Devos's paper looks at the example of Louis Cloquet (1849-1920) who, although he trained as an engineer, became a Professor of Architecture published widely on architectural practice. This paper looks at the crucial role he played in a series of complex Belgium building projects in this period. Professional organisations for architects and engineers in the German States are the subject of Christane Weber's paper. Although the German Confederation, which had been created at the Congress of Vienna in 1815, sought to provide some form of economic and political unity, it was not until the unification of the German states in 1871 that Germany as we know it today came into existence. Before that the 39 constituent states operated in more autonomous fashion and this led to fragmentation in professional schools, publications and organisations, the complexity of which Christiane's paper describes.

Twentieth Century

The twentieth century section is the largest in this book, boasting 20 papers. The first paper in this section, by Lukas Stampfer, is very difficult to fit into the chronological development because it is describing 20th century practice in making turf dwellings and how that compares to Roman walling techniques and suggests the route of these ancient traditions might be found in Roman techniques being copied in Scotland and thence to Scandinavia.

The second paper, looks at a more straight-forwardly twentieth century topic; concrete and its use by the Swiss engineer Robert Maillart (1872-1940) to produce a 1909 patent for *Pilzdecken* (girder less slabs). Andreas Thuy's

paper shows Maillart's system in action in the building the Federal Granary in the Swiss city of Altdorf constructed in 1912.

Earthquakes in many regions on seismic faults happen at such long intervals that the reasons for measures put in by one generation to strengthen buldings to resist them are often forgotten and omitted by later ones. Thus the earthquake in Calabria in 1905 was particularly devastating. Valentina Guagliardi's paper looks at the aftermath and the steps taken to rehouse the inhabitants of the region in earthquake-proof dwellings.

Dimtris Theodossopoulos and Irini Gratsia's paper returns to the subject of reinforced concrete. It examines the introduction of reinforced concrete to Greece between 1910 and 1941. It shows the dominance of the Hennebique system and introduces a number of individuals who have been previously overlooked.

The discussion of laminated arch structures has already been mentioned above. This obviously relates to the subject of the next paper, by Roshanak Haddadi and Mario Rinke, which covers the development of glulam as a structural material in the early part of the twentieth century in Switzerland. This is followed by a paper by Leda Dimitriadi on the Europe 1 Transmitter building that is in Germany close to the French border, completed in 1955. It was designed by Jean-François Guédy ad André Nejavits-Méry as a concrete hall with glass walls covered by a curving free form roof. This paper looks at the discussions around the setting out of this form and its relationship to hyperbolic structures so popular in the post-war period, popularized by figures such a Candela and Xenakis. The roof was not entirely successful as the paper reveals.

Render and finishes are not commonly discussed in papers in construction history so it is particularly refreshing to see two papers in this volume. The first, by Ann Verdonck, examines the history and development of Hasco-Relief and how it was invented in the Netherlands but popular in Belgium. Hasco-Relief was a textured oil-based finish which contained a "cold glaze" which made it waterproof and easy to clean. It was invented in 1932 but Verdonck's paper places it elegantly in the context of other textured renders of the time and discusses in detail its features and rise to popularity.

Laura Greco's paper looks at the design of alpine emergency shelters between 1925 and 1944. Today these are often built using helicopters to fly in materials, but in the early years of the twentieth century building on mountain tops meant loading everything onto donkeys and thus the buildings were normally exercises in prefabrication. Laura's paper details the challenges involved and the solutions adopted, both large and small to resist the high winds involved. Resistance to high winds is also the subject of Anne Marie Sowder and Edward Sowder's paper on the construction of stormproof houses in the 1930s in the US. Their paper starts by detailing the appalling havoc reaped by the hurricane in Florida that tore through flimsy wooden houses in September 1935. It then discusses the concrete hurricane proof houses that were built in response, noting sadly that concrete buildings remain unusual despite the risk and that although the concrete houses survive to this day, the US continues to build in these areas in flimsy timber framing with terrible consequences.

Concrete is also the subject of the next paper. Sofia Nannini's paper, like Ann Verdonck's already mentioned, looks at render. In this paper the product chosen is *Steining,* a render specifically designed to protect concrete surfaces from the freeze-thaw problems associated with the cold and used in Iceland and invented by Guöjón Samúelsson in 1930. Maryia Rusak's paper looks at a 19th century Norwegian joinery firm, Moelven Brug and how it transformed itself into a major producer of prefabricated timber homes in 1970s in Norway.

