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Corrugated Iron Buildings in Britain: Cultural Significance and Conservation Challenges

Volume I

By

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Degree of Doctor of Philosophy in Architecture

The University of Edinburgh

2019
Abstract

Corrugated Iron Buildings in Britain: Cultural Significance and Conservation Challenges

By the early part of the nineteenth century it had become possible to roll wrought iron into large flat sheets. At the same time, driven by the need for better trade facilities, the London docklands were being built. In 1829 the engineer at the docks, Henry Robinson Palmer, and collaborators created corrugated iron for use in building.

Acclaimed by engineers and entrepreneurs alike, this exciting and innovative material was rapidly integrated into industrial, religious, migration and military uses. Since it was patented in 1829 this corrugated iron has been used around the world, particularly in frontier lands, where habitation would not be possible without it. But by the end of the nineteenth century, corrugated iron had become a victim of its own success – so common that it was anonymous.

This thesis explores why corrugated iron’s cultural significance in Britain is no longer recognised. From the patenting in 1829 to the present day, perceptions and opinions about the material have varied considerably. By describing the origins of national architectural heritage, and the relationships between heritage values, I demonstrate how historical and current perceptions of corrugated iron’s cultural value came to be established.

This thesis stresses the importance of corrugated iron as part of the narrative of Britain’s architectural, social and technological development. The invention and deployment of corrugated iron is a key indicator of how the Industrial Revolution changed British society. This research strongly indicates that Britain is in danger of ignoring the cultural significance of corrugated iron buildings, thus running the risk of distorting the nation’s architectural narrative. Corrugated iron is shown to be an important part of that story and deserves to be designated and promoted alongside the stately homes and thatched cottages of Britain.
Declaration

I declare that this thesis is entirely my own work based on my original research, with acknowledgement of other sources and references, and that the work has not been submitted for any other degree or professional qualification.

Signed:

Dated:
Acknowledgements

I am particularly grateful to the people who helped with my case studies, all of whom gave up their valuable work time on several occasions: Sonia Linskaill the repairing architect for St Fillan’s Church, the Balmoral factor Daniel Watson who took us on an entertaining ride round the estate, the Cultybraggan team – Fiona Davidson and Blair Urquhart and the buildings’ curators at St Fagans museum, Daffyd Wiliam and Gerallt Nash.

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Introduction

Corrugated iron buildings are under threat. Despite the material’s crucial role in Britain’s architectural and industrial history, corrugated iron structures are rarely selected for heritage protection and are frequently at risk of demolition. The severity of this risk has gone largely unexamined, with corrugated iron buildings rarely valued as heritage assets worth serious investigation and conservation. The thesis examines the history of corrugated iron buildings and the resulting cultural and historical values. This thesis is the first extended academic study on corrugated iron buildings and their relationship to British national heritage.

The Beginnings of the Project

This thesis has its roots in the perceived risks to corrugated iron buildings which became evident to the author from around the year 2000. At this time I conducted a survey to investigate why a number of the corrugated iron buildings – industrial and otherwise – that had once been familiar in the landscape were disappearing rapidly from the environment. An opportunity arose to apply for a Millennium Fund grant to record some of these sites, which generated a travelling exhibition of large black and white photographs of the corrugated iron buildings of Dorset. The survey took about 6 months to complete, and succeeded in locating and recording about forty out of a predicted hundred corrugated iron buildings. However, during this process many of the structures themselves were also receiving funding – for their demolition, because European Union money had become available for the replacement of older village halls. This funding source was not the only reason for the disappearance of the corrugated iron buildings. Despite often being of considerable age and having fascinating associated narrative histories, many were demolished. Often, this was due to the high land values which exceeded the rent that could be raised from them; in other cases, because they were
simply perceived as being sheds of no worth at all. Many of the corrugated iron buildings were well-loved by their owners, and were carefully refurbished – but these were the minority.

The Dorset research process raised many questions about why some historic buildings were considered worth preserving but others were not, and why corrugated iron might differ from other building materials when decisions regarding demolition are taken. With this questioning came the realisation that the narratives and histories that are recorded in the nation’s architectural landscape are being selectively eroded, and our sense of history distorted by the eradication of particular building types such as corrugated iron buildings. The rapid disappearance corrugated iron buildings is often compounded by the ignorance of the general public and a lack of awareness by those that care for them.

**General Difficulties: Designation, Perception and Ignorance**

Amongst architects and conservation professionals this research has found a widespread lack of knowledge of the potential age of corrugated iron buildings. This was aggravated by widespread ignorance of how early corrugated iron employed craft-based production techniques, and used wrought iron rather than mild steel. The realisation that any discussion of corrugated iron needs to go beyond the material itself, acknowledging instead the attitudes and aspirations of its developers, has strongly influenced the development of this research.

It appears likely that the lack of academic study of corrugated iron is at least partly due to a perception that it is a material with little to offer in the way of heritage value. The lack of national surveys regarding its use and survival may also be explained because it has not been recognised as a part of a system of building that promoted, and was an integral part of, social change. This research aims to demonstrate the social value of corrugated iron and to
establish the cultural value of corrugated iron by examining the subjective nature of the perceptions of value. It also aims to establish an intellectually strong connection between corrugated iron and its heritage value and so increase the academic status of study in this field.

How we value buildings depends as much on our subjective perceptions of them as on any objective scheme of values.¹ Our perceptions are built from personal events that happen to us, as well as our culture, history, politics or art. In other words, the perceived value of corrugated iron depends largely on the cultural context in which it is placed.

Another measure of how we value buildings is the process of designation. Listed building or scheduled ancient monument status might be presumed to be based on an objective and dispassionate valuation of our entire building stock. However, the designation process, originally created using the age and perceived quality of buildings as its primary criteria is demonstrated by research skewed in favour of large and grand buildings using traditional construction. The available evidence suggests that it is much harder to obtain designated status for Modernist and corrugated iron buildings than it is for those conforming to picturesque, Gothic, or classical styles. This effectively valorises some buildings at the expense of others – an issue explored in detail in chapter 3. Both Historic England and Historic Environment Scotland gave some recognition to the challenges posed by assessing the value of corrugated iron buildings by applying established elite architectural norms. This is evidenced by Historic Environment Scotland’s publication of technical literature on the conservation of corrugated iron,² and, less directly, by the

adoption of ‘thematic listing’ by Historic England which has led to the recognition that even petrol station canopies can have cultural significance.

The research has uncovered some serious technical conservation problems. There is little agreement on, or interest in, how corrugated iron should be repaired and given future protection. A limited attempt has been made provide protection through the listing system, but this has been applied very patchily and does not appear to have resulted in any case of enforcement action. 

Greater protection appears to have been offered by the movement of corrugated iron buildings into open air museums or Skansens. The most serious problem revealed by the research is that despite the recent interest in corrugated iron buildings, many good examples are still being destroyed. A possible reason for this continued destruction is the lack of information about why it is worth conserving these buildings.

**Research methodology**

Research data was gained from primary sources such as patent descriptions and newspapers, but also from contact with those currently involved with the practical application of conservation values. These included academics, national agencies such as Historic Environment Scotland and Historic England, local authority conservation officers, museum conservators and curators, architects the owners of corrugated iron buildings, and museum visitors. This contact was made via emails, face to face interviews, and visits to archives. Site visits played a major part in the capture of both interview data and original photographic recording.

Secondary source material was gathered by a thorough review of all accessible published sources, including all traceable published and

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3 This is a best estimate on the available evidence. There is no centralised record of enforcement action in regard of listed building status, and direct interrogation of local authority planning departments in Scotland and England produced no meaningful response.

4 Museums that display buildings.
unpublished theses. References were gained from early trade journals such as Architects Journal and The Builder, newspapers such as The Illustrated London News and the patents for corrugated iron and the galvanising process. Data gathering concentrated on attitudes and philosophies, but also included the practical problems encountered, and approaches adopted, by those involved in the conservation of corrugated iron buildings.

A difficult problem has been defining what constitutes a corrugated iron building. Even where corrugated iron forms a major part of a building, it is usually one element of a larger building system. Implicit in its use are wholly new attitudes to the manufacture of buildings, their prefabrication and transport. Search terms for Historic Environment Scotland and Historic England have defined any building making use of the material as a corrugated iron building. This has created significant difficulties in the analysis of designation data: buildings that have only minor elements of corrugated iron show up on searches as corrugated iron buildings.

This research has therefore included buildings where the corrugated iron played a significant part in the design ethic, even when that included or depended on other materials. Within these parameters corrugated iron has proved a useful material across a very wide range of buildings and structures from vast airship hangars to tiny tin churches. The range and diversity of corrugated iron deployments has been discussed within the confines of the primary focus of corrugated iron buildings’ cultural significance. Four diverse building types are discussed in depth in chapter 4.

The principal aim of this research is to determine how and why we ascribe particular cultural significance to corrugated iron, and how the designation system implements and manages those valuations. The values accorded to corrugated iron have changed over time, and are affected by historical events, politics, key personalities and wider cultural development. How we value buildings also depends on how we perceive them. Our perceptions are built
from personal events that happen to us, as well as our culture, history, and politics. In other words, the perceived value of corrugated iron depends largely on the cultural context in which it is placed.

The complexity of the competing multiple influences that determine perceptions of cultural significance makes any universal set of values very difficult. As Jokileto argues, ‘If we value everything equally, then we value nothing.’

To discuss the cultural significance of corrugated iron adequately, it is also necessary to analyse its technical history, its day-to-day performance and its conservation strengths and weaknesses – because all these factors influence perceptions of the material. This thesis attempts to provide sufficient insight into all these areas, supporting analysis of the core questions set out above.

**Literature review**

In order to answer these research questions it was necessary to examine the history of corrugated iron, from its patent for use in building in 1829, through the development and manufacture of the material, to its use in the many forms of buildings that can now be found all over the world. To understand how the cultural significance of corrugated iron had changed, I needed to review all material that was written about it, from newspaper reviews to book and academic publications.

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The content available has varied tellingly over time. When corrugated iron was first patented and used in buildings there was an outburst of enthusiasm for this new material, which was reflected in articles and reports in magazines, newspapers and catalogues; but as it became more commonplace, corrugated iron attracted remarkably little attention, academic or otherwise, before the twenty-first century.

One of the best sources of information on corrugated iron buildings is the large number of sales catalogues printed toward the end of the nineteenth century. They aim to sell all types of small farm buildings, and usefully demonstrate the enormous range of corrugated iron buildings offered by a single manufacturer at the peak of corrugated iron’s popularity. However, caution should be exercised in assuming that the inclusion of a design for a corrugated iron building in this catalogue is an indication of how many, if any, of the designs were actually sold and erected. Good examples of these are A. and J. Main & Company’s catalogue of *Galvanised Iron Roofing and Shedding, Iron Structures, &c, Patent Portable Steel Railways, Railway Plant, Iron Bridges* (1884), and William Cooper’s *The Gardeners’ and Poultry Keepers’ Guide and Illustrated Catalogue* (1901).6

Nineteenth century magazines and newspapers provide an excellent resource and are particularly interesting because they inadvertently documented the change in public taste, from initial enthusiasm towards corrugated iron to later indifference and dislike. Of special interest are *The Builder* and *The Illustrated London News*, particularly the latter, which contains a wealth of illustration to support the articles. Other newspapers and magazines were *The Architects’ Journal*, *The Practical Mechanic*, *The Atlas*, the *London Daily News*, the *London Evening Standard*, *The Advocate: Or, Irish Industrial Journal* and the *Staffordshire Advertiser*. The dates examined ranged from 1836 to 1938, but

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not every edition of every publication scrutinised. It must be emphasised that this was largely an index-based search reliant on third-party indexing undertaken by The British Newspaper Archive.\textsuperscript{7}

This initial public enthusiasm for corrugated iron was also reflected in John Claudius Loudon’s book, published in 1833, in An Encyclopaedia of Cottage, Farm and Villa Architecture and Furniture (Volume VI), in which there is a significant treatment of corrugated iron.\textsuperscript{8} Typical of early Victorian illustrated pattern books, it deals with vernacular styles and techniques for designing and making estate buildings, and is one of the few contemporary descriptions of very early corrugated iron. Less than five pages are devoted to the material, but its positive enthusiasm for the possibilities of the material’s uses is characteristic of the literature of the time. It is remarkable that corrugated iron, then so newly invented, is featured in Loudon’s publication; the inclusion suggests that corrugated iron was considered revolutionary and exciting by the author’s contemporaries. Because it is one of the few sources of information on early corrugated iron, it is frequently quoted as source material in later texts, such as Mornement and Holloway.

Although published at a slightly later date, James Davies’ \textit{Galvanised Iron: Its Manufacture and Uses} (1899) explains the galvanising processes that were well established by the time of writing, as well as discussing how to improve the physical difficulties of running a successful galvanising business. He also offers opinions on the corrugated iron market and the quality of corrugated iron. It is interesting to note that by the turn of the century the quality of corrugated iron was frequently sacrificed to save on the cost of manufacture.

\textsuperscript{7} The British Newspaper Archive, accessed 28 June 2019, https://www.britishnewspaperarchive.co.uk.
In the long term this would be to the detriment of corrugated iron, a change is borne out by the paucity of literature in the early to middle of the twentieth century.

H. W. Dickinson’s ‘A Study of Galvanised and Corrugated Sheet Metal’ (1943)\(^9\) is one of the earliest academic papers to be published in the twentieth century, and is a review of the process of making the galvanising of corrugated sheet metal in its earliest form.

Another 17 years passed till A. W. Skempton’s ‘The Boat Store, Sheerness (1858-60) and Its Place in Structural History’ (1960) was published.\(^10\) In this paper he notes the importance of this 100 year old building, the architect, Greene’s design and Eric de Mare’s discovery of it. He also mentions the corrugated iron cladding, which had by then been replaced by a modern equivalent.

Unlike Britain, Australia has a number of academics who have published material on corrugated iron and prefabricated buildings since the 1980’s, which is in itself a reflection of the cultural regard that the country has for corrugated iron buildings.

Miles Lewis, an Australian academic has been publishing about prefabricated buildings, including corrugated iron since the 1980s. His online publications have made academic literature freely available world-wide and have added well-informed new material to the debate on the cultural significance of corrugated iron. In 1982 he published ‘The Corrugated Iron Aesthetic’,\(^11\) which opens up the discussion as to why men like John Ruskin and A. W. N. Pugin

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are so averse to the material; also available is ‘Prefabrication in Australasia’,\(^\text{12}\) and ‘The Portable Church in Australia’ (1984)\(^\text{13}\) amongst his many others.

Anne Warr, after writing her master’s dissertation of corrugated iron in 1976 has moved to Australia and written a number of articles ‘Corrugated Iron – Options for Repair’ (2000),\(^\text{14}\) ‘Making Corrugations – A Cultural Journey’,\(^\text{15}\) and recent contribution ‘Corrugated Iron: Forming New Perceptions in the Australian Landscape’,\(^\text{16}\) in the book *Function and Fantasy in the Long Nineteenth Century* (2017), which builds on existing knowledge and expands on the integration of corrugated iron into the Australian landscape and its current accepted place in Australian culture.

One of the best books about corrugated iron buildings is *Corrugated Iron: Building on the Frontier* by Mornement and Holloway was published in 2007.\(^\text{17}\) This is a handsomely produced overview which covers the history of the making of corrugated iron and its relevance to frontier life. The historical sections of the book owe a considerable debt to the thesis of Pedro Guedes, an Australian academic, whose PhD dissertation is discussed below. *Corrugated Iron: Building on the Frontier* is the only comprehensive survey of world-wide corrugated iron architecture from its invention in 1829 to the present day. This book broadens the scope of the academic study of


corrugated iron, not just covering the prefabricated buildings, but including the exciting new architectural vocabulary of corrugated iron buildings in the frontier regions of the world, such as Shuhei Endo in Japan and Glen Murcutt in Australia. The photographic illustrations are sumptuous and informative from both a technical and artistic point of view. This book should serve as a turning point in attitudes towards corrugated iron buildings as it challenges the prejudices against the material that are currently popular in British culture. It is however not intended as an academic work, and carries only a gesture towards referencing and bibliography.

Pedro Guedes’, PhD thesis, ‘Iron in Building 1750-1855: Innovation and cultural Resistance’, has been extremely helpful. This unpublished thesis explores the history of iron in buildings using patents as the primary source material and is worldwide in scope, reflecting the extensive travel experience of the author. The subject matter covers the general use of iron in buildings from 1800 till 1855, so corrugated iron forms only a part of the discussion. It is nevertheless extensively discussed, with the innovative quality of Henry Robinson Palmer’s invention forming a key part of the argument. Of particular interest is Guedes’ hypothesis that iron in building was promoted in two ways, either by innovation or substitution. This immense research effort is properly referenced with an extensive bibliography and well-illustrated with the use of prints from patents and magazines such as The Illustrated London News.

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Most recently Australian Dirk H. R. Spennemann has published ‘Recording Corrugated Iron, A Guide to Techniques’ (2015)\(^{19}\) alongside ‘Why Do Corroded Corrugated Iron Roofs Have a Striped Appearance?’ (2015).\(^{20}\) Spennemann has contributed much needed research into the problematic area of corrosion.

By the turn of the twenty-first century a sea change, created by a growing nostalgia for the rapidly disappearing corrugated iron buildings, spawned a number of hardback publications and an academic interest resulting in several master’s theses. This resurgence of interest in corrugated iron increased the quantity of non-academic publications also. In 2004 Ian Smith wrote *Tin Tabernacles*,\(^{21}\) and in the same year Historic Environment Scotland’s TAN 29, was published.\(^{22}\) David Mitchell for Historic Environment Scotland, published an INFORM booklet about corrugated iron in 2008,\(^{23}\) and Nick Thomson brought out the Shire publication *Corrugated Iron Buildings* in 2011.\(^{24}\)

Historic Environment Scotland’s Technical Advice Note 29, ‘Corrugated Iron and Other Ferrous Cladding’, is a useful and practical document which aims to raise awareness of the need to understand, conserve and repair corrugated iron buildings. It provides technical advice for anyone trying to conserve corrugated iron, and contains a large amount of information on the chemistry of iron, a list of suppliers, how to identify the profile of corrugated iron and the kinds of paint available to protect it. It is diverse, and the content of the book

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\(^{22}\) Walker, ‘Corrugated Iron’.


suffers from dilution; for example, the sections on how to record buildings and how to study building history do not integrate effectively with the technical material on the repair of wrought iron. However, the book itself acknowledges these limitations, pointing out that the conservation of corrugated iron is still in its infancy. That the guide was published at all was a remarkable step forward in the recognition of the cultural significance of corrugated iron, and its publication strongly reinforces the view that the cultural values embodied in the study of historical architecture in Scotland are significantly different from those in the rest of Britain.

Ian Smith, *Tin Tabernacles* (2004) is a photographic survey of a selection of corrugated iron churches of Britain. The content is limited entirely to tin tabernacles and is a collection of historic photographs followed by a brief history of each building. There are several chapters on tin tabernacles in different parts of Britain, concluding with one on corrugated iron churches abroad. Whilst not an academic work, and consequently not providing a detailed or philosophical reflection on the material, it is an excellent collection of photographs and represents a significant effort in field survey.

The late twentieth century and early twenty-first century also spawned a number of dissertations about corrugated iron.

Paul Dadson’s ‘Rediscovering Corrugated Iron’ (1989)\(^\text{25}\) is often quoted by later academic authors and is a detailed examination of the invention, design and production of corrugated iron. Dadson discusses and extensively illustrates portable buildings and corrugated iron buildings produced for the colonies, including churches and houses. He raises many interesting issues, for example, how church authorities resisted the use of corrugated iron in churches until tin tabernacles took on elements of the thus ‘delaying inception

rather longer than was the case with secular buildings.\(^{26}\) In secular buildings, Dadson shows there was less resistance by architects to the new curved forms made possible by corrugated iron. Also detailed are early uses of corrugated iron as a structural material, for example, its use in lightweight, but strong, fireproof floors.\(^{27}\) As part of this discussion the complex issue of why enterprising and successful new uses for corrugated iron were not more systematically exploited is raised, but not fully addressed. This highlights one of the limitations of Dadson’s research. Although he does not deal explicitly with the cultural significance of corrugated iron or the philosophical issues underlying cultural significance itself, his thesis is a critical contribution to the general understanding of corrugated iron, and has been very helpful as a basis for following up informed research. It is unfortunate that Paul Dadson’s dissertation has never been published, for it is a very readable overview of most aspects of corrugated iron.

Other master’s dissertations have been available and have given much background information about the variety of corrugated iron buildings in many areas of Britain. Eoghan Campbell and Nick Thomson have written about Scotland. Eoghan Campbell’s ‘The Prefabricated Churches of the Highlands’ (2000),\(^{28}\) was a helpful link between the corrugated churches of the Highlands and the religious tensions which led to their construction.

Nick Thomson is one of a very few practicing architects working in corrugated iron. Thomson’s master’s dissertation, ‘The History of Corrugated iron in the Highlands and Islands’ (2002)\(^{29}\) seeks to establish if the corrugated iron buildings of the Highlands and Islands constitute a culturally significant part of Scotland’s built heritage. The main basis of the study is a survey of the extent

\(^{26}\) Dadson, ‘Rediscovering Corrugated Iron,’ 36.
\(^{27}\) Dadson, ‘Rediscovering Corrugated Iron,’ 76.
and distribution of corrugated iron buildings in the north-west.; this is supported by an evaluation of the historical and aesthetic context, which also considers whether these buildings are worthy of conservation. The dissertation includes a review of the history of corrugated iron, the patents relating to corrugated iron, its manufacturers, and a review of the transport infrastructure that was a key element in the success of corrugated iron.

Thomson’s dissertation also includes a short investigation into the wider issue of corrugated iron’s cultural significance, and is inspired by Paul Dadson’s assertion of ‘the conservation worthiness of the better examples.’ Tellingly, he repeats Dadson’s hypothesis that the lack of appreciation and discernment of what is worthy of conservation and what is not. This discussion is supported by an exploration of the aesthetics and also the social significance of corrugated iron buildings, which contains a paragraph on corrugated iron in other countries.

Thomson’s final chapter considers the continuing loss of, and changes to, corrugated iron buildings, and whether the statutory protection of these buildings is effective in ensuring their preservation. In doing so, he expresses doubts about how much experience, understanding and knowledge planning departments have, but does not explore this in any detail.

Nick Thomson has continued to publish work about corrugated iron. The Shire Publication Corrugated Iron Buildings (2011)30 is a detailed and well-researched overview of corrugated iron buildings in Britain. There is a good balance between text and photographs, and it is an excellent starting point for the study of corrugated iron buildings, with a limited but useful bibliography. In 2006, ‘A Study of Early Corrugated Iron Buildings in Rural Scotland’31 was

30 Thomson, Corrugated Iron Buildings.
presented, which gives much information on the construction of ET Bellhouse’s Balmoral Ballroom.

D. H. R. Pritchard’s ‘Conservation of Corrugated Iron Farm Buildings’ (2007)\(^\text{32}\) concentrates on corrugated iron farm buildings in Yorkshire, and is an investigation into the use of corrugated iron as a building material, and the cultural significance accorded to it. Chapter 2 covers a brief history and technical developments of corrugated iron building, and chapters 3 and 4 are general explorations of corrugated iron agricultural buildings from the nineteenth century, with a brief consideration of farming as the context of corrugated iron. Chapters 5 and 6 study the history of conservation and conservation in practice, and chapter 7 is an overview of the cultural significance of corrugated iron. Although primarily focused on farm buildings, his dissertation contains much that is relevant to the wider study of corrugated iron. The chapters dealing with cultural significance and the working of the planning system have been particularly useful. It is another good example of how the publication system for academic material fails to capture much excellent work, on account of it being unpublished.

Ashley Batten’s ‘Understanding Corrugated Iron Buildings in North West Wales,’\(^\text{33}\) provides much needed information on the remaining stock of historic corrugated iron buildings in Wales.

As well as understanding corrugated iron buildings it was necessary to support the discussion on the cultural significance and perception of corrugated iron buildings. Examination of how we apply values and cultural significance to the assessment buildings are explored in the academic publications from the Getty Conservation Institute. These include: *Economics and Heritage Conservation*

by Maria de la Torre and Randal Mason (with David Throsby) (1999); Values and Heritage Conservation (2000) by Erica Avrami, Mason, and de la Torre; and Assessing the Value of Cultural Heritage: Research Report (2002), edited by de la Torre – all of which are all major contributions to the debate on defining cultural significance. Although none of these publications deal directly with corrugated iron, their discussion of cultural significance is crucial to the understanding of the current status of this material.

Other published sources which have made helpful contributions to the relationship between conservation values and cultural significance are Conservation of Buildings by John Harvey (1972), The Future of the Past, edited by Jane Fawcett (1976), and Building Conservation Principles by John Earl (2003). Historic England’s (formerly English Heritage) ‘Conservation Principles’ (2008) and the Scottish Historic Environment Policy (2011) have also contributed significantly to the recent literature dealing with cultural significance.

Much information for this dissertation has been gleaned from sources that are not wholly focused on corrugated iron, but nevertheless have contributed to its study. J. M. Richards’ The Functional Tradition (1958) is based on a collection of photographs taken by Eric de Mare. In the introduction Richards

34 Maria de la Torre, Randal Mason, and David Throsby, Economics and Heritage Conservation (Los Angeles: Getty Conservation Institute, 1998).
35 Erica Avrami, Randall Mason, and Maria de la Torre, Values and Heritage Conservation (Los Angeles: Getty Conservation Institute, 2000).
argues for the buildings constructed for industry need to be valued for their functional design, focussing on deign for the needs of the industry or the people that use them, rather than their architectural style.

Theodore Prudon’s *Preservation of Modern Architecture* (2008),\(^43\) has been invaluable for its exploration of how perceptions of modernist buildings affect the way that we assess them; this has, of course, implications for perceptions of corrugated iron buildings.

*A History of Architectural Conservation* by Jukka Jokilehto (1999)\(^44\) and more recently *The Conservation Movement* by Miles Glendinning (2013)\(^45\) have both set out to define conservation values and explain how they have arisen. An understanding of the history of conservation itself, as explored by both these authors, is an essential prerequisite to understanding current attitudes to corrugated iron.

Andrew Saint’s *How Listing Happened in Preserving the Past: The Rise of Heritage in Modern Britain* (1996), though not recent gives a good background information on the origins of the designation process.

Dorothy Bell in ‘The Value of Ruins: Present Definitions and Methods of Perspective’ (2007)\(^46\) initiates a debate about the different kinds of value that might be applied to ruins.

Corrugated iron has featured in episodes of Grand Designs on Channel 4, particularly the Strathaven Airfield house designed by Richard Murphy which clad in corrugated aluminium. This building is much praised by Kevin McCloud

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\(^43\) Prudon, *Preservation of Modern Architecture*.


\(^45\) Glendinning, *The Conservation Movement*.

and his opinions give a delightfully fresh perspective on the aesthetics of buildings made from corrugated cladding.\textsuperscript{47}

**General background reading**

Keith Mallory and Arvid Ottar’s, *Architecture of Aggression: Military Architecture of Two World Wars* (1973).\textsuperscript{48} Published as a result of a photographic survey this unusual collection of photographs shows buildings designed for war time use, and includes corrugated iron buildings such as Nissen huts and Quonset huts.

Gilbert Herbert’s *Pioneers of Prefabrication*, (1978)\textsuperscript{49} is possibly the first major study of prefabricated buildings showing the general trends of prefabrication. It includes a whole chapter on corrugated iron, and helped with my understanding of earlier prefabricated designs such as the Manning house.

David Evans’ *Building the Steam Navy: Dockyards, Technology and the Creation of the Victorian Battle Fleet 1830-1906* (2004)\textsuperscript{50} is a thoroughly researched book, which contains a section devoted to the difficulties encountered by early corrugated iron users at Chatham docks. It has also been helpful contributing to my understanding of the role the naval architects played in the use and development of corrugated iron for functional purposes in naval architecture.

Andrew Saint’s *Architect and Engineer: A Study of Sibling Rivalry* (2007)\textsuperscript{51} is an interesting and detailed exploration of the important role of the engineers in

\textsuperscript{47} ‘Channel 4 Grand Designs revisits the Strathaven Airfield House,’ 30 August 2018, YouTube video, https://youtu.be/g87kJXsrPPw.


early building design. Although it does not focus on corrugated iron as such, it does inform about engineers such as I. K. Brunel, and his use of corrugated iron at Paddington Station.

*Architecture and Urbanism in the British Empire* by GA Bremner (2016) offers historical background discusses the architectural and urban transformation in the British Empire and the relationship between empire and architecture. It was of use in assessing Victorian church architecture.

*The Shock of the New*, by Robert Hughes (1980)\(^{52}\) has provided a crucial contribution to rationalising how perceptions of cultural significance change dynamically over time. As an Australian, Hughes has an outsider’s view of the valuation of European culture, and speaks with a lucidity and clarity on the subject. Indeed, all the Australian contributors to the literature of corrugated iron are particularly valuable in assessing how corrugated iron has been received, as they provide an international and detached perspective on European culture.

The texts set out above have been of value in furthering the aim of this thesis: to redress the historically low cultural status of corrugated iron buildings by providing new understanding of its significance. Their use has been determined by keeping specific research questions in mind: have implicit, but unacknowledged, cultural valuation assumptions skewed the application of conservation practice and listed building designation to the detriment of corrugated iron buildings? And how have concepts of *impermanence*, *industrialisation* and *newness* affected perceptions of corrugated iron buildings?

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Chapter 1: The Patenting and Making of Durable Sheets of Corrugated Iron

1.0 Introduction

The invention and development of corrugated iron was contingent on the incremental advances of the iron industry as a whole. Its production demanded the ability to economically manufacture thin sheets of malleable or wrought iron\textsuperscript{53} of consistent quality. The sheets needed to be sized uniformly and accurately, and the metal itself of sufficient quality to allow the formation of corrugations. Until the nineteenth century it was impossible to meet these demands. To understand why, it is necessary to look in some detail at the production and physical properties of metallic iron. This chapter seeks to explain the technical history of corrugated iron production.

1.1 Technology and Chemistry of Early Iron

In order to understand corrugated iron as a material, it is crucial to grasp the difference between cast iron and wrought iron. Cast iron was the direct output of nineteenth century blast furnaces. Due to its high carbon content, cast iron was brittle and could not be shaped by rolling or pressing. Wrought iron was the forerunner of modern steel, and if well-made, was malleable and ductile, meaning that it could be rolled into thin sheets and formed into corrugations.

\textsuperscript{53} Malleable iron describes the physical property of iron with a low carbon and phosphorous content. It means the iron can be shaped by hammering or rolling. Malleable iron can be produced directly from the smelting process whilst wrought iron, by definition, has been worked (wrought) to achieve its physical properties.
1.1.2 Making Iron: The Bloomery Furnace

_Smelting_ in a furnace is the process of extracting metallic iron from iron-ore. Heat in the furnace drives off oxygen from the ore and separates the metallic iron from the other minerals present; this mixture of other minerals is known as slag. The furnace operation is far from straightforward and the technology developed very slowly until the advances of the industrial revolution.

The first type of furnaces were _bloomeries_, a high-temperature furnace which fired to about 1200°C. The aim was to melt the ore sufficiently to remove some of the impurities and produce a _bloom_ – a mix of iron and slag with some carbon. After a few hours of firing, as much slag as possible was tapped off, the bloom extracted, and the furnace left to cool. This _bloom_, so named because of its bubbling appearance, was then hammered to remove the impurities of slag, thus being converted into wrought iron with a low carbon content. This method of production, called the direct method, was not a continuous process, and required that the bloom be cooled and reheated multiple times. Regardless of its finished quality, which was inconsistent, _bloomery/finery_ iron was expensive in labour and fuel; it also only produced small quantities of iron, not enough to make sheet iron, and hence corrugated iron.
Figure 1.1. Early iron work: locksmith-style wrought iron in the chapel at Farleigh Hungerford Castle, Somerset, c1470. Such decoration is on a very small scale not comparable to the demands of the sheet iron needed for corrugated iron.
The typical output of an individual bloomery was small. A bloom might typically weigh 14 kilos and form part of an annual output of 1.5–3 tons.\textsuperscript{54}

Figure 1.3. Diagram of bloomery production. Provided by Jake Keen in personal communications with the author.

KEY:
1: Crushed iron ore
2: Fuel: Charcoal
3: Combustion products: Carbon dioxide and water vapour
4: Body of the furnace. Shapes varied, but clay was the usual material.
5: Burning zone: Burning zone: Heat from the burning fuel takes oxygen from the iron ore and combines it with carbon to form carbon monoxide and dioxide. Because of the cooling effect of the cold-blast, here is insufficient heat to fully melt the iron or separate it from the silica in the ore.
6: Cold-blast: Although the air forced into the furnace provides extra oxygen and increases the rate of combustion, the same air is cold and simultaneously cools the interior of the furnace.
7: The bloom: This is a plastic mass of partially molten iron and silica slag.

It was not possible to produce iron in sufficient quantity to make sheet and hence corrugated iron till the eighteenth century. This depended on the radical changes in furnace technology that centred on the development of the blast furnace.
1.1.3  The Hot-blast Iron Smelting Furnace

Throughout the late eighteenth and early nineteenth centuries ironmasters experimented with larger, more efficient and hotter furnaces. A particular advance was the adoption of the hot blast.


KEY:
1: Pre-prepared crushed iron ore.
2: Fuel: Charcoal, coal or coke, depending on date, location and operator.
4: Body of the furnace: Refractory brick lining supported on masonry (or later by steel plates).
5: Burning zone: Heat from the burning fuel takes oxygen from the iron ore and combines it with carbon to form carbon monoxide and dioxide. At the same time, the heat melts and separates the iron from the silica (slag). As the iron is melted it absorbs carbon from the fuel: it is this carbon absorption that gives cast iron its characteristic brittleness.
6: Hot-blast: Pre-heated air is blown into the furnace. This is the one of the key innovations of the nineteenth century iron smelting furnace. Blowing air into the furnace is essential to provide enough oxygen to combust the fuel and melt the iron ore, but blowing in cold air simultaneously lowers the temperature. Pre-heating provides the extra oxygen without the severe cooling effect.
7: Provided the temperature in the furnace reaches 1450°C, both the silica and the iron in the ore will melt and separate. The molten silica is lighter than the molten iron and floats on top of it. The furnace can be tapped and the molten silica run off as slag.
8: Molten iron can be tapped from the bottom of the furnace and run into moulds. This casting process gives ‘cast iron’ its name.
Casting cast-iron from the furnace

Figure 1.5. Diagram of casting of molten iron.

KEY:
1: Feed of molten iron from the furnace
2: The central channel or ‘sow’ distributing metal to the moulds
3: Individual moulds for ingots or pigs: cast iron was often referred to as pig-iron.

Figure 1.6. Blaenavon blast furnaces in Wales. Note the difference in scale in comparison to the small bloomery furnace. Photograph by the author.
Blast furnaces could be run continuously and produced iron on a scale that had hitherto been impossible. As an unintended consequence of using hot-blast to achieve the 1450°C needed to liquefy the silica in the iron ore, much more carbon from the fuel becomes combined with the liquid iron. This high carbon content makes the iron brittle and unsuitable for shaping into corrugated sheets or any other application requiring malleability. It was, however, eminently suitable for casting metal columns or cooking pots.
Blast furnaces developed slowly over hundreds of years, but their full potential was not realised until an effective way of reducing the carbon content of the cast iron was developed. Two strategies were introduced to deal with the problem. The first was to develop new uses for cast iron, and the second was Henry Cort’s application of the puddling furnace. This involved re-melting the cast iron in a separate puddling furnace and stirring with an iron rod. The key feature of Cort’s puddling furnace, was that the fuel did not contact the iron: the fire was kept separate from the melted metal and so problems of carbon absorption were removed. A flow of ‘reducing’ flue gas was passed across the surface of the molten iron and burned out the carbon content. The reducing flue gas was so called because it was depleted in oxygen and rich in carbon monoxide. The carbon monoxide combined chemically with the excess carbon in the melted iron to produce carbon dioxide which was then exhausted through the chimney. Cort realised that the melting point of iron was influenced by its carbon content, and that the high carbon cast iron from the blast furnace required only 1150°C to liquefy. Cort’s puddling furnace reduced the carbon content of blast furnace iron for around 3-4% to around 1%.
By 1784, the combination of the blast furnace, refinery and puddling furnace had created a vastly improved system of iron production. However, the mechanical reshaping of bar iron was still done by mechanical hammering, which remained slow and imprecise. Henry Cort overcame this by substituting a rolling mill in place of the forge hammer.

Figure 1.9. A rolling mill, used here for slitting sheets of iron in 1704. Image from William F. Durfee, ‘The Development of American Industries Since Columbus,’ *Popular Science Monthly* 31 (January 1891), 315.
Simple rolling mills had been in place since about 1590,\(^55\) when they were used with a slitting mill to produce strip iron. John Hanbury had devised a way of rolling sheet iron for tin plate in 1720,\(^56\) but Cort went further and realised that metal profiles could be produced by rolling with shaped rollers. The importance of this innovation to the development of corrugated iron is crucial. Cort’s commercial success using rollers proved that it would be possible to produce cheap profiled sheets of iron even though such sheets were not actually produced for another fifty years.