The next three papers all look at free-form structures. The first, by Guila Boiler and Joseph Schwartz, looks at how Heinz Isler and Frei Otto used models to find the shapes of their tension structures. Marisela Mendoza and Juan Ignacio del Cueto Ruiz-Funes look at one of Felix Candela's concrete shell structures: the Los Manantiales restaurant in Mexico City while the paper by Marisela Mendoze, Mariana Esponda, Laila Cordero and Valeria Méndez looks at the first of Candela's shell-structures, the Cosmic Rays Pavilion built in 1951, again in Mexico City.

Many construction projects end in difficult negotiations about unexpected things that have gone wrong, some of which end up in court. Jelena Dobbels's paper looks at the dispute resolution of one particular Belgium Company, Enterprises Générales Henri Ruttiens et Fils over the 20th century. Alejanda Albuerne's paper grows out of a legal battle to save a building, in this case Robin Hood Gardens, by Alison and Peter Smithson, constructed between 1968 and 1972. Although Alejandra suggests that the Estate was influential, as English Heritage pointed out in their report on why the building could be demolished, it was poorly received at the time and largely only known for its association with the Smithsons, whose ability at self-promotion arguably far outweighed their actual success in building terms. As a social housing project, by the time I visited it in the 1990s, its tenants and social workers judged it one of the greatest failures in London. This did not prevent the Twentieth Century Society and the architectural community, almost none of whom had been there (or talked to anyone who had) from setting up a spirited defense, but in the end logic won out and the building was scheduled for demolition with one small part of its cladding being saved for the Victoria and Albert Museum. Alejanda's paper examines, in detail and with careful use of surviving archival sources, this cladding and its significance. It seems ironic that the one part of the building which will be exhibited in the V&A was not heavily influenced in its deisgn by the Smithsons, whose association with the building is its sole reason for its preservation. However the need to contextualise this unusual object in view of its inclusion in a National collection is certainly beyond doubt.

Ilaria Gianetti's paper also looks at concrete cladding, this time the Balency prefabricated panel system and how it was used in France and Italy. The Balency system was invented in France in 1948, patented in 1950 amd introduced tot the French market 1952 and into Italy in 1964 (the same year it was first used in the UK). The article details the system and its adoption, with clear diagrams and photographs showing how it worked.

Vladimir Ladinski's paper returns to the problem of the building professions, looking at the legacy of émigré Russian architects after the First World War. Paula Fuentes and Rosa Ana Guerra-Pestonit look at the transfer of technology rather than people, examining how thin tile vaults were used in the vaulting of St Theresia's church in Dilbeck in Belgium in the 1930s. The role of the Guastavino Company in the US in popularizing the use of thin tile vaulting has been documented by John Ochsendorf. However the use of tile vaulting elsewhere has been less well-explored and this paper linking France and Belgium is a welcome addition to literature.

The last two papers look at roof structures. Mario Rinke and Roshanak Haddadi's paper looks at glulaminated timber. Glulam, as it is popularly known, was first patented in 1906. Mario and Roshanak detail how the exclusive rights for its use in Switzerland were brought Swiss engineers Bernhard Terner and Charles Chopard. This paper looks at one specific project, the sports hall at Birsfelden, which contains curving principle rafters and purlins in an otherwise surprisingly traditional roof form. The last paper in this volume is by Stephanie Van de Voorde and Linsy Raafels. It gives a description of how an engineer designed and built for himself an extraordinary house with a thin shell hypar roof with the help of a fellow engineer who was an expert in these structures. The result was both experimental and a fascinating study in what could be achieved using the form even in a domestic situation.

Concluding Remarks

These 53 papers that make up this the seventh volume in the series cover the whole field of construction history from the study of the profession and legal and contractual problems to archaeology and the history of engineering. There are a number of trends that can be observed.

Subject	Number	Percentage
Iron and Steel	16 papers	30%
Roofs	9 papers	17%
Concrete	9 papers	17%
Prefabrication	8 papers	15%
Timber structures	5 papers	9%
Fountains/Water supply	5 papers	9%
Contractors	4 papers	7%
Bridges	4 papers	7%
Cladding	4 papers	7%
Stone/Brick Vaults	4 papers	7%
Thin concrete shells	4 papers	7%
Laminated arches	4 papers	7%
Professionals	4 papers	7%
Fire-proof floors	3 papers	6%
Render	2 papers	4%

Table. 2 Table showing distribution of papers in this volume by subject (many papers are on several of these topics)

In a year when the theme was iron and steel, 30% of the papers were on these subjects. Roofs, concrete, and prefabrication are the next most popular subjects of papers. The distribution of materials is not so surprising when one considers the distribution of periods. Stone and timber would be more common if papers had been predominantly on earlier periods.

The result is a volume covering a wide range of topics in the field of Construction History which will hopefully give readers a idea of the richness of the subject and the number of fascinating topics it covers.

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