The early iron masters had only the most rudimentary understanding of the processes they were using. For example, they knew that ‘red-short’ iron had been contaminated in some way during smelting, but they did not know that the contaminant was phosphorous. ‘Red-short’ iron was brittle at high temperatures. ‘Cold short’ iron was contaminated with sulphur, and was brittle at all temperatures, particularly cold temperatures.\(^57\) It was not until the work of Sidney Gilchrist-Thomas (1850 –1885) in the 1870s that proper scientific analysis was systematically applied in the iron industry.

The lack of fundamental understanding of iron is interesting from a corrugated iron perspective because it highlights how bold Palmer was in giving thin wrought iron a structural role, when the material was only poorly understood even by its manufacturers.

\(^56\) Gale, *British Iron and Steel Industry*, 46.
1.2 The Development of Iron in Roofs

The late eighteenth and early nineteenth centuries are characterised by multiple co-dependent economic, social and technical changes.\(^{58}\) The development of the London Dock, fully described in the appendix, provides an excellent example of how social change driven by economic necessity provoked and utilised technical innovation.

The Dock Company recognised the need for a radical overhaul of traditional warehouse design: the new buildings needed better access, larger internal clear spans, better weight bearing capabilities and improved fire resistance. Recognition of these new necessities led to the adoption of iron stanchions and Palmer’s substitution of corrugated iron for traditional roofing materials.

At the time that the docks were being built, the idea of covering roofs with iron tiles was not new. In 1783, Robert Ransome, an iron founder of Norwich, developed a method of making cast iron roofing tiles.\(^{59}\) In 1814, Richard Tomlinson, an ironmaster from Bristol, patented a system of iron tiles for roofs made from interlocking sheets of iron.\(^{60}\)


\(^{60}\) Guedes, ‘Iron in Building,’ 171.
Sheet iron roofing tiles were common in Russia in 1814, and were also exported to Quebec.

Sheet iron coverings are now universally made use of on all new buildings in Petersburg, Moscow. In the case of a fire no harm can come to a house from sparks falling on a roof of this description. When the sheets are on the roof they measure only two feet wide by four feet in length: this is owing to the overlapping.

The fire resistant qualities of iron roofs, particularly in contrast to wooden shingles, made an impact in north America, and in 1802 Benjamin Latrobe, an English architect, had the Nassau Hall at Princetown recovered with ‘Latrobe’s iron sheet’, and in 1804 the White House in Washington was also re-roofed in sheet iron.

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63 Loudon, An Encyclopaedia, 206.
64 Dadson, ‘Rediscovering Corrugated Iron,’ 8.
At much the same time, the Shropshire iron master Thomas Botfield patented a system of iron roofing, which according to Guedes ‘depend[ed] entirely on the inherent strength of curved sheet metal to enclose space, or act as a rigid surface without any subsidiary framing.’\textsuperscript{65} Although Botfield built at least one practical example of his roofing system, it does not appear to have been a commercial success. Despite this lack of success, the significance of Botfield’s invention cannot be overestimated. It was the direct forerunner of Henry Robinson Palmer’s first warehouse, except that the iron was not corrugated. Botfield, like Palmer was more than an inventor; he was dedicated to communicating new ideas to others (Guedes notes his membership of many learned societies).\textsuperscript{66} Though not proven, it is quite likely that Palmer knew of Botfield’s design, and may well have known Botfield himself.

\textsuperscript{65} Guedes, ‘Iron in Building,’ 173.
\textsuperscript{66} Guedes, ‘Iron in Building,’ 172.
Another example of early iron roof covering was designed by Elias Carter an iron manufacturer of Exeter. Unlike Botfield’s system, Carter’s roofing appears to have been produced in some quantity and examples of it still survive in situ today.
Figure 1.12: Carter’s roofing tiles at Spreyton, Devon. Photograph from Keystone Historic Buildings Consultants, 1999.

Figure 1.13. Drawing for the patent for Elias Carter’s tiles, 1827. Image from Guedes, ‘Iron in Building,’ 172.
Carter took out his patent in 1827 for ‘Covering for the Roofs of Houses and other buildings’. His system was cast iron tiles, shaped into trays with moulded edges, designed to hook over neighbouring tiles. They were large and heavy, being 2 feet square and three sixteenths of an inch thick, with two inch lips.

Figure 1.14. An example of a Carter roofing tile. This is one of the cover tiles marked ‘t’ in the patent drawing. It is noteworthy that although the tile is significantly corroded, it is still waterproof and is over 180 years old. It does not appear to ever have been painted or protected in any way. The tile belongs to Jo Cox of Keystone Historic Building Consultants. Photograph by the author.
The example in figure 1.14 was manufactured at the Toll End Foundry near Bromsgrove, and is stamped with the manufacturers name and dated 1827. Carter’s roofing tile is a metal copy (somewhat modified) of a ceramic interlocking tile. Cast iron tiles never replaced clay tiles because advances in dust pressing\textsuperscript{67} clay tiles removed any cost benefit of using iron ones.

Despite long-term lack of commercial success, there are numerous examples of Carter’s tiles found, mostly in the South West region of England. A good example is the Old Vicarage in Spreyton, Devon, where the tiles are still in use, and also on the Gloucester County Lunatic Asylum, where Carter’s tiles were used to help prevent the spread of fire. It seems possible that they were also used for the same reasons on the Devon County Pauper Lunatic Asylum in Exminster, on St Leonard’s Church, Exeter, Broadclyst Parish Church, and possibly at the house known as ‘Paul’s’ in Honiton.\textsuperscript{68} Botfield’s system was a wholly new approach to roofing problems that did not substitute iron tiles for traditional slates and tiles, and dispensed with traditional roof support structure.

1.3 Henry Robinson Palmer's Patent

1.3.1 Palmer: The Man and the Engineer

Henry Robinson Palmer invented, patented and applied corrugated iron for use in building, in an environment of increasing commerce, invention and rapidly developing iron technologies. His patent embodies the spirit of adventurous discovery – of experiment, rather than incremental substitution⁶⁹ – that characterised the output of many early professional engineers. The corrugation of iron for strengthening was already understood,⁷⁰ so Palmer's patent addressed the idea of the manufacture and the deployment⁷¹ of corrugated iron in buildings.

In 1827 Palmer was appointed as engineer on the London Dock project, when Daniel Alexander resigned his post as surveyor. Prior to his appointment at the docks, Palmer, then 32 years old, had enjoyed a brilliant career, working with Thomas Telford, and came highly recommended to the position. His role at the London Docks was to continue the work started by Rennie and Alexander.⁷²

There is little direct evidence about the personality and motives of Henry Robinson Palmer, though he most certainly had a lifelong interest in engineering, inventing and patenting. In 1823 he wrote a short book 'Description of a Railway on a new Principle' describing his monorail ideas, and then in 1829 his patent for corrugated iron. This was followed in 1831 by two papers on tides and the movement of shingle and in 1833 by a patent for improvements in the construction of arches and roofs. In 1835 he was involved in various surveys for potential railways, docks and harbours including Port

⁶⁹ See Pedro Guedes’ distinction in the history of iron between the path of ‘incremental changes’ and the path taken by inventors ‘where unprecedented answers, made possible by the properties of the new materials, were harnessed to create uniquely new distinctions.’


⁷¹ Dickinson, ‘Galvanised and Corrugated Sheet Metal,’ 27.

⁷² Herbert, Pioneers of Prefabrication, 34.

Talbot, Ipswich, Penzance, and Neath. In 1837 he wrote a patent for improvements on giving motion to barges and other vessels on canals, and in 1842 returned to the design of roofing with a patent ‘for improvements in the construction of roofs and the application of corrugated plates or sheets’.\footnote{British Library, Patent Library, Abridgements.}

His obituary refers to his apprenticeship with Bryan Donkin and Co, which ran from 1811–16 and suggests that he was particularly interested in supporting young civil engineers. It states that during this time, ‘about the year 1813–14, he organized at Bermondsey, a society of workmen, composing practically a Mechanics’ Institute,’\footnote{‘Memoir of the Late Henry Robinson Palmer, C.E., F.R.S.,’ \textit{Mechanics’ Magazine, Museum, Register, Journal, and Gazette} 42 (4 January – 28 June 1845), 140.} for young workmen to improve their skills and knowledge. By 1817 Palmer had finished his apprenticeship and began work for Thomas Telford. Keen to support learning and knowledge, particularly for young civil engineers, he became a founder member of the Institution of Civil Engineers, and in January 1818 the inaugural meeting took place. Henry Palmer gave the address, and observed that:

\begin{quote}
The Engineer is a Mediator between Philosopher and the Working Mechanic… and like an interpreter between two foreigners, must understand the language of both, hence the absolute necessity of possessing both practical and theoretical knowledge.\footnote{Garth Watson, \textit{The Civils: The Story of the Institution of Civil Engineers} (London: Thomas Telford, 1988), 9.}
\end{quote}

By defining the role of the engineer as being distinct from that of the architect (the ‘philosopher’), Palmer is accurately noting that the engineer is a new and separate entity. It also carries an implicit insight: that the art of working collaboratively with other skill bases was essential. It is this understanding, and its practical application in 1829, that made the patent of corrugated iron so successful. As Guedes stated: ‘…he was able to understand and call upon the skills of others and orchestrate their efforts at an optimum outcome.’\footnote{Guedes, ‘Iron in Building,’ 215.}
1.3.2 Palmer, Jones and Walker

As engineer for the London Dock project, Palmer did not work alone; he was supported by many skilful and talented people. Amongst others he appears to have collaborated closely with James Jones, who he met whilst working for Telford. James Jones (1790-1864) started life as a copper and tin worker near the London Docks. He was employed by both Telford and Palmer to run the engineering department of the London dock project, and had a special talent for making models of machines. He also worked with Palmer on St Katherine’s dock and Ipswich dock. He died when he fell into a vat of boiling liquid at Evans’ brewery in Oxford, where he was giving advice on the pipework.

Jones had much experience of working with sheet metal, and there is some evidence that they had known each other before Palmer began work at The London Docks, where Jones’ obituary suggests that they had become great friends:

These [machines] were completed in such a satisfactory manner as to induce a considerable intimacy between the two, then, young men, and led to Mr. Jones being eventually offered a position under Mr. Palmer, whose principal assistant he ultimately became; assisting him in several ingenious inventions, particularly in the introduction of corrugated iron, for which Mr. Palmer took out a patent.

They were both founder members of the Institution of Civil Engineers in 1818.

The productive innovation of Palmer and Jones’ cooperation went well beyond the invention of corrugated iron. Excavation of the London Dock basins involved the pioneering use of steam powered machinery, which was used to

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79 ‘Memoir of James Jones,’ 532.
80 ‘Memoir of the Late Henry Robinson Palmer, C.E., F.R.S.,’ 139.
raise excavated material and deposit it in barges. It is notable that most heavy excavation, for example in railway construction, was still being undertaken manually until the end of the nineteenth century.\textsuperscript{81} Palmer and Jones were as innovative in their approach to warehouse construction as they were to basin digging, and here they were joined by Richard Walker.

The construction of warehouses required carpenters, and from 20\textsuperscript{th} November 1827, Richard Walker, carpenter, appears in the London Dock Company’s records. Early in the following year, on 20\textsuperscript{th} January 1829 the minutes state that:

Mr. Palmer having reported that he is in want of an assistant on the works for a short time [...] it was resolved that Mr. Richard Walker be employed for a period of three months under Mr. Palmer’s direction and that he be paid for his services at the rate of four guineas a week, it being expressly understood that whilst so engaged he shall not enter into any contract or transact any business on his own account.\textsuperscript{82}

### 1.3.3 The Patent for the Use of Corrugated Iron in Buildings

This combination of technical advance in iron making and commercial necessity, together with the personalities and skills of Jones and Walker, stimulated Palmer to experiment with corrugated iron. Certainly, these three formed an ideal team; a perfect blend of skills – a carpenter, a metal worker who could make machinery, and an inventor and engineer. With the help of Jones and Walker, on the 28\textsuperscript{th} April 1829, Henry Robinson Palmer was able to patent the use of corrugated iron in building.

Palmer’s invention for ‘the use or application of fluted, indented or corrugated metallic sheets or plates to the roofs and other parts of buildings,’ was based


\textsuperscript{82} London Dock Company, \textit{Treasury Plans Valuation and Law Minute Books}, vol. 7 (1829).
on wrought iron sheet which, in itself, was not a new product. Neither was the concept of fluting sheets of metal to give extra strength. As Dickinson states, this concept was well known even in the Bronze Age,\(^3\) and would certainly have been understood by Jones, who had great experience of working with sheet metal.

However, corrugated iron for use in building was an entirely new concept. This lightweight, structurally rigid and strong material could be used as a waterproof roofing system, without the necessity of major structural support. It could also be used as a cladding system combining lightness with structural rigidity.

Palmer was fortunate to enlist the services of an experienced patent agent, William Newton, who advised him on the wording of his patent. With Newton’s help, Palmer was able to make the wording of his patent concise and clear. It reads:

My improvement... consists in the application of metallic plates or sheets, in a fluted, indented, or corrugated form, to the purposes, in relation to buildings, for which metallic plates with even or plain surfaces have been already applied. The advantage to be derived from the form or forms proposed consists in the addition of strength obtained in the metal itself, so that less aid is required from framework supporting or attached thereto to preserve the plates in their proper form and position. Various forms of the flutings, indentations, or corrugations may be adopted; but that which I prefer is the fluted or that which is composed of curved or waving lines... The fluted sheets or plates of metal may be applied to roofs of buildings, to the sides of them, to the doors, the shutters, and to partitions in the building, whether movable or stationary. The form of the flutings, and the manner of applying the fluted sheets or plates, may vary according to circumstances and the taste of those who require their use... I do not claim as my Invention any particular mode of forming the plates or sheets, as herein described, the means of producing such forms being well known; neither do I claim...any particular mode of connecting the fluted, indented, or corrugated sheets or plates

\(^3\) Dickinson, ‘Galvanised and Corrugated Sheet Metal,’ 27–36.
of metal together, or the mode of attaching them to buildings so as to form a part or parts of such buildings; but I claim .. the use or application of fluted, indented, or corrugated metallic sheets or plates to the roofs and other parts of buildings, as herein-before described.  

Figure 1.15. A copy of the original illustration from Palmer's 1829 patent for corrugated iron, which claims the use and application of 'corrugated metallic sheets to the roofs and other parts of buildings.' Note that the two pitches of the roof illustrated, are self-supporting, and have no directly reinforcing structure. Image from Guedes, 'Iron in Building,' Fig. 05-027.

The patent emphasises the rigidity of the material, and illustrates how, by overlapping, the sheets become weathertight. The illustration also shows that with framing the corrugated iron could have other structural uses, for example, as a door. In the patent drawings the roof is shown as a shallow double pitch.

84 Dickinson, 'Galvanised and Corrugated Sheet Metal,' 28.
However, when applied it to the London Dock warehouse buildings, the design is modified. Instead of flat pitches, a single curved surface is used, thereby gaining extra rigidity and simplifying the structure by removing the need for a ridge piece.\textsuperscript{85}

Henry Robinson Palmer’s vision as an inventor must have been equalled by his power of persuasion. On the 9\textsuperscript{th} June 1829, the Treasury Plans Valuation and Minute Book of the London Dock company states that the committee were presented with Palmer’s plans to incorporate his new material into the building of a new warehouse at the dock.\textsuperscript{86} By January 1830 they had agreed to back the new material, and Palmer was instructed:

\begin{quote}
to prepare a plan and estimate for the expense of erecting a shed with a patent iron roof to cover the said vaults, to protect them from moisture.\textsuperscript{87}
\end{quote}

It is known that sheet iron was bought in from the Midlands Company of Hollis Solly and corrugated and curved on site.\textsuperscript{88} It was expensive to make, costs varying from between £12/10/0 and £11/5/0 per ton.

\textsuperscript{85} Loudon, \textit{An Encyclopaedia}.  
\textsuperscript{86} Guedes, ‘Iron in Building,’ 233.  
\textsuperscript{87} London Dock Company, \textit{Treasury Plans}, vol. 7, 250.  
\textsuperscript{88} Guedes, ‘Iron in Building,’ 211.
There is no precise record of how the corrugations were made, but it is known that ‘corrugating rollers driven by the steam engine that had been employed in the excavations [of the dock] was involved.’ Pedro Guedes notes that many payments to Richard Walker are recorded for work specifically connected with corrugated iron at various times and places within the dock, and though he does not draw this conclusion, the piecemeal nature of the payments may suggest that the corrugated iron project proceeded in a very experimental way.

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As noted above, curved metal roofs had already been patented by Thomas Botfield in 1803, but Palmer’s adoption of corrugated iron sheeting meant that roof was stronger, stiffer and lighter than Botfield’s. Crucially, Palmer’s corrugations meant that much thinner metal could be used so that his design was not only lighter and stronger than Botfield’s, it was cheaper.
1.4 Making Durable Corrugated Iron Sheets

1.4.1 Iron Corrosion

The manufacture of early corrugated iron was highly experimental and was constantly pushing at the frontier of what was possible in metalworking technology. This includes the process of making the corrugated iron itself and also the process of applying a surface protection.

No other metal offers the same advantages of cost and workability of iron and steel, as the basis for corrugated iron. However, iron has the problem of corrosion, a process of deterioration, commonly known as rusting. This can be rapid and catastrophic and occurs whenever metallic iron is exposed to moisture and oxygen.\(^{91}\) Rusting converts the surface of metallic iron into iron oxide or rust. Iron is not alone in spontaneously oxidising, whilst some metals such as aluminium form an inert and waterproof oxide layer, iron does not. When iron rusts the oxide layer that is porous and permeable and offers no protection against ongoing oxidation.\(^ {92}\)

This section briefly examines the nature of corrosion itself and the strategies for its control.

In the early nineteenth century understanding of the chemistry of iron was in its infancy and processes of corrosion little understood. The hot-dip galvanizing process was not patented by the Frenchman Sorel until 1836, so at the time of Palmer's invention of corrugated iron, paint was the only viable means of protecting against corrosion despite many different systems which were experimentally adopted, such as oil, tin and lacquer.

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\(^{91}\) Walker, ‘Corrugated Iron,’ 7.

Even when good quality paint was skilfully applied, the quality of the corrugated iron sheet itself relied mainly on the factory worker and the care and skill that they applied to the job in hand. The results were variable – some corrugated iron sheets were well made, and were quite durable, whilst others were badly rusted after 10 years.93

The destructive power of iron corrosion cannot be overstated, and until effective hot-dip galvanising was introduced from the late 1830s, the durability of corrugated iron was a serious issue.

Figure 1.19. Early twentieth century wrought iron fencing showing the expansive power of iron corrosion. At the left of the picture the bolt has constrained the expansion of the two iron strips but in the centre it has been allowed to proceed unchecked. The particular significance of this corrosion is that it is occurred in an area that could not be painted i.e. the space between the two metal strips. This has always been a major problem in using paint to protect corrugated iron. Corrosion will spread from any areas that cannot be painted. Photograph by the author.

93 Evans, Building the Steam Navy, 129.
Iron, in common with all other metals, is formed of a crystal structure. Any impurities, such as carbon, or other alloying elements, take up positions within this crystal lattice. In the presence of water and oxygen, ions (charged particles detached from the iron and alloying atoms) migrate within the metal creating pits and accumulations of corrosion products.
To fully capitalise on the materials potential advantages of lightness and low-cost, corrugated iron has to be rolled thinly. Because the metal is quite thin it is much easier for corrosion to occur. Fortunately applying a layer of zinc to both surfaces of the corrugated iron inhibits the electrolytic corrosion described here, and is described in greater detail below.
1.4.2 Surface Protection

One of the earliest and most effective answers to the problem of corrosion was to coat the iron in hot-dipped tin. This process, which mostly done in South Wales, protected small items such as domestic items such as plates, boxes or toys. But the cost of tin meant that it was never realistic as a practical method of preventing corrosion for a mass material such as corrugated iron. The price of Cornish tin, at the mine head in 1837, was approximately £84 per ton.\(^{94}\)

Sheets of wrought iron needed to be cleaned to remove scale and rust before they were treated with any surface protection, either painting or galvanising. The sheet iron was put into baths of acid (pickled) – either hydrochloric (muriatic) or sulphuric – to clean the rust and scaling off. Muriatic acid was quicker (15 minutes) and was mixed to a strength of 35 Twaddle (a hydrometer measurement). The use of sulphuric acid was slower as the sheets had to be stood in water to aid cleaning, taking 24 hours at a time. The pickling with sulphuric acid was done in wooden tanks lined with lead, with the acid heated to about 90 degrees F. For hydrochloric acid stone tanks were used. The acid has less fumes than sulphuric so is more pleasant to use. After the acid bath the sheets were cleaned in a water bath and scrubbed to remove scaling.\(^{95}\)

Scaling, or mill scale is a hard layer of iron oxide that is formed when the metal is heated and then rolled hot. Most of the steel used in the modern production of corrugated iron is cold rolled, a process which produces a high quality surface that is free of mill scale. Historically however, cold rolling was not possible and the wrought iron and mild steel used in Victorian and Edwardian corrugated iron buildings was hot rolled. Although mill scale can adhere very well to the underlying metal, it is not a permanent coating and always spontaneously detaches in the long term. Thus all early successful surface


treatments for corrugated iron had first to remove it. It is hard to imagine just how unpleasant and dangerous this work must have been, and it is likely hand-pickling process introduced a considerable element of variability into the quality of galvanising.

### 1.4.3 Paint Systems

Once pickled and cleaned, early corrugated iron could be painted, but this posed numerous challenges. From a modern perspective it is hard to remember that the early Victorian paint industry was fragmented, locally-based and largely untouched by scientific development.\(^96\) Local painters were still preparing individual blends of linseed oil, pigment and lead made to the recipes of their grandfathers or those available in paint recipe book such as Jameson’s.\(^97\) Corrugated iron posed two wholly new challenges to this traditional industry. Firstly, the surface of corrugated iron was non-absorbent requiring undercoats to develop unprecedented adhesion and secondly wrought iron has a relatively high coefficient of thermal expansion\(^98\) and zinc expands and contracts even more markedly. This level of expansion required paint systems to be more flexible and elastic than had historically been necessary.

These challenges were in addition to all the standard difficulties inherent in designing a paint system. All paint systems require a primer, an undercoat and a finishing coat, all of which have quite different properties. The primer must adhere to the substrate. In the nineteenth century the most commonly used primer was red lead (Lead Oxide) which takes a long time to set but is very


durable. Also used was Iron Oxide, which is very stable, and makes a red-brown pigment but is not so durable. An undercoat gives coverage and body to the paint layer. The finishing coat protects against the elements – sunshine (especially ultraviolet light), rain and wind. Traditionally, linseed oil/lead based paints were used. It is unrealistic to suppose that locally produced paint always achieved high performance standards. It is also unrealistic to assume that local traditional painters understood the new demands presented by corrugated iron. It is thus not surprising that paint protection for corrugated iron was very rapidly replaced by galvanising as soon as that technique became available.

![Figure 1.23. An advert for Torbay paint. Image from 'Torbay Paint Co.' Grace's Guide to British Industrial History, accessed 18 August 2020, https://gracesguide.co.uk/Torbay_Paint_Co.](image)

Torbay paint, a linseed oil based paint, was recommended by James Davies in 1899 as the best system for the protection of un-galvanised corrugated iron sheets.99 The Torbay Paint Company, who made this paint, was started by entrepreneur Richard Walter Wolston. He was naturally enthusiastic about his paint and at an exhibition in 1862 claimed that:

In the year 1859, two of the iron roofs over the slips Nos. 8 and 9 in Pembroke dockyard were found on inspection to be so corroded, as in the opinion of the authorities to need entire renewal; but in lieu of this, trial was made of Wolston's Torbay Iron Paint, and two coats were applied. The result has been most satisfactory, renewal now being unnecessary, and a very considerable outlay being thereby saved to the department.100

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99 Davies, Galvanised Iron, 89.
100 Richard Walter Wolston, 'Wolston’s Torbay Iron Paints and Composition for Coating Materials Under Water,' in The International Exhibition of 1862: The Illustrated Catalogue of
The naval dockyards had much need of a system of protection from rust of the early corrugated iron roofing. Paint was applied to help remedy the persistent rusting of corrugated iron sheets at Portsmouth Docks, and also to improve the surface of the new door of the Chain Cable Store, which showed deterioration after only 10 months.\textsuperscript{101}

Bitumen is not usually regarded as a paint, but seen as a surface treatment in its own right. Traditionally it was used for coating and caulking boats (in the form of pitch, bitumen or tar), and in maritime areas this tradition was also been applied to buildings.

![Figure 1.24. Pitch applied to quayside building at Mudeford, Hampshire. Photograph by the author.](image)

The great advantage, and disadvantage of bitumen or pitch is that it never fully sets. This means that it is excellent at accommodating the high thermal expansion coefficient of corrugated iron - it happily stretches and contracts with the material - but it also sticks to everything it touches, and gradually flows

\textit{the Industrial Department, vol. 1, British Division 1,} by Anonymous (Cambridge: Cambridge University Press, 2014), 35.

\textsuperscript{101} Evans, \textit{Building the Steam Navy}, 129.
...down slopes. In order to make it usable with metals such as corrugated iron, bitumen needed the addition of lime to neutralise the acidity of the material.\textsuperscript{102}

Bitumen or pitch has proved reasonably successful in preventing corrugated iron corrosion, but its inherent ugliness and its tendency to imprint on anything that touches it has largely restricted its use to agricultural and industrial buildings.

\textsuperscript{102} Walker, ‘Corrugated Iron,’ 13.
1.4.4 The Barff System of Protection

The Victorian period saw many attempts and inventions for the protection of iron from rust. In 1877 Professor Frederick Barff developed a process of heating cleaned iron sheets to 1,200 degrees Fahrenheit in an oven and then adding super-heated steam. This created a layer of black magnetic iron oxide, which, to a certain extent, protected the iron from rusting. The process was advocated by the Times newspaper, which suggested that at some stage in the future it might be used for ‘goods of every description’ including copper cooking vessels, and also superseding lead water pipes with iron ones. However, the process is little different from the accidental formation of mill scale during hot rolling, and although the magnetic iron oxide does effectively prevent rusting it is poorly attached to the underlying metal and inevitably flakes off.

1.4.5 Galvanising Corrugated Iron

The term ‘galvanising’ describes a method of electrochemically adhering one material to another and was pioneered by the Italian physicist Galvani in 1770. It is highly effective but relatively expensive, and was not feasible for the mass production of corrugated iron. The term ‘galvanised iron’ is strictly incorrect as the method actually used was (and is) to coat the corrugated iron sheets by dipping them in a bath of hot zinc heated to about 450°C. This process was patented by a French man - Sanislas Sorel in 1837 and the process remained broadly the same till the end of the nineteenth century.

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104 'The Preservation of Iron,' 529.
105 'The Preservation of Iron,' 529.
Sorel's process:

The first process—that of coating the articles to be protected with metallic zinc—is to be effected much in the same manner in which tinning is performed: that is to say, the articles to be coated must be rendered clean and free from oxide by processes analogous to those followed in preparing them for ordinary tinning, such as immersing them in diluted sulphoric [sic] or muriatic acid, scouring them, &c which processes, being well known, need not be described. The zinc in like manner must be poured in proper crucibles or other convenient vessels adapted to the nature and size of articles to be operated upon, special care being taken to keep the metal covered with sal-ammoniac or other proper flux, and to regulate the heat in such way as is required by the volatile nature of the metal. The articles to be coated, after being dipped into the melted zinc, are to be withdrawn slowly, that too much of the metal may not adhere to them. They are then to be thrown into cold water, rubbed with a sponge or brush, and dried as quickly as possible, as otherwise they may be injured by the appearance of dark spots, which it is desirable to avoid" (Sorel, 1837).

Once dipped in zinc the iron is no longer be exposed to atmospheric moisture and oxygen, thus preventing rust formation. More importantly the zinc layer will act as a sacrificial anode and provide cathodic protection to the iron, thus preventing the formation of electrolytic corrosion pits.

**Figure 1.26.** Diagram showing how the zinc coating tends to corrode preferentially, giving up positive cations ($\text{Zn}^{2+}$). Dissolution of this sacrificial coating leaves behind electrons which concentrate in the iron, making it cathodic and thus preventing dissolution. Diagram from Stephen Lower, 'Electrochemical Corrosion', *chem1 virtual textbook*, accessed 12 August 2019, http://www.chem1.com/acad/webtext/elchem/ec-7.html.
Figure 1.27. Fredrick Braby’s Corrugated Iron Works, 1863. This image from *The Illustrated London News* will have been published because of pride in the efficient running of the system. It gives considerable insight into the process of dipping and corrugating the iron sheet but it cannot be totally accurate and appears to have some aspects of the dipping system missing, for example there is no visible mechanism for the heating of the zinc in the dipping baths. Image from *Illustrated London News* (October 1863).

1.4.6 The Early Hot Dipping Processes

Over the years many patents were taken out hoping to improve Sorel’s method. When James Davies wrote his book *Galvanised Iron* in 1899, methods were still experimental and variable. Various patents were taken out for different processes which involved different materials such as acids or fluxes used or how much rolling and heating should take place. An example is the patent taken out by Richard Heathfield in 1879 where the addition of a set of rollers in the zinc bath apparently improved the quality of the galvanising. James Davies also advocated the best way of galvanising iron which was apparently out of date by the time of Heathfield’s patent.¹⁰⁷

¹⁰⁷ Davies, *Galvanised Iron*, 57.
In the initial system of hot dipping the iron sheet, a flux (sal-ammoniac) was added to the surface of the hot zinc and kept to one side of the dipping tank with a fixed metal bar running the length of the tank. The rolled iron sheet was lowered into the tank at one side of the iron bar and brought up on the other, where the flux was floating. This appears to have prevented the hot zinc from oxidizing immediately. The sheet was gradually removed from the tank, and when the zinc had set, was put it into water to cool.

Later methods which used rollers in the zinc bath to improve the surface of the zinc coating were dipped into separate container containing the sal-ammoniac (ammonium chloride) flux.

Because hot dipping iron was largely experimental there were potentially many problems and errors and much care needed to be taken to make galvanised corrugated iron of a reasonable quality. Cost cutting of the process lead to inferior sheets. Great care needed to be taken with cleaning and dipping the iron sheet because if the sheet of iron was not cleaned properly small rust spots would appear which will eventually make holes in the surface of the metal.

All the cleaning and galvanising processes were done prior to the corrugating of the iron sheet. This is perhaps surprising because if the iron and zinc were too brittle cracking could occur, which would render the dipping process wasted. However, the iron used was wrought iron, which if well-made was malleable, and the dipped sheets may still have been hot from the dipping process, so would have increased flexibility.

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1.5 Early Production of Corrugated Wrought Iron Sheet.

Just as the nineteenth century developments in the hot-dip galvanising process were the subject of constant minor modifications and improvements, so too was the development of corrugated iron sheet manufacturing.

Henry Robinson Palmer’s 1829 patent specified the principle of using corrugated iron in building not any precise manufacturing process. When Richard Walker took over the patent there is no reliable documentary evidence on the details of his manufacturing process, but it is known that the corrugations were handmade using pairs of rollers.\(^{110}\) It is not clear how many corrugations were produced simultaneously, perhaps only one at a time, and it is likely that the hand feeding of sheets into the rollers often produced inaccuracies.

When Walker’s patent expired in 1843 many new manufacturers entered the field and began experimenting with improved production techniques. The standard rule remained that each sheet was produced individually but mechanisation appears to have been relatively rapid. Dickinson suggests that the first machinery for pressing the corrugations was made, ‘one flute at a time...’\(^{111}\) which is confirmed by John Spencer in his patent application of 1844,

> The methods hitherto employed for producing grooved or corrugated plates of iron or other metal, have been either by stamping between dies, when sheets or plates of metal are used, or by casting in a mould.\(^{112}\)

\(^{110}\) Guedes, ‘Iron in Building,’ 211.
\(^{111}\) Dickinson, ‘Galvanised and Corrugated Sheet Metal,’ 30.
\(^{112}\) Dickinson, ‘Galvanised and Corrugated Sheet Metal,’ 30.
Figure 1.28. This illustration of a press at John Thompson, that appears to be forming single corrugations. Image from ‘John Thompson,’ Grace’s Guide to British Industrial History, accessed 18 August 2020, https://www.gracesguide.co.uk/John_Thompson.

Other early entrepreneurs experimenting with the corrugating process were John Porter of Southwark, who was the first to apply galvanised corrugated iron to roofs, Morewood and Rogers in 1843, and John Spencer of the Phoenix Iron Works, who in 1844 obtained a patent for new rolling techniques which allow multiple corrugations to be formed simultaneously.

Figure 1.29. John Spencer of the Phoenix iron Works’ patent for rolling corrugated iron sheet. Image from London Journal of Arts and Sciences (1844).

\[\text{To John Spencer, agent of the Phoenix Iron Works, West Bromwich, in the county of Stafford, for improvements in manufacturing or preparing plates of iron or other metal, for roofing, and other purposes to which the same may be applicable.—[Sealed 23rd November, 1844.]}\]

This invention consists in a novel mode of manufacturing or preparing sheets or plates of metal with corrugated or grooved surfaces, and of giving to such sheets or plates of metal the required forms with greater facility and at less cost than by the processes at present in use.

The methods hitherto employed for producing grooved or

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\[113\] Thomson, ‘History and Conservation,’ 6; Herbert, Pioneers of Prefabrication, 37.

\[114\] Herbert, Pioneers of Prefabrication, 37.
From Spencer’s patent, as described in more detail in the *London Journal of Arts and Sciences*, it is possible to infer that prior to this no one had succeeded producing simultaneous multiple corrugations:

This invention consists in a novel mode of manufacturing or preparing sheets or plates of metal with corrugated or grooved surfaces, and of giving to such sheets or plates of metal the required forms with greater facility and at less cost than by the processes at present in use.

The methods hitherto employed for producing grooved or corrugated plates of iron or other metal, have been either by stamping between dies, when sheets or plates of metal are used, or by casting in a mould. The improved plan consists in passing the sheets or plates of metal, in either a warm or cold state between fluted rollers mounted in strong standards as seen in plate XV111. [image missing], where fig. 1, represents a front elevation of the rollers; and fig. 2, a transverse vertical section of the same, shewing the sheet of metal passing between the rollers in the direction of the arrow, and being delivered at the opposite side with corrugated services, corresponding to the flutes or longitudinal grooves of the rollers. The corrugated or grooved plates thus produced, may be employed either for constructing rooves or other parts of buildings, or for the various purposes to which such plates are, or may be, considered applicable.\(^{115}\)

It is difficult to visualise how Spencer’s system worked exactly, but it may well have been similar to modern rolling systems where the central corrugations are produced first, allowing the overall width of the sheet to diminish without stretching. This is repeated by pairs of rollers placed progressively closer to the edges of the sheet.

By 1845 Morewood and Rogers had developed a system of feeding the sheet iron, long edge first, into pairs of rollers fluted along their length.\(^{116}\) The benefit of this was that the sheet decreased in width one corrugation at a time, without being stretched, which put less stress on the metal.

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\(^{115}\) *London Journal of Arts, Sciences and Manufactures and Repertory of Patent Inventions.*

\(^{116}\) Dickinson, ‘Galvanised and Corrugated Sheet Metal,’ 30.
Stretching was not the only problem; wear and tear of the dies could also cause irregularly sized corrugations where a one-sixteenth of an inch variation in pitch made a half-inch variation in the overall size of the sheet. This gave problems when fitting to buildings and could make a 25 inch variation over a whole roof.117

James Davies, commenting on the process in 1899 suggests that the process of making corrugations was, ‘…not so easy as it appears, [...] The chief requisite is confidence, and alertness necessary to prevent the fingers from being corrugated in addition to the sheet iron.’118 He also notes that sheets of 22 and 24 wg119 were pressed in pairs, 26 and 28 wg was pressed in threes and the thicker sheets, individually.

Figure 1.30. Fluted rollers at Lysaghts’ Australian factory in 1939, similar in concept to those pioneered by Morewood and Rogers in 1845. Image from John Lysaght Ltd Pty, Lysaght’s Referee: A Handbook of Useful Information, 17th ed. (Sydney: Websdale, Shoesmith Pty Ltd., 1939), 102–03.

118 Davies, Galvanised Iron, 51.
119 ‘wg’ is an abbreviation for wire gauge which had become a standardised measure for wire and sheet metal by the later part of the nineteenth century. The higher the number, the thinner the sheet.
1.6 The Components of Corrugated Iron Sheet

1.6.1 Corrugated Steel

With the development of steel towards the end of the nineteenth century, it became possible for corrugated iron to be mass produced on a hitherto unprecedented scale.

Steel is an alloy of iron and other materials, most commonly carbon. Different grades of steel have widely varying carbon contents and often include other metallic alloying elements. Steel existed in the ancient world and was certainly being produced by medieval sword makers, but judging whether the 1% carbon content required to make good steel had been attained was very difficult. Consistent steel was not reliably achieved until both Bessemer and Siemens independently pioneered processes for removing all the carbon and then deliberately adding back the required amount. After the innovations of Bessemer and Siemens, the steel produced became a much more consistent product, and could be rolled and corrugated much more reliably.

The mass production of mild steel at the end of the nineteenth century made it possible to manufacture corrugated iron buildings on an unprecedented scale. Most of the corrugated iron buildings that survive today are made of steel and this makes surviving examples of wrought iron based corrugated iron rare and culturally significant as they represent a material produced by traditional craft-based techniques.

The development of mass-produced steel enabled the cheap mass production of corrugated iron. This profoundly changed the perception of corrugated iron as a culturally significant material. Mass production ensured that this strong, versatile and cheap material was used in every area of life, from giant airship

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120 Gale, *British Iron and Steel Industry*, 95.
121 Gale, *British Iron and Steel Industry*, 90.
hangers to Anderson shelters. The proliferation of corrugated iron buildings meant they became anonymous – so common that they were unnoticed, reviled and ignored.

1.6.2 Sizes of Corrugations

The general principle of making sheet iron rigid by forming corrugations did not immediately lend itself to standardisation. For many years after its invention there was no standard size for either the size of the sheets or the corrugations; both were variable according to each individual manufacturer.

However, by the end of the nineteenth century most of the major British manufacturers of corrugated iron such as Braby, Lysaght, Hemmings, Gospel Oak and George Adams and Sons,\textsuperscript{122} had standardised the size of sheets. However, as Bruce Walker notes, smaller manufacturers continued to produce non-standard sheet and corrugation sizes.\textsuperscript{123} The size of the sheets remained variable and could be bought in 4 foot to 10 foot lengths, and sometimes 12 foot lengths.\textsuperscript{124}

Improvements in rolling mills enabled the reliable production of thinner sheet iron of different gauges and by the late nineteenth century sheet thickness had become standardised at between 1.2mm and 1.6mm.\textsuperscript{125} The thickness of the sheets was generally given in Birmingham Wire Gauge (BWG) and the sheet iron for corrugating was usually between 16 and 26 were, 26 being the thinner.\textsuperscript{126} According to Ewing Matheson, writing in 1873, the 22 gauge and 26 gauge was exported to the colonies.\textsuperscript{127} The adoption of mass produced steel allowed thinner sheets to be produced and standardised at between 0.42mm to 0.8mm.

\textsuperscript{122} Davies, \textit{Galvanised Iron}, 54.
\textsuperscript{123} Walker, ‘Corrugated Iron,’ 23.
\textsuperscript{124} Walker, ‘Corrugated Iron,’ 21.
\textsuperscript{125} Warr, ‘Corrugated Iron – Options for Repair,’ 4.
\textsuperscript{126} Thomson, ‘History and Conservation,’ 9.
\textsuperscript{127} Ewing Matheson, \textit{Works in Iron: Bridge and Roof Structures} (London: Spon, 1877), 214.
Even after increased standardisation, different pitch sizes and profiles continued to be commonly available. The pitch is the distance from ridge to ridge of the corrugations, and commonly varied from one inch up to nine and a half inches.\textsuperscript{128} For example, the pitch of the corrugated iron on the Balmoral Ballroom is 5 inches.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1_31.png}
\caption{\textit{Left}, 5-inch pitch corrugated iron at the Balmoral ballroom. Note that the corrugations run horizontally, a design feature unique to ET Bellhouse. Photograph by the author.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1_32.png}
\caption{\textit{Right}, Heather Lodge, Kinbrace, showing a recently replaced roof covering using a non-standardised asymmetric angular profile corrugated iron typical of applications on modern industrial buildings. The walls retain the standardised 3-inch pitch sinusoidal profile. Photograph by the author.}
\end{figure}

\textsuperscript{128} Thomson, ‘History and Conservation,’ 9.
The sinusoidal profile most commonly adopted from the earliest manufacture of corrugated iron has a deceptive appearance of standardisation. It was not till the twentieth century that the pitch was generally standardised to 3 inches,¹²⁹ with a depth ¾ inch from the top of the ridge to the bottom of the valley.¹³⁰ This is the size most commonly seen on standard corrugated iron buildings today but the ‘profiled metal’ used for modern industrial architecture is produced in a very wide range of pitches and profiles with little standardisation. This illustration from Braby’s catalogue, thought to date from the 1930s gives an indication of the variety made possible by modern rolling techniques:

Figure 1.34. Different corrugated iron profiles from Braby's catalogue. Image from Walker, 'Corrugated Iron,' 22.
1.6.3 Fixing for Corrugated Iron Buildings

Corrugated iron sheets need to be supported by a frame and fixed in place. Davies and Matheson, both writing at the end of the nineteenth century, give a list of the fixings that can be used with corrugated iron. They both agree that they should be galvanised.\textsuperscript{131} This is particularly important because fixings made from a material different from the galvanised sheets are likely to generate rapid electrolytic corrosion.

The illustration from A & J Main’s catalogue (figure 1.35) shows the range of simple fixings that have remained more or less standard since the mechanised manufacture of screws, bolts, nuts and nails became commonplace in the late eighteenth century.\textsuperscript{132}

\textbf{Figure 1.35.} From A & J Main’s catalogue, showing the different sizes of corrugated sheet iron and the variety of fixings available for buildings.

\textsuperscript{131} Davies, \textit{Galvanised Iron}, 111; Matheson, \textit{Works in Iron}, 216.

\textsuperscript{132} Mechanisation of screw production was pioneered by the Wyatt brothers from 1760 to 1780, but underwent many technical improvements during the nineteenth century. See Witold Rybczynski, \textit{One Good Turn: A Natural History of the Screwdriver and the Screw}, (New York: Scribner, 2000).
Applying fixings to hold corrugated sheets to structural framing needs some skill, but the difficulty lining up ready-made holes for fixing the corrugated iron onto the framing can be avoided if the holes are punched in situ.  

1.6.4 Framing for Corrugated Iron Buildings

From the moment in 1829 when Henry Robinson Palmer gave his patent for corrugated iron to Richard Walker it was an experimental and evolving product. Walker exploited this and was quick to realise the potential of corrugated iron as a cladding for prefabricated buildings. These were mostly based on pre-cut timber frame kits, supplied ready to assemble on-site. No site carpentry was needed, and jointing was done with the simplest of nailed butt-joints.

Figure 1.36. Components of a framing kit for an iron church at the Weald and Downland Open Air Museum. This timber is not packaged as it would have been for original delivery. It has been dismantled and is awaiting re-erection. Photograph by the author.

133 Matheson, Works in Iron, 216.
Figure 1.37. An example of the simple carpentry used in the corrugated iron framing kits. The lapped half-joint shown here was typically used on long structural elements such as wall and sill plates to avoid the transport of overly long components. The timber on the right is a replacement added as part of the repairs done to the church at the Weald and Downland. Photograph by the author.

Figure 1.38. More complex joints, like this junction of wall to rafter, were all factory produced and only required fixing with nails on site. This is another detail from the re-erection of the iron church. Photograph by the author.
Just as the effective deployment of corrugated iron depended on the mass production of standardised fixings, it also depended on the introduction of mechanised sawing of timber. The softwood framing and lining of nineteenth century prefabricated corrugated iron buildings could only be produced economically by mechanisation of the conversion process.\(^{134}\) A crucial development here was the development of an effective bandsaw by the French woman Anne Paulin Crepin in 1846.\(^{135}\)

Not all corrugated iron buildings were timber framed. Where the insides of the building were at least partially open to the weather, or by a large roof spans were required, metal framing was used. Until the introduction of cheap steel this was usually formed in wrought iron.\(^{136}\)

Tongue and grooved match board lining for domestic corrugated iron buildings was almost universal. As with timber framing its economic viability depended on the mechanisation of sawing and planing.

Figure 1.39. Left, the softwood board interior of St Fillan’s Church, Killin. Right, the tin chapel at the Weald and Downland under repair. Here the new insulation was Tyvek boarding, but traditionally it would have been felt. Photograph by the author.


The air gap between match board internal findings and the corrugated iron shell was sometimes insulated with a layer of felt. An example of this is the South Wonston Chapel that has been reconstructed at the Weald and Downland Living Museum.

Figure 1.40. *Left*, remains of felt insulation adhering to the frame of the chapel at the Weald and Downland. *Right*, a label from the Chapel for insulating felt, discovered amongst the frame timbers during rebuilding.

Installing insulating felt was a significant design innovation. It may well have reduced condensation problems and made corrugated iron buildings easier to heat, but it also have increased the risks of dampness by restricting airflow between the lining and the outer skin.

Tin tabernacles and commercial corrugated iron buildings such as cafes sometimes had sophisticated stencilled decoration on their match board interiors, though survivals of this feature are vanishingly rare.

Although we have good evidence of the completed output from corrugated iron building manufacturers some of the detail of commercial design remains elusive. A prime source of information on manufacturing techniques might be expected to be manufacturers own catalogues, but these are remarkably hard to find. As Bruce Walker comments:
Unfortunately it is impossible to check all the manufacturers’ catalogues of the period, [...]. This is partly due to the low survival rate and partly to the reluctance of many holding institutions or individuals to lend or copy.\textsuperscript{137}

Bruce Walker’s experience of this reluctance has been shared by this research, and there is clearly scope for further research on how prefabricated building kits were manufactured and how the manufacturer’s instructions were adapted on site.

1.7 Conclusion

Almost continuous technical innovation from the seventeenth century onwards made the production of cast and wrought iron both economically viable and more plentiful. The mass use of iron in buildings, for both structure and decoration, became possible.

However, technical developments were only one feature of the eighteenth and nineteenth centuries. Britain developed a culture of innovation and entrepreneurship that challenged traditional established practices of design and procurement in the building industry. Specifically for corrugated iron, not only did technical innovation make the manufacture of the material possible, it placed it into the hands of newly empowered engineers and fabricators.\textsuperscript{138} Traditionally trained architects of the time had neither the knowledge nor the understanding to play a significant part in the design of iron work in buildings. It was the work of figures such as Richard Walker, who designed the Eastern Counties railway terminus, and, of the outstandingly innovative naval engineering architects, Colonel GT Greene and William Scamp who created the great naval slips at Chatham docks. These and many other engineers and

\textsuperscript{137} Walker, ‘Corrugated Iron,’ 21.

\textsuperscript{138} Guedes, ‘Iron in Building,’ 304.
fabricators felt free of the restraints of architectural convention and worked towards a new architectural vocabulary for iron.

Thus the vastly increased use of structural iron during the nineteenth century was accompanied by a widening division between architects and engineers. This division provided fertile ground for critics and commentators such as AWN Pugin and John Ruskin to lament the new challenge to the traditional vocabulary of architects.\(^{139}\)

Newspapers, magazines and journals such as *The Builder* were filled with opinions of those keen to share in this new technology and architecture. Corrugated iron also stimulated significant public interest, characterised by early enthusiasm for its novelty, but this rapidly progressed to indifference based on familiarity. The new architecture of corrugated iron and the perceptions, opinions and reactions given to it will be explored in the next chapter.

\(^{139}\) Miles Lewis, ‘The Corrugated Iron Aesthetic,’ 49.
Chapter 2: The Acceptance of Corrugated Iron into New Building Technologies

2.0 Introduction

Acceptance of iron as a legitimate material for building went through phases of early-unqualified optimism to guarded scepticism as a result of unqualified disasters. In the main, builders, unfettered by aesthetic inhibitions, were opportunistic and pragmatic. They learnt to absorb the new material where it clearly offered advantages. Architects, particularly in Britain, went in the opposite direction, becoming progressively more coy at embracing the possibilities offered by iron.\textsuperscript{140}

In 1829 the patenting and early development of corrugated iron does not appear to have generated a hostile reaction, and early opinions of the material were universally favourable. It was an exciting new concept created in an age when innovation was seen as supremely praiseworthy. The late Georgian period was in love with new engineering and architecturally aware commentators, in newspapers and journals such as Loudon’s encyclopaedia, welcomed the new material of corrugated iron and saw it as a solution to many traditional building problems.\textsuperscript{141}

By the middle of the nineteenth century the many difficulties of working with this new material had become apparent. Difficulties with making corrugated iron, construction faults in the buildings and the problems with temperature control as well as design issues all contributed to the relegation of corrugated iron to the role of utilitarian material to be used and never seen. Not till the twentieth century, in remote locations did corrugated iron develop an acceptable vocabulary in architecture.

\textsuperscript{140} Guedes, ‘Iron in Building,’ ii.
\textsuperscript{141} Loudon, \textit{An Encyclopaedia}.
This chapter describes the integration of corrugated iron into new building technologies, the physical, aesthetic and moral problems they created throughout that time. The chapter also explores how the problems of negative associations and assumptions of impermanence were created for corrugated iron in building.

2.1 The Acceptance of Corrugated Iron in Architecture

2.1.1 New Buildings for New Uses

Corrugated iron was one challenging development amongst many that demanded new cultural responses. The factors that influenced reactions to corrugated iron were diverse and interconnected, but often inconsistent. In the nineteenth century, the development of railways, rapid growth of the navy, and universal education all encouraged the development of new buildings, for new uses. There was no precedent for the styles and materials that were required – this created new opportunities for designers and makers, particularly fabricators, engineers and architects. It also resulted in dynamic opportunities for the role of corrugated iron.

2.1.2 Technical Innovations and New Materials

When Palmer patented corrugated iron in 1829, the process of industrialisation was well underway. Although picturesque, Arcadian ideals were well-established and remained the foundation of the elite cultural values of wealthy land owners, there were many in early Victorian society who saw the new industry and its associated buildings as culturally significant. A newly literate\textsuperscript{142}

\textsuperscript{142} Adams, \textit{The Prometheans}, 4.
and increasingly self-confident middle class saw progress through invention and technical advance. This desire for new knowledge began to be fulfilled by improved communication. The development of the railway system meant that news of innovation could be promulgated more widely and rapidly than ever before. Newspapers and journals, hitherto restricted to local circulation, now had national availability. Just as important was the establishment of specialist learned societies, such as the Institution of Civil Engineers, a body set up to promote, in Thomas Tredgold’s words, ‘the general advancement of mechanical science, and more particularly for promoting the acquisition of that species of knowledge which constitutes the profession of a Civil Engineer’. This spread news of technical innovation by journals and lectures effectively.

The increasing self-confidence and thirst for knowledge and innovation shown by the early nineteenth century middle class was matched by growing political confidence in the exploitation of the British Empire. A major driver of colonial activity was the hunger for raw materials and new markets for industrial output. Public awareness of this reinforced new attitudes towards the cultural significance of technical innovation. The Great Exhibition in 1851 was attended by six million people – about a third of the population of England at that time. This provides strong evidence that the public saw evidence of the link between technical innovation and their personal prosperity, and thus accorded innovation enhanced cultural significance. The innovative appeal of the corrugated iron turpentine warehouse at the London Dock in 1830 resonated with all those who understood the economics of their age. It was a direct response to mercantile demands for improved warehousing; but, more

importantly, it was also a physical manifestation of an educated middle class’s cultural valuation of technical innovation. Where the new wealth was being created, as noted by George Herbert,\textsuperscript{148} new materials were seen as exciting and valuable.

2.2 Public Reactions to Early Corrugated Iron Buildings

The mass production of iron in the nineteenth century raised many questions regarding how the material could be included into the language of architecture. Should it form part of the structure of buildings, and should it contribute to their decorative ornamentation? Running alongside this was a search for an architecture that reflected the spirit of the age. What style would reflect the nineteenth century; and was it appropriate that iron, in its many forms, be considered a key part of that zeitgeist?

In the ten years after corrugated iron buildings were first constructed, they were reported as a miraculous innovation – a strong new material that could cover a wide span roof without the need for a substantial structure to support it. The bright metal with, as yet, no opportunity for rust and deterioration was hailed as miraculous invention that would be used in permanent buildings. Eight years later, in 1837, the patenting of the hot zinc dip process by Stanislas Sorel further propagated the idea that galvanised corrugated iron was a material with a very long life. As yet it had no negative associations.

\textsuperscript{148} Herbert, \textit{Pioneers of Prefabrication}, 2.
2.2.1 Reactions to Richard Walker’s Turpentine Warehouse

The development of the London Docks was highly public, and sightseeing trips for the general public were regularly organised, with guidebooks printed. As noted above, such tourism often involved sampling the wines stored in the newly constructed vaults. Unsurprisingly, the new corrugated iron roofs attracted considerable professional interest. For example, George Herbert was moved to write, as editor of the ‘Register of Arts and Sciences’ that Palmer had designed an ‘extraordinary light and simple roof:

EXTRAORDINARY LIGHT AND SIMPLE ROOF.

On passing through the London docks a short time ago, we were much gratified in meeting, among the numerous important works going forward there, with a practical application of Mr Palmer’s newly-invented roofing, which was briefly described in our monthly report of new patents for August, 1829. This singular roof, supported by light cast iron pillars, forms a shed on one side of the basin near Wapping Church, and covers an area of about 4000 feet. Every observing person on passing by it, cannot fail being struck (considering it is a shed) with its elegance and simplicity, and a little reflection will we think, convince them of its effectiveness and economy. It is, we should think, the lightest and strongest roof (for its weight), that has been constructed by man, since the days of Adam. The total thickness of this said roof, appeared to us from a close inspection (and we climbed over sundry casks of sticky turpentine for that purpose,) to be, certainly not more, than a tenth of an inch! although stretching over a space of about 18 feet, by a slightly curved arch. It is composed wholly of malleable iron plates or sheets, about 2 feet wide and five feet long; and each plate is bent, as to form a series of uniform undulations, producing thereby, alternate grooves and ridges longitudinally, (corresponding somewhat with the figure of the ordinary earthen pantiles) which serve as watercourses for the rain. This grooving, or as we might say arching and counter arching,

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150 George Herbert, ‘Register of Arts and Sciences’ (London, 1830), 5:153–54.
confers great strength to resist the longitudinal and vertical pressure to which roofs are subjected. Every plate appears also to be slightly arched in the transverse direction, and as they afterwards form a portion of the curved line of the roof, a shell-like stiffness is given to the plates, which enables them to resist a greater force than they would be able with plane surfaces, were they several times their present thickness. It is also worthy; of observation, that the inconvenience usually resulting from the expansion and contraction of such extended surfaces of metal by variations of temperature, is, by Mr Palmer's arrangement of the grooves and arches in opposite directions, in a great measure, if not entirely, obviated.

Four of the plates we have described (5 feet by 2 feet) are riveted together end to end, and the united length of these (20 feet) forms the curve of the roof; these 20 feet pieces, like so many ribs, are next riveted together laterally the whole length of the roof, which is about 200 feet. Parallel to this line, and connected to it at the back, is another range of similar roofing, differing only in the form of the arch, to take advantage of the support afforded by the brick wall of an adjoining warehouse. To prevent leakage, a cement is applied between the plates where they are riveted together, and the rain is carried off by cast iron gutters, which receive the edges of the arched roof plates, the gutters being supported by a series of light cast iron pillars about 18 feet apart, to which they are connected by ornamental cast-iron brackets, adapted to that purpose. The gutters therefore connect the pillars together at the top in one direction, and the tie-rods are employed to connect them transversely, or at right angles to the former.\textsuperscript{151}

From an engineer’s perspective Herbert’s words are high praise: an often-cited mantra of the engineering profession runs, ‘when in doubt, add lightness and simplify.’\textsuperscript{152} The lightness was hugely important because it facilitated large clear spans without the need for elaborate structural support, and the simplicity meant that the design was easy to replicate and transfer to other types of building.

\begin{footnotesize}
\begin{enumerate}
\item[\textsuperscript{151}] Herbert, ‘Register of Arts and Sciences,’ 5:153–54.
\item[\textsuperscript{152}] Keith Wilkinson (chartered mechanical and civil engineer), interview by author, July 2015.
\end{enumerate}
\end{footnotesize}
2.2.2 The Early Commercial Development of Corrugated Iron

In 1832 Walker took out a full page advert in Robson’s London Directory, which was seen by John Claudius Loudon. Loudon was always keen to publish the latest building inventions in his *Encyclopaedia* which contained over a thousand pages and two thousand illustrations, and was published in 1833. Loudon’s treatment of corrugated iron in his *Encyclopaedia* reveals his enthusiasm for the material. There is a flattering mention in the introduction, which notes that corrugated iron aimed to ‘improve the dwellings of the great mass of society.’ He develops this with a three-page article on the new architecture of the London Dock development which is particularly enthusiastic about Palmer’s new corrugated iron turpentine warehouse. Loudon’s general excitement for the use of corrugated iron and its future development is shown in the text of the article:

> a still larger span, say 200 feet, a tie-rod might be combined with a trussed iron beam... by which roof of this span, or even one of more than double the extent, might be covered without a single rafter appearing inside. In short, no material hitherto brought into notice at all approaches this, in its capacities of forming light and economical roofs of the greatest extent of span, and with the least loss of interior room.

Loudon also uses some of the illustrations from an advertisement by the then patent holder Walker, to elaborate the text, and his enthusiastic comment on the turpentine warehouse and the possibilities of corrugated iron was widely disseminated. The Mechanics Magazine reviewed Loudon’s encyclopaedia and picked out the article on corrugated iron as being of ‘outstanding interest.’

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Richard Walker must have been a man with a good eye for an opportunity as he used corrugated iron to build many forms of structures. In 1839 he supplied the corrugated iron for the Eastern Counties Railway terminus which required a very large span roof. 155

2.2.3 The Eastern Counties Railway Station

Although Richard Walker had worked for and with Palmer on the London Dock development, they appear to have had very different interests. Walker seems to have been an entrepreneur as immediately he received the patent, he began to successfully manufacture corrugated iron buildings on a profit-making basis, the first being the turpentine shed at the London Dock. His business acumen certainly extended into effective marketing and advertising and for the next 13 years Richard Walker was the sole owner of the patent for using corrugated iron sheet.

During those 13 years Walker went on to construct many buildings from corrugated iron including the Eastern Counties Railway Station at Shoreditch, the London Gaslight Company’s gasworks at Battersea, 156 and in the 1840s the corrugated iron for Price’s Candle Factory, which covered an area of three acres in Battersea. 157 He also exported many corrugated iron houses and warehouses to Australia and America and the rest of the world. 158

155 Mornement and Holloway, Corrugated Iron, 13.
156 Mornement and Holloway, Corrugated Iron, 13.
157 Mornement and Holloway, Corrugated Iron, 14.
158 Herbert, Pioneers of Prefabrication, 47.
The design for the Eastern Counties Railway Terminus was very similar to the warehouses at the London Docks; it had three parallel rows of vaults and was a considerable size, being 230 feet in length.\textsuperscript{159} The corrugated iron covered the entire roof:

The corrugated iron is bolted to flanges running the whole length of these gutters. The columns are cast in two parts, the upper being let 3 feet into the lower part, Pieces are cast on the columns to let into the girders and panelling, thus, in connecting the columns with the girders, panelling and gutters, no bolts whatever are used.\textsuperscript{160}


\textsuperscript{160} Evill, ‘Description of the Iron Shed,’ 289.
The new station roof proved very popular, and a reported in *The Builder* by *A Constant Reader* on 16th November 1843:

During the period of great depression in the price of iron, I am surprised that no one has turned their attention to manufacture corrugated iron roofing, like the most beautiful roof at the Eastern Counties Railway, Shoreditch, excelled no-where in elegance, lightness and simplicity. [...] I hope some of your readers will consider and extend such a beautiful and useful method of using sheet iron, and thereby render roofing cheaper than ever; if galvanised it will be everlasting.\(^{161}\)

Walker did not restrict his buildings to Britain. From an early date he had been exporting prefabricated corrugated iron buildings to Australia, noting its, ‘economy, durability, lightness and strength,’\(^{162}\) and, as stated by Herbert were, 'valued as much for their security against theft as for the protection they offered against the weather.'\(^{163}\)

Because Walker had the monopoly of the patent, he was able to charge as much as he liked for his corrugated iron buildings, even when, as stated above, the price of iron was low:

This manufacture was patented by Mr. Palmer, in April 1829, which patent expired in April 1843, but from the enormous price of £5. to £7. per square of 100 feet, weighing about 3 cwt., and having no rafters requisite, it gained no custom, whilst the price of such 3 cwt. iron was only 15s. or 20s. per 100 feet: a profit of 400 per cent being charged for rolling the like.\(^{164}\)

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\(^{163}\) Herbert, *Pioneers of Prefabrication*, 40.

\(^{164}\) *A Constant Reader*, ‘Corrugated Iron Roofing and Doors,’ 511.
When Walker's patent expired in 1843, the potential of corrugated iron was not lost on the building fabricators and engineers of Victorian Britain. Iron production, and hence corrugated iron production, increased dramatically; with further improvements in the manufacturing process, such as galvanising, corrugated iron became more reliable, universally available and increasingly cheap. The scale and variety of buildings created by the innovative engineers and corrugated iron manufacturers at this time was astounding. Nothing was impossible.

2.3 The New Architectural Vocabulary of Iron

2.3.1 The Commentators of the ‘Truthfulness’ of Iron in Construction

In the nineteenth century, imperial expansion and increasing wealth and industry within Britain resulted in an environment which required a new form of architecture to reflect the spirit of the age. This elicited much scholarly debate over which architectural forms were appropriate, particularly among architects who had learned their skills by studying past architectural styles, and cultural critics of buildings such as John Ruskin. As iron was increasingly used for structural parts of buildings it was inevitable that its use in architecture became a key part of this scholarly debate. The perception of iron and corrugated iron in architecture is in part rooted in these early discussions. It is thus important to consider their significance in more detail now.

The first third of the nineteenth century, with the spirit of the Enlightenment, was an age of adventure, risk taking, and was open to more exciting forms of architecture.\textsuperscript{166} As discussed earlier, George Herbert’s ‘Extraordinary Light and Simple Roof’ is supported by inclusion in Loudon’s encyclopaedia in 1833 and in 1833, using Loudon’s illustrations, the Mechanics Magazine wrote of corrugated iron as being an item of ‘outstanding interest.’\textsuperscript{167} By 1841 the early enthusiasm for iron as a material fit for inclusion in architecture was being debated. The inclusion of iron was not the only issue. Generally the architectural debate became moralising and a concept of \textit{truthfulness} in architecture, which according to French architect Viollet le Duc meant, ‘stone appear really as stone, iron as iron and wood as wood,’\textsuperscript{168} was discussed, with iron one of the key points.

In his book \textit{Contrasts} written in 1836,\textsuperscript{169} AWN Pugin aims to show that the architecture of the time reflects the state of society, and suggests that, ‘We have shoddy buildings because we have shoddy souls.’ He claims that, in order to improve the state of what he perceived as moral deterioration in society, it was necessary to revive the Gothic style of architecture and so ‘return to the faith and the social structures of the Middle Ages’ – a style which was, by default, exemplary. At the foundation of these ideals, he argued that architecture should be honest. Perhaps unsurprisingly, he considered the inclusion of iron in the vocabulary of architecture debatable, and considered it dishonest:

\begin{flushleft}
\textsuperscript{166} Guedes, ‘Iron in Building,’ 308.
\textsuperscript{169} A. W. N. Pugin, \textit{Contrasts: Or, A Parallel Between the Noble Edifices of the Middle Ages, and Corresponding Buildings of the Present Day, Shewing the Present Decay of Taste} (London: published by the author, 1836).
\end{flushleft}
Cast-iron is a deception; it is seldom or never left as iron. It is disguised by paint, either as stone, wood or marble. This is a mere trick, and the severity of Christian or Pointed Architecture is utterly opposed to all deception: better is it to do a little substantially and consistently with truth than to produce a great big false show…¹⁷⁰

Pugin had a considerable impact on the opinions of later commentators. The Ecclesiological Society began in 1838 and was initially called the Cambridge Camden Society. It was a club set up for undergraduates who were interested in promoting a vision of church architecture advocating the implementation of thirteenth century Gothic style. Like Pugin, they believed that piety of the middle ages could be restored to nineteenth century society by the application of the correct form of architecture – that of the thirteenth century.

Figure 2.2 Slater’s iron church, as published in Instrumenta Ecclesiastica (1856).

Their publication *The Ecclesiologist* advised on the design of both the liturgical organisation of the church alongside the church furnishings. They debated the use of iron in churches and in 1856 published drawings for an iron church with corrugated iron cladding, designed by architect William Slater, in *Instrumenta Ecclesiastica*. The aim was to demonstrate to builders that it might be possible to design a church that, whilst made from iron, was not completely utilitarian (as in the designs of Samuel Hemmings in Bristol). It would also be also *truthful*, not hiding the ironwork behind a stone façade. The corrugated iron cladding did not appear to be a problem, being perceived as *honest*. Their booklet stated that:

> Our drawings show that the framework of this design is of iron. The columns, instead of being cast iron imitations of stone forms are composed of four detached rods bound together by a spiral band.

Clearly the Ecclesiologists had an open mind as to the inclusion of iron, and even corrugated iron in churches.

Iron ornament in churches was not the only difficulty. From the 1830s, because of mass production, iron became plentiful enough to be considered for use as a structural element. Eventually the use of hidden structural ironwork became commonplace in the vocabulary of Victorian architects. In Barry’s design for the Houses of Parliament, Pugin’s Gothic stone decoration was supported on an iron frame. George Gilbert Scott also displayed a willingness to use corrugated iron as a hidden structural material. His work at the Midland hotel at St Pancras station is a good example of this innovation, where corrugated iron was used as permanent formwork for the cast concrete floors. The concept

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of *truthfulness* was less of a concern than the success of the structure of the building.

![Figure 2.3: A view of the underside of one of the Midland Hotel concrete floors, showing corrugated iron used as permanent formwork. Photograph from PAYE Stonework.](image)

John Ruskin and William Morris of the Society for the Protection of Ancient Buildings (SPAB) were major promoters of the Gothic revival. Ruskin was particularly vociferous in this regard – his publications and lectures on the nature of architecture were widely known and well respected, and he used these platforms to express his profound dislike of the use of iron, particularly cast iron, in architecture. Of particular importance is his book, *The Seven Lamps of Architecture*. In The Lamp of Truth, Ruskin states that:
No ornaments, on the contrary, are so cold, clumsy, and vulgar, so essentially incapable of a fine line, or shadow, as those of cast iron [...] there is no hope of the progress of the arts of any nation which indulges in these vulgar and cheap substitutes for real decoration.\footnote{173}

For Ruskin, the inclusion of iron in a building implied deceit, and again in ‘The Lamp of Truth’ he goes on to comment that: ‘But the moment that the iron in the least degree takes the place of stone…the building ceases, so far as such applications of metal extend, to be true architecture.’\footnote{174}

Both men promoted a form of nineteenth century intellectual romanticism which emphasised the dignity of craftsmanship and rejected mass-produced materials, rather than the uses and aesthetics of iron. Both saw mass-produced materials as symbolic of the evils of Victorian society. Ruskin does not single out corrugated iron for discussion, but Morris, writing in his pamphlet for the SPAB in 1890, felt that corrugated iron buildings ‘were spreading like a pestilence over the country.’\footnote{175} Fortunately this dislike of corrugated iron promoted by the Society did not continue. In more recent times the SPAB has been supportive of the use of corrugated iron, particularly when used to protect deteriorating thatched roofs. For Ruskin, the innovative and economic attractions of corrugated iron did nothing to enhance its cultural significance. Such was their vehemence and eloquence that both Ruskin and Morris have had a profound, enduring impact on perceptions of corrugated iron and its cultural significance.

\footnote{173}{John Ruskin, \textit{The Seven Lamps of Architecture} (Orpington and London: George Allen, 1889), 56–57.}
\footnote{174}{Ruskin, \textit{The Seven Lamps of Architecture}, 41.}
\footnote{175}{Mornement and Holloway, \textit{Corrugated Iron}, 30.}
Figure 2.4 Henton Chapel, Chiltern Open Air Museum. A typical Victorian chapel with Gothic detailing; the windows, door and roof details are of a design approved by the Ecclesiological Society.

2.3.2 The Crystal Palace and Oxford History Museum

Iron, and even corrugated iron can be used in buildings both structurally and decoratively. How to include this new material in the architecture of the nineteenth century was much debated by architects and academic critics, all of whom had difficulty with the concept of including iron in their building designs. The engineers, however, whose main concern was the structure of the building, had no such qualms about the inclusion of iron. Andrew Saint, discussing the integrity of architecture observes that:
The need to make a building firm, sound or whole is as old as architectural theory. Indeed it is older, since the stone blocks, timber posts, mud walls and thatched roofs of the different ancient architectures were always the ultimate determinants of the way in which they were designed. ...in the end the properties of available materials, together with man's ingenuity in extending them, have always done the most to shape buildings.\footnote{Saint, Architect and Engineer, 2.}

The success of the Crystal palace depended not just on the decorative qualities of the ornament, but on the largely prefabricated structure built with iron that dictated the design of the building. The achievement of the building of the Crystal Palace, designed to serve an unprecedented urgent need for an exhibition space which had to be constructed in nine months, was brought about by innovative engineering and collaboration. It was made possible by the modular design of the building, using iron as one of the key components. This would have been almost impossible to realise with traditional building materials and techniques.
The 1851 Exhibition to be held in Hyde Park, had been inspired by the French Industrial Exposition held in 1844 which demonstrated the products of French industry. It required a vast exhibition hall to display the achievements of the industrial revolution in Britain, so a competition for the buildings design was set up. This was overseen by a committee of architects, but none of the entries received was considered appropriate. Horticulturalist and glasshouse designer Joseph Paxton sketched an idea for a modular design for the exhibition space and quickly visited Charles Fox, an engineer with much experience in railway engineering, to discuss how it could practically be made in practice. Fox discussed the design with Henry Cole, assistant record keeper at the Public Record Office, who helped him make improvements in accordance with the regulations of the competition.

Figure 2.6. The Crystal Palace on its original site in Hyde Park with the arched transept designed by Charles Barry. At the close of the Great Exhibition in 1851, the Crystal Palace was dismantled and moved to a new site at Sydenham, where it remained until it was destroyed by fire in 1936. Image from ‘North Transept, Great Exhibition’, in John Tallis, *Tallis’s History and Description of the Crystal Palace, and the Exhibition of the World’s Industry in 1851* (London and New York: Tallis, 1852).
Finally, with an achievable working design, the architects and designers added the elements that raised from a shed like structure to architecture. Many other contributors were involved in this massive project, including the glass makers, Chance Brothers of Birmingham, Charles Barry, architect, who added the vaulted transept to Paxton’s design and the architects and designers who were part of the committee whose role it was to oversee the project.

The Crystal Palace was important for promoting the use of iron in building to the general public. Nearly every day an article would appear in the newspapers which discussed the project in great detail. Just days before the grand opening, *The Illustrated London News* reported that:

> The fairy-like but substantial structure, itself the greatest and noblest work of art and manufacture which the Exhibition has called forth, is completed, and challenges the admiration of daily crowds, many of whom, perhaps, will have no opportunity of entering within its portals.\(^{177}\)

It also happened over a very short period of time, which helped to retain the excitement of the new building concept. The whole project was very successful, with 6 million visitors to the site over the time of the exhibition. In the public eye the Crystal palace associated iron with success.

Use of iron in buildings did more than create new architectural possibilities: it changed the culture of the Victorian building industry by creating a new role for engineers and contactors.

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‘The Crystal Palace brought together architects, engineers and industrialists some who had previously worked with each other while also creating the opportunity for long lasting professional relationships to develop.’

As the nineteenth century progressed, the purely functional role of iron as an engineering material within buildings continued and developed, but with an increasing expression of iron in a decorative role.

The Natural History Museum in Oxford, built in 1855, is a striking early form of the intentional expression of iron as both structure and decoration and is an interesting example of how the new material of mass produced iron could be incorporated and displayed in a modern design. Here, a Gothic design mixed two materials, glass and iron, to create a secular cathedral dedicated to the modern science of the Victorian Age.

Figure 2.7. Oxford Natural History Museum. A cathedral to the natural sciences created in the Gothic style despite the use of modern material -- glass and iron. Using these materials shows a sense of adventure, even when they were used only in the interior; the exterior was traditional stonework. Photograph by the author.

The technical success of the Crystal Palace, together with its public popularity, caused iron, cast, wrought and corrugated, to start being used in a wealth of building types. Although still much discussed for its role in ‘polite’ architecture, it was readily accepted into new building types such as railway termini and naval dockyards. These buildings were functional, innovative and had no precedent.

The introduction of standardised and mass-produced building components – again the Crystal Palace is a spectacular example – not only created a new class of engineer designers, but also gave a prime role to contractors and fabricators. The iron used in the turpentine shed or the Crystal Palace not only required new engineering design skills, it also challenged the frontiers of material production. Thus, the new engineers had to develop a close relationship with the manufacturers supplying these experimental new materials. Use of iron in buildings did more than create new architectural possibilities: it changed the culture of the Victorian building industry by creating a new role for engineers and contactors.

This collaboration between designers, engineers/fabricators and architects who created the Crystal Palace and the Oxford Natural History Museum, won instant respect and admiration from the public and, amongst professionals, began a change in attitudes towards mechanised building.

Neither the invention of corrugated iron nor much of its early application involved traditional architects. Palmer the engineer, Walker the carpenter and James Jones the mechanic and expert in sheet metals, worked together to develop the concept of corrugated iron for building, as well as to make possible its manufacture and installation. The turpentine warehouse at the London Docks made from corrugated iron, was the practical result of this fusion of experimental skills and economics.
The key commentators Pugin, the Ecclesiologists, Ruskin and Morris were some of the most vociferous critics of any material innovation that had connection with industrialisation. Each had a profound effect on nineteenth century public perceptions of the cultural significance of corrugated iron. Consequently, the designers and builders of corrugated iron churches responded to the nineteenth century desire for the use of Gothic architecture and the tin tabernacle was born. In the early twenty-first century, it is the one form of corrugated iron architecture that receives universal acclaim.

In short, there was no simple single Victorian \textit{zeitgeist}: their enthusiasm for innovation was always matched, and sometimes exceeded, by their nostalgic romanticism. On the one hand, nostalgic craving for an idealised past meant that Ruskin and Morris’ rejection of new materials and techniques was highly influential, and became the foundation of the Arts and Crafts Movement. On the other, the Crystal Palace, and the Oxford Natural History Museum beloved by the newly educated middle class, depended entirely on new materials and mass production techniques. Amongst these perspectives, there was no general agreement on what constituted a culturally significant building. These debates had a major impact on the cultural significance associated with all building materials, both old and new.\(^{179}\)

The spectacular success of the Crystal Palace and the Oxford Natural History Museum is relevant to the development of corrugated iron because it improved public perceptions of the cultural significance of new building materials and techniques. However, the Crystal Palace did not itself utilise corrugated iron, but the new Victoria and Albert Museum did, and provoked a very different public reaction.

2.4 Prefabricated Buildings Using Corrugated Iron

2.4.1 The Development of Prefabricated Buildings

The practical deployment of corrugated iron as a building material broadly divides into two areas. Firstly, it allowed the development of the semi-self-supporting roof, where the rigidity of curved corrugated iron roof panels allowed completely new designs to emerge. These included warehouses, farm and military buildings. Secondly, corrugated iron enabled the rapid development of factory produced prefabricated buildings. When used in this way, corrugated iron was integrated into composite structures relying on wood or metal for increased stiffness. These were often prefabricated into sections that were assembled on site.

Corrugated iron was invented as a response to rapidly changing socio-economic conditions and these changes prompted engineers and fabricators to adopt and experiment with the new material. This experiment resulted in marked changes in both the scale and number of revolutionary buildings.

Prefabricated corrugated iron buildings were attractive because they were quick to build, were movable and provided utilitarian but effective accommodation. Colonial demand was so great that a new industry was established in Britain specifically to manufacture corrugated iron buildings, manufactured by companies like Speirs and Co, Samuel Hemming of Bristol or Francis Morton and Co. of Liverpool. Industrial manufacture meant that corrugated iron buildings were unlike any previous form of building. They were not just collections of compatible materials; they were designed and manufactured as a system. Each prefabricated building was shipped complete with all the components needed for the finished structure. In contrast, an
individual house brick is a manufactured and prefabricated building component, but it is not part of a systematised building kit.\textsuperscript{180}

Once the industry producing corrugated iron buildings was established, it naturally sought all the available markets for its products. Many corrugated iron buildings were not exported to the colonies but were erected on home soil. The advantages of adaptability and flexible reusability held true both at home and abroad.

Perhaps the most spectacular examples of how the scale and diversity of Victorian architecture was extended by corrugated iron were the roofs of the naval dockyard covered slips designed by Colonel Godfrey Greene and William Scamp. This naval application was paralleled by the use of corrugated iron in the roofs of railway termini. These new designs were highly experimental but as the nineteenth century progressed and the twentieth century began, techniques for producing and using corrugated iron became established. This lowered the cost of production and triggered new inventiveness on the part of designers.\textsuperscript{181}

The facilitation of new designs using corrugated iron was part of a wider process that redefined the roles of architects, engineers and fabricators within the building industry. The new possibilities created by using iron in architecture meant that engineers and fabricators became key parts of the design team, often eclipsing the role of architects.

Above all, it was the socio-economic changes of the nineteenth and twentieth centuries that drove the demand for lightweight, transportable and cheap prefabricated buildings that established corrugated iron as a mainstream building material.

\textsuperscript{180} Herbert, \textit{Pioneers of Prefabrication}, 30.
\textsuperscript{181} Evans, \textit{Building the Steam Navy}, 127.
One of the social phenomena that characterised the Victorian age was mass emigration to America and the colonies of the British Empire.\textsuperscript{182} This produced an acute demand for instant accommodation in the newly settled areas. Corrugated iron was highly successful in meeting this demand. It was strong and light and most significantly, and was ideally suited to the creation of prefabricated buildings. Very large numbers of prefabricated corrugated iron buildings were supplied to colonists in Australia, Africa and India, and notably to miners and gold seekers in America. All types of buildings were created including housing, hospitals and warehousing. Many manufacturers supplied this demand amongst which were Lysaght’s of Bristol and Gospel Oak from Wolverhampton.\textsuperscript{183}

Prefabrication is an approach to building in which the maximum amount of work is done in controlled conditions away from the construction site itself. At its most effective, prefabrication dramatically reduces weather dependency and accelerates the overall building timetable.

One of the key drivers of increased use of prefabricated buildings was colonial expansion. Overseas activities stemming from the development of the British Empire included war, mining, exploration and settlement. Each of these created acute shortages of local housing in environments where traditional building skills and materials were almost wholly lacking.\textsuperscript{184}

Prefabrication was the lifesaver for many of the new inhabitants of British colonies. It allowed the adventurers, pioneer settlers and entrepreneurs who built the empire to survive and succeed in often hostile conditions. As quoted in Loudon, John Manning when discussing his portable cottages, stated:

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\textsuperscript{182} Herbert, \textit{Pioneers of Prefabrication}, 12.
\textsuperscript{183} Herbert, \textit{Pioneers of Prefabrication}, 144.
\textsuperscript{184} Mornement and Holloway, \textit{Corrugated Iron}, 30.
These cottages were found to be of the greatest service to settlers, both in protecting their families from the weather, and their property from theft. Many persons who took out only tents, suffered severely in both respects; their tents being frequently blown down in the middle of a stormy night, and their goods being thus not only exposed to the weather, but also pilfering. Provided with a cottage of this description, an emigrant might land from a ship in a new country in the morning, and sleep in his own house on shore at night. Whoever can use a common bed-wrench can put this cottage up; and as none of the pieces are heavier than a man or a boy could easily carry for several miles, it might be taken even to a distance, without the aid of any beast of burden.\textsuperscript{185}

Prefabrication greatly reduced the need for skilled site labour. By using prefabricated building kits, the self-build construction of simple houses, churches and other buildings, became possible for semi-skilled owners and users. This made it possible to provide shelter for new immigrants and congregations where previously construction costs had been prohibitive.

This evolution in building technology marked a significant change in the culture of architectural supervision. Prefabricated buildings no longer required skilled architectural design on site and instead created a new breed of skilled architectural engineers.

By no means all these prefabricated buildings used corrugated iron.\textsuperscript{186} Many early examples were constructed completely from timber, and more exotic experimental buildings using zinc sheeting, cast-iron and even papier-mâché were tried. As quoted earlier, the pioneering design for portable housing was the Manning \textit{Portable Colonial Cottage}.

\textsuperscript{185} Loudon, \textit{An Encyclopaedia}, 256.
\textsuperscript{186} Herbert, \textit{Pioneers of Prefabrication}, 3.
The principle object of the portable cottage is, to supply emigrants with comfortable and secure lodgings on their arrival at a foreign settlement.187

John Manning, a builder and carpenter from London, designed a cottage 1833 specifically with easy transportation in mind. None of its components was too heavy for a single man to lift, and each prefabricated component required no further work on site once it had been erected. Though it did not utilise corrugated iron, Manning’s cottage embraced the concept of standardisation, where individual components were made to standard dimensions with all corresponding parts ‘the same length, breadth and thickness.’188 In 1837, Manning was advertising in the South Australian Record,189 a newspaper which was also published in London. There is a Manning cottage still in existence in Adelaide, being used as a Friends Meeting house.

Figure 2.8. The Friends Meeting House, Adelaide – a Manning house. Photograph by Bahudhara © Wikimedia Commons / CC-BY-SA-3.0

187 Loudon, An Encyclopaedia, 251.
189 Herbert, Pioneers of Prefabrication, 14.
Manning also designed furniture, which could also be packed—one item inside another—to save space when being shipped abroad. Unfortunately, Manning’s cottages suffered from a lack of insulation, which together with low ceilings, gave a poor circulation of air in hot weather. Manning was not alone in designing portable housing and other building types. Competition was provided by the designs of Peter Thomson, which were not prefabricated but were better insulated. Both Manning and Thomson used traditional materials such as timber.

2.4.2 Prefabricated Corrugated Iron Buildings

When corrugated iron started to be manufactured in 1829 it rapidly became obvious that it was a material that could be relatively easily be incorporated into a prefabricated building system. Corrugated iron enabled the standardised replication needed. In the words of Gilbert Herbert:

Corrugated iron was considered a material whose strength, portability, impermeability to water, invulnerability to termites, and presumed resistance to fire, gave promise of a shaving and roofing system infinitely superior to wood. It was a material moreover entirely consonant with the spirit of the times, for if it lacked the fruity richness of cast-iron, it nevertheless reflected that other attribute of the Victorian era, the quality of stern utility.

At the same time that Manning and Thomson were building prefabricated timber housing, Richard Walker had acquired the patent for corrugated iron from Henry Robinson Palmer. Walker had set about pioneering the manufacture of the application of corrugated iron as a key component of prefabricated buildings; from 1837 he was advertising the sale of a variety of portable buildings in the South Australian Record.

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190 Herbert, Pioneers of Prefabrication, 22.
191 Herbert, Pioneers of Prefabrication, 32
192 Herbert, Pioneers of Prefabrication, 40.
As soon as Richard Walker’s 14-year patent for corrugated iron expired in 1843, and his tight grip of ownership of the manufacture of the materials and associated buildings was relinquished, there were opportunities for the development of the material, both in design and manufacture. New ways of making corrugated iron were developed, speeding up production and inventiveness of design. For example, as discussed earlier in 1844, John Spencer, of the Phoenix Ironworks in Birmingham, developed and patented a more efficient way of making corrugated iron sheets.

By 1840, John Walker (Richard Walker’s son) was manufacturing prefabricated houses to be exported to San Francisco, where the gold rush had created a demand for temporary buildings. His design used the concept of the semi-self-supporting structurally curved roof, as conceived in Palmer’s original design. This became a generic design and was used in many types of corrugated iron building at that time.

By the mid-1850s, manufacturers began to export abroad such as Charles D Young, Edwin Maw and Samuel Hemming.

Corrugated-iron buildings, which at first were not necessarily galvanised, came also from C.D. Young, but more commonly from Samuel Hemming’s giant factory at Bedminster, Bristol (houses, churches and shops), from E.T. Bellhouse of Manchester, whose patent cast-iron stanchions were shaped to fit the corrugations (houses, warehouses and G.S. Coppin’s Olympic Theatre), from Francis Morton of Liverpool and London (especially schools), from G.H. Porter of Birmingham (schools and industrial buildings), and from Edwin Maw of Liverpool (classically pilastered churches and warehouses).¹⁹³

Many other small-scale manufacturers appear to have been active at this time in the export market. One of the main drivers of this activity was the Australian gold rush, which lasted from 1851 to 1854, and drew in substantial numbers of settlers. Such was the scale of this emigration that more iron buildings were exported to Australia than ever before or since.\textsuperscript{194} An indirect consequence of the scale of these exports was that Australia developed its own corrugated iron manufacturing industry and by 1856 was able to rely on the domestic manufacture of corrugated iron buildings.

The design of prefabricated buildings did not remain simple. Manning’s original design was soon superseded by a rich variety of styles. John Walker advertised houses of many different sizes, ranging from £40 two room cottages to mansions costing £5000.\textsuperscript{195} Samuel Hemming’s buildings were even more elaborate and intricately designed. Not just houses but shops, rows of shops and hotels featured in catalogues designed to show the range of possibilities offered by corrugated iron prefabricated buildings.

The colonial experience of corrugated iron was generally satisfactory. It provided good accommodation in difficult circumstances and although there were some voices which demanded traditional good taste even in frontier architecture, utility triumphed over traditional aesthetic appeal.

\textsuperscript{194} Lewis, ‘Prefabrication’.
\textsuperscript{195} Herbert, \textit{Pioneers of Prefabrication}, 58.
2.4.3 Prefabricated Corrugated Iron Churches

Figure 2.9. Adeline Dance Hall in Boscombe, Bournemouth. One of the first churches to be built in Bournemouth. Prefabrication does not just allow easy and rapid first assembly; it also permits cost-effective dismantling and re-erection. The Adeline Dance Hall, built in 1875 and initially called St George in the Wood, is a good example. It was created as a response to Boscombe and Bournemouth’s sudden growth in population, and further extended in 1882 by incorporating an iron chapel imported from Notting Hill, London. A stone church was subsequently built, and the tin chapel became a Masonic Lodge, then a dance hall, with all the accompanying decorative features. Photograph by the author.

The social and economic changes that characterise the nineteenth century extended well beyond industrialisation issues. Urbanisation and population growth created immense social stress and led to profound changes in religious observance. In England, urbanisation outstripped the provision of church buildings in the newly growing cities. This created an urgent need for new church buildings which could be rapidly deployed. Urbanisation also occurred in Scotland, but at the same time, the growth of non-conformism produced an
extra demand on church buildings which led directly to the increased use of tin tabernacles. For example, many of the corrugated iron churches in the Scottish Highlands belong to the United Free Church; the United Free Church being formed by a combination of the Free Church and the United Presbyterians in 1900. The ‘United Frees’ had to build their own new churches when their main buildings were relinquished to the larger congregations of the Free Church.\footnote{Campbell, ‘The Prefabricated Churches of the Highlands,’ 4.}

Certainly one of the most remarkable examples of the adaptability of corrugated iron churches was the floating church at Strontian on Loch Sunart, which solved one of the problems faced by the growth of non-conformist congregations. Here, the local laird refused to allow the Free Church to build on his land and the congregation was forced to meet by the side of the loch. Inclement weather made such open-air meetings intolerable and in 1843; it was decided to build a church onto a barge moored in the loch. The local people were delighted to have such a versatile building

How gladly the people left the storm-beaten hillside for this strange Highland Church of the sea, need not be said. It was a singular spectacle on each returning Sabbath morning, as the hour of public worship drew near, to see the boats coasting along from North and South, each with its contingent of hearers, while numerous groups could be descried far inland, wending their way down from the hills to where the floating church lay moored.\footnote{W. J. Seaton, ‘The Floating Church, at Strontian, Ardnamurchan, Argyll-Shire,’ The Wicket Gate Magazine, February 1972, accessed 24 September 2017, http://www.wicketgate.co.uk/issue85/e85_1.html.}

The floating church cost £1400 and survived till 1860, when a storm arose and the church broke its moorings and capsized.\footnote{Seaton, ‘The Floating Church’.
Nor was the need for new churches confined to Britain. Missionary activity and emigration to the colonies further stimulated the demand for new and rapidly deployable churches.

The emigration stimulated by the Australian gold rush in the 1850s also created a demand for new churches. For example, Samuel Hemming of Bedminster in Bristol made six corrugated iron churches for export to different towns in Australia. These churches differed in size and design, with at least one said to have been of a classical design. It is a mark of Hemming’s attention to the quality of his buildings that all were pre-erected in Britain before export.

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199 Herbert, Pioneers of Prefabrication, 99.
200 Herbert, Pioneers of Prefabrication, 112.
Initially, corrugated iron churches, made solely to fulfil an urgent need for new buildings, were functional, utilitarian designs. Where architectural decoration was introduced, this appears to have been most often in a classical or Italianate style. However, such styling does not appear to have proved popular, so Victorian taste in corrugated iron church design rapidly adopted a more ecclesiologcal or high church Gothic style, following the influence of the Ecclesiologcal society and of the architect Pugin. As discussed earlier. Tin tabernacles rapidly came to be decorated with Gothic details; we now think of tin tabernacles of being wholly of that style, due to the survival of this design rather than a classical one.

Most early corrugated iron churches were built and designed by the fabricators, who were already working in the iron trade, rather than by specialist architects. The lack of input into the design of corrugated iron churches by specialist architects is exemplified by fabricators, Francis Morton.
and Co. of Liverpool. From 1863, they began designing and manufacturing complete corrugated iron churches without third-party architectural supervision, even though their expressed aim was to produce tin churches as comfortable and beautiful as stone ones.

Although tin tabernacles are the defining image of corrugated iron in the current public consciousness, they are far from forming the bulk of corrugated deployment. It is little short of astounding how much corrugated iron was used for industrial buildings from the smallest workshop to the largest factory. Prefabricated Dutch barns are still an integral part of farming architecture, as is the replacement of thatched roofs with corrugated sheeting.

Delivery of these buildings was easily and effectively achieved from the manufacturing centres such as Glasgow, Liverpool, London, Birmingham and Bristol by means of the rapidly expanding railway system. It is no exaggeration to say that the success of prefabricated corrugated iron buildings in Britain was completely dependent on cost-effective distribution by railway. Distribution to the colonies was equally dependent on the development of steam shipping.

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201 Only one of the two books devoted entirely to corrugated iron discusses tin tabernacles (Smith, *Tin Tabernacles: Corrugated Iron Mission Halls, Churches and Chapels of Britain*).
Manufacturers of corrugated iron buildings, such as William Cooper, realised the difficulty posed by the entrenched conservatism of Victorian romantics and began adding Gothic details to tin tabernacles, which greatly increased their popularity.\textsuperscript{202} It is not without some irony that medieval Gothic detailing became the publicly appealing face of corrugated iron architecture, and has indeed remained so. Tin tabernacles are now the stuff of coffee-table books about corrugated iron and are even seen as charming and picturesque.\textsuperscript{203}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.12.png}
\caption{A corrugated iron chapel from William Cooper's catalogue, designed in the Gothic style.}
\end{figure}

\textsuperscript{202} Cooper, \textit{Gardeners' and Poultry Keepers' Guide}.
\textsuperscript{203} Smith, \textit{Tin Tabernacles}.
2.5 Corrugated Iron as a Structural Building Material

2.5.1 Agricultural Corrugated Iron Buildings

Since it was patented in 1829 corrugated iron has been used for many purposes in agriculture. As early as 1833, its virtues in the construction of farm buildings are extolled by Loudon in his *Encyclopaedia of Cottage, Farm and Villa Architecture*:

> In short, no material hitherto brought into notice at all approaches this, in its capacities for forming light and economical roofs of the greatest extent of span, and with the least loss of interior room. Its durability will depend on the application of oil or tar paints: for barns, sheep-houses, and various other country buildings, and for all manner of sheds, both in town and country, it is particularly suitable.  

Despite Loudon’s enthusiasm, the incorporation of corrugated iron into agriculture was slow at first. However, by the 1880s it had become an essential addition to ‘modern’ farm practice. In *Stephens Book of the Farm*, a standard reference work for farming in the nineteenth century, a corrugated iron ‘Dutch barn’ was illustrated. The Dutch barn was used for storing hay, which would traditionally been done by making haystacks or hayricks. Roy Brigden states that:

> …emphasis was now laid on cheapness and convenience so that iron –or timber – framed dutch barns were a popular new feature of farmsteads as they provided good storage for hay and corn without the time and trouble necessary to build thatch ricks.

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204 Loudon, *An Encyclopaedia*, 207.
205 Prichard, ‘Corrugated Iron Farm Buildings,’ 23.

Farmers in the nineteenth century were able to take advantage of corrugated iron as a strong and lightweight roofing material. The covered yard, developed in the 1850s and used to provide shelter for cattle and making manure, was often built using corrugated iron in the 1880s.
Shepherd’s hut

Figure 2.15. Shepherd’s Hut, a versatile shed on wheels that could be moved from pasture to pasture. This particular structure was in a garden in Dorset. Photograph by the author.
The versatility of corrugated iron sheeting was utilized to the full in the farm and there was almost no building type or structure that it could not be put to. Below is a Richmond’s Corn Rack, using a corrugated iron roof.

Figure 2.16. Richmond’s Corn Rack, a four-post structure with a corrugated iron roof which could be raised and lowered as necessary. Originally designed to dry sheaves of corn or hay which were stretched between the posts. This building at Bridgerule in Devon was used for storing logs. Left photograph by the author (June 2015). Right image from Stephen’s Book of the Farm (1889).

However, the use of corrugated iron on the farm was not always considered a success. Corrosion was a particular problem. Despite the process of galvanising, corrugated iron still suffered from deterioration because of rusting, and it remained necessary to paint the buildings on a regular basis. J. B. Denton, writing in the Journal of the Royal Agricultural Society of England in 1861 stated that sheet iron is incapable to roof farm buildings, but ‘it may be advantageously adopted in situations free from damp and vapour, and where durability is not of the first importance.’

Also in the Journal of the Royal Agricultural Society, Philip Tuckett, land agent and surveyor observed that:

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207 Prichard, 'Corrugated Iron Farm Buildings,' 25.
…the coating of zinc which the iron receives in this process is scarcely ever so pure and uniform as to secure this result, and unless pretty frequently painted or otherwise coated (an inconvenient and expensive liability) the iron is very liable to rust through in a few years, producing leaks, which involve constant trouble and cost in repairing.  

Despite ongoing concerns with the use of corrugated iron in agriculture, it became an enduring feature of farms and has integrated successfully into the aesthetic of British agriculture. Peter Beacham, writing about Devon farm buildings suggests that:

Although indisputably a newer arrival in the family of traditional farm buildings this is a structure that seems comfortably settled into the farm cluster. Its modest scale relates well to older ranges and can even mitigate the impact of much larger twentieth century buildings by providing a transition in a scale and materials between the vernacular and the contemporary.  

By the end of the nineteenth century catalogues specialising in selling a vast variety of building types were used to publicise the virtues of corrugated iron. All farm and agricultural buildings were available in this way, such as Cooper's The Gardeners' and Poultry Keepers' Guide and Illustrated Catalogue, or A. and J. Main's catalogue of Galvanised Iron Roofing and Shedding, which was published in 1884. Both had a large section put over to agricultural buildings as well as other corrugated iron buildings.

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209 Peter Beacham and James Ravilious, Down the Deep Lanes, 2nd ed. (Oxford: Bardwell, 2008), 83.
2.5.2 Railway Architecture

The newly developing Victorian railway companies were quick to understand the potential of corrugated iron. Initially, it was used as a structural component in the large span roofs at several mainline terminal stations.

Richard Walker, who had exclusive rights over the use and manufacture of corrugated iron until 1843, was able to supply and build the London terminus of the Eastern Counties Railway station in 1839,\textsuperscript{210} which was sited where the Northern and Eastern railways met. The roof was designed in a similar way to the Palmer warehouses at the London dock, with three barrel-vaulted corrugated iron roofs on cast iron columns. It was also huge, covering 17,000 square feet, all built without structural framing such as purlins and rafters.\textsuperscript{211}

Possibly the most well-known use of corrugated iron in a mainline railway station roof is Brunel’s design at Paddington station in London. Brunel, always aware of the latest inventions, was not slow to see the potential of corrugated

\textsuperscript{210} Mornement and Holloway, \textit{Corrugated Iron}, 13.
\textsuperscript{211} Mornement and Holloway, \textit{Corrugated Iron}, 13.
iron. In 1844, working with Tupper and Carr, he set up a galvanised iron company a year after the patent held by Sorel had expired.

Aware of the structural integrity of corrugated iron, he used it as part of the roofing structure in the Paddington terminal. Typically innovative and creative, Brunel laid ‘the corrugations at right angles to the slope of the roof, thus providing integral bracing for the roof trusses and greatly stiffening the whole structure.\(^{212}\) By doing this, he was able to eliminate a whole layer of structure. As noted by Mornement and Holloway:

> Paddington is remarkable for having no purlins (longitudinal beams to support the rafters) or, indeed, tie rods, helping to create the soaring and uncluttered atmosphere inside the station.\(^ {213}\)

Brunel’s roof had three barrel vaults, the centre being 102 feet and 6 inches in span, flanked by two of over 68 feet, creating a roof covering of 180,000 square feet.

Not only was Brunel a gifted engineer, he was also an adept publicist. Almost all his designs for engineering structures attracted extensive public interest. However, it is not possible to claim that Brunel’s use of corrugated iron at Paddington enhanced the public reputation of the material to any significant extent. The lack of public commentary specifically related to the corrugated iron elements in the roof of the train shed suggest that it was the overall design that captured the public imagination and not the inclusion of corrugated iron.

At Liverpool Lime Street Station in 1850, Richard Turner, together with Joseph Locke and Richard Fairbairn, used corrugated iron to construct a clear span of 153 feet. Four years later, in 1854, Birmingham New Street Station was built for a consortium of five rail companies. Designed and constructed by Fox,

\(^{212}\) Mornement and Holloway, *Corrugated Iron*, 19.

Henderson (and later EA Cowper), the corrugated iron canopy had an even larger clear span than Liverpool Lime Street at 212 feet.

Smaller scale but no less innovative, applications of corrugated iron in station canopies along the London and South-Western Railway Company mainline also failed to generate major public interest.

Railway applications in general do not seem to have greatly influenced public attitudes towards corrugated iron. Perhaps because everything about the railways was quintessentially new and experimental, the public mind did not apply traditional tastes and expectations of architectural form. In other words, the new Victorian railway system was so obviously irreconcilable with the picturesque notions of Ruskin or Morris, but simultaneously so undeniably useful, that the public simply suspended architectural criticism.

2.5.3 Naval Architecture

At the same time as the indifference to the use of corrugated iron in the new railway architecture, the Admiralty was enthusiastically making use of it in the innovative and creative application to the covered slips of the naval dockyards. Because of the massive expansion and modernisation of the naval bases, the Naval architects and engineers were able to successfully use this opportunity to exploit the structural qualities of corrugated iron in their new buildings.
The Navy adopted corrugated iron for the roofs of its covered slips and other buildings, without any consideration of aesthetics or the need to embrace public opinion. There was a simple, practical need for a strong, lightweight, cladding material to cover the construction slipways on which new, larger, ships were being built, and other buildings. Naval opinions of corrugated iron were founded solely on the practical, applied success of the material in fulfilling a specific engineering task.

As with the London Dock thirty years earlier, the naval shipyards of the 1860s were centres of great innovation. Military designers were not restricted by any civilian obsession with style and taste; for them, form needed to follow function. Naval dockyards were a private world, perfect for experimentation with iron in all its forms, and the navy exploited this privacy to solve new engineering problems. Wrought, cast and corrugated iron were tested and pushed as far as possible to create bigger roofs with lighter cladding.

The combination of engineering necessity and freedom from the restrictions of public taste not only encouraged the Navy to use new materials, it also encouraged new methods of design and construction. As Neil Cossons explains in the introduction to ‘Building the Steam Navy’ by David Evans,
In the eighteenth and nineteenth centuries the Royal naval dockyards were amongst the largest manufacturing complexes in Europe, a direct consequence of the Royal Navy’s role not only as Britain’s first line of defence but as the means of protecting and promoting her world imperial power.\textsuperscript{214}

Well before the nineteenth century, the navy had long recognised the efficiency gains of roofing the slipways used to construct warships but the increasing size of nineteenth century warships demanded exceptionally large roofs that presented new challenges.

The first covered slips, built before 1814, were made from timber framing clad with wood or tarred canvas. Later designs used slate, copper or zinc\textsuperscript{215} roofs; but they suffered badly from rot and presented a fire hazard because candles were used to light the interior space. In addition to these intrinsic problems, restricted imports of timber during the 1840s induced the Admiralty, in 1842, to initiate iron slip roof construction. Just as significant was the building of the first steam driven warship in 1822. The revolutionary technology of the new ships that followed demanded a new approach to all aspects of naval dockyard design. New metalworking shops and specialised buildings such as coal stores were needed. Iron construction allowed the new ships to be bigger, and bigger ships meant the need for bigger slipways to build them on.

Between 1844 and 1857, the Navy invested heavily in dockyard expansion and eighteen widespan iron slipway roofs were erected across five dockyards during this time.\textsuperscript{216} The first were constructed at Pembroke dock by Fox, Henderson in 1843; it was the largest iron roof ever made at the time of construction. A design not taken up by the Admiralty was by a GM Palmer

\textsuperscript{214} Evans, \textit{Building the Steam Navy}, 7.
\textsuperscript{216} Hawkins, Butler, and Skelton, ‘The Iron Slip Cover Roofs’.
done in the Gothic style, which might have made a significant impact on slip designs if it had been take up. It was not accepted as a good design but ‘might be tried on a smaller scale.’ It also incorporated the use of corrugated iron as a roofing material.

This work was collaborative, with engineers, architects and fabricators all bringing their own specialism to the new experiment. Using Royal Engineers, the Navy had, by 1837, developed substantial in-house iron engineering expertise. Particularly notable was the partnership between Colonel GT Greene and William Scamp. Colonel GT Greene (1807-86) worked as the Director of Engineering and Architectural Works for the British Admiralty between 1850–64, and was responsible for the factory, smithy, foundry, shipfitting shop, and boat-store at Sheerness, Kent in 1856. William Scamp (1801-1872) was a civil engineer and became Greene’s chief assistant. He eventually

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217 Evans, Building the Steam Navy, 59.
became the Deputy Director of Engineering and Architectural Works in the Admiralty, and was responsible for extensive improvements to many major naval dockyards.

Together they made a significant impact, as noted by Evans:

Greene was to design several notable buildings, continuing the use of iron as a constructional medium, while Scamp’s great achievement was in rational factory and yard planning. As a team they made the 1850s the most significant decade in creating buildings for the Steam Navy.  

From the start, Scamp and Greene used corrugated iron as an integral material within their designs. Particularly interesting was the Keyham (Plymouth) steam factory, *The Quadrangle*, built in 1855 to house steam driven machinery for many purposes; a large building which is still standing. As Evans says:

… the Steam Factories in the 1850s were well-equipped multifunctional centres of expertise. Many of the buildings themselves demonstrated the engineering lead of Great Britain.  

It was a particularly useful design because of its versatility in terms of housing different ‘shops’. Corrugated iron was an integral part of the overall design in the form of corrugated iron partitioning, which could be removed or added if needed.

At Portsmouth in 1851, Greene designed a great Smithery. This building was ‘a massive iron framed structure’ clad with corrugated iron, and significant because it was designed to be permanent rather than temporary.

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220 Evans, *Building the Steam Navy*, 90.
221 Evans, *Building the Steam Navy*, 12.
222 Evans, *Building the Steam Navy*, 104.
The close working relationship between the Royal Yards and civilian manufacturers and engineers... underpinned Britain’s lead in so many aspects of industrial technology. 223

The Royal Engineers produced the design brief, but fabricators and leading contractors such as George Baker and Sons of Lambeth, a family of contractors,224 Fox, Henderson, or Grissell’s of the Regents Canal basin, designed the details and were in charge of construction. These contractors were carefully chosen, having expertise in the manufacture of iron as well as their skills in building – skills which complemented those of the engineers. Fox, Henderson, George Baker and Son and Grissell’s did not so much work for Scamp and Greene, but with them as partners.225

Fox-Henderson’s ran businesses in London and Birmingham. Sir Charles Fox was an English civil engineer and contractor known especially for his work on the construction of the building for the Great Exhibition. His work focused on railways, railway stations and bridges.

Henry Grissell – sometimes known as *Iron Henry* - and his brother Martin De La Garde Grissell, ran a business as iron-founders and contractors, and were based at the Regent’s Canal Ironworks in London.226 Henry Grissell had an extensive knowledge of iron making and had worked with major engineers such as Stephenson and Cubbitt. The Grissell’s work for the Admiralty is particularly interesting as an example of contractor-led design. The number 7 slip at Chatham is described in the Historic England listing description as having been designed by Greene.227 However, Hawkins, Butler, and Skelton,
in their article ‘The Iron Slip Cover Roofs’ suggest that Grissell’s contribution was substantial, as the number 7 slip is similar to the Boat Store at Sheerness and the Smithery of Sheerness, also built in 1855–6 by Grissell’s. Henry Grissell was known for his technical knowledge of iron, derived from his own experiments. Contractors such as Grissell’s, Baker’s and Fox, Henderson appear to have been strongly motivated to provide the best material possible. There seems little doubt that they believed in iron, were passionate about its success and experimented at their own risk to verify the safety and utility of a revolutionary new building material.228

Out of the original eighteen iron roofs, two still survive at Chatham. Originally built at Woolwich but after 1869, they were dismantled and re-erected at Chatham as Machine Shop number 8 and the Boilershop.

One of the last slips to be built at Chatham was number 7 slip, which was designed by Greene in 1852, using Fox, Henderson’s roof at Woolwich as an inspiration.229 The building tender was offered to Grissell’s. Their competitor, Baker’s, appear to have lost out because of poor work on other slipway roofs. This is significant because it demonstrates that the Navy appreciated the crucial importance of the fabricators as well as the designers to the success of early iron buildings.

Perhaps the most remarkable survival in a naval dockyard is the Boat Store at Sheerness Docks, built from 1856–60. The building has a wrought iron frame with corrugated iron cladding and roof, again designed by the outstandingly innovative naval engineering architects, Col GT Greene and William Scamp.

This survives and has been listed. The list entry contains this description:

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228 Hawkins and Butler with Skelton, ‘The Iron Slip Cover Roofs’.
229 Hawkins and Butler with Skelton, ‘The Iron Slip Cover Roofs’.
The Sheerness store is remarkable however for its size and efficient storage and handling arrangement, and also for its innovatory structural system. The all-metal frame was made rigid by portal bracing, subsequently adopted by the skyscraper pioneers in Chicago, and universal for modern steel-framed building. Precedents can be found in the slip covers built in the royal dockyards during the 1830s and 40s, notably the fine series at Chatham, culminating in Greene's own No.7 slip cover (qv). The Boat Store, however, was the first structure to depend for its stability entirely on the rigidity of the joints. While a pioneer without immediate followers, it is of international significance in the development of modern architecture.\textsuperscript{230}

The Sheerness Boatstore is a very early multi-storey iron-framed building, with corrugated iron cladding, and is ‘... probably the most significant early multi-framed building to survive.’\textsuperscript{231} This iconic building, of a surprisingly modern appearance for a building of this date (1858-60) is, as the listing description states, ‘of international significance in the development of modern architecture,’ a design that inspired the first tower blocks in Chicago. Though the corrugated iron cladding appears to have survived for around 100 years, it is sadly no longer original.\textsuperscript{232}

This building is particularly interesting, not just because of the early use of corrugated iron, but because of the way the contractors, engineers and architect all collaborated in the design. Although the design has been attributed solely to Greene, recent research by the Greater London Archaeological Society suggests that, because of the similarity of designs of the Number 7 slip and the Sheerness Smithy, both constructed by Grissell’s, the Sheerness Boat store is ‘clearly part of a ‘family’ of buildings, which can be attributed to Grissell,’\textsuperscript{233} the contractor, as well as Greene.

\textsuperscript{231} Evans, \textit{Building the Steam Navy}, 126.  
\textsuperscript{232} Skempton, ‘The Boat Store,’ 57.  
\textsuperscript{233} Hawkins and Butler with Skelton, ‘The Iron Slip Cover Roofs’.
As the GILAS report notes,

Although there is no documentary or drawn evidence to support it, there must have been extensive preliminary discussions between Greene and his design team with the subsequent building contractors before the design drawings for the building were finalised. This would fit well with Greene’s approach to tendering in which only selected contractors, principally Fox, Henderson and Grissell, were awarded contracts while others such as the Bakers were excluded. The implications are that the design of this building, although executed under Greene’s direction were, in fact, as much the product of the contractors as of Greene and his in-house design team.\textsuperscript{234}

\textsuperscript{234} Richards, \textit{The Functional Tradition}.
The innovation displayed in the construction of the Sheerness Boat store or the Chatham slips not only encouraged the collaboration between the designers and the fabricators; it probably depended on it. A new relationship between architect, engineer and fabricator had been born out of experimental necessity. Although never universally adopted, this relationship of collaboration and partnership has strongly influenced more recent design practices such as that of Ove Arup.

The Boat Store at Sheerness also uses corrugated iron as an integral part of its design; in 1959 the building was recognised as being of considerable architectural interest by A. W. Skempton and Eric De Mare. In his paper written for the Newcomen Society, Skempton discusses the importance of this very early multistorey building. However it was not listed because of the corrugated iron, as Skempton states: ‘Perhaps the chief criticism of the Boat Store is the use of corrugated iron for the wall panels; since brick panels would have provided better insulation and a more weatherproof construction.’

Well before Richard Walker’s patent ended in 1843 and he lost sole control of the manufacture of corrugated iron, most of its early technical deficiencies had been overcome. Galvanisation, for example, had effectively addressed corrosion problems. Corrugated iron had become well established as an excellent lightweight material, ideal for roofing wide span buildings, as well providing effective cladding. Given this success, it is not surprising that numerous companies took up manufacture when the patent lapsed. This diversity of manufacture appears to have had an impact on the quality of the material. In 1850, the Admiralty decided to review the condition of the corrugated iron being used on their buildings. This inspection revealed that the corrugated iron roofing that had been applied in 1844 to the timber-built sheds at Deptford was already decaying, with the galvanising starting to thin. However, the corrugated iron roof of Number 1 slip that had been applied in

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235 Skempton, ‘The Boat Store,’ 70.
236 Evans, Building the Steam Navy, 129.
1845, was in better repair, and the roofs at Woolwich were still in excellent repair.\textsuperscript{237}

At Chatham, the slips were covered in both galvanised corrugated iron and galvanised iron sheets. None of the galvanising seems to have survived well on either material. The corrugated iron which was placed on slips 4, 5 and 6 in 1848 had started to decay and the iron had started to rust, especially in the channels; and this was only two years after it had been put there.

It seems to us so great a drawback, as to neutralise any advantage it might have on the score of cheapness in the first cost, or of lightness in the case of the corrugated Iron from its being used without a lining – How this latter may answer in heavy gales, we have not yet had sufficient experience to form a judgment.\textsuperscript{238}

In Devonport, the new steam hammer shop had been roofed in corrugated iron in 1848–9 and was reported in 1850 as being in generally good condition, although there were some defects, ‘apparently caused by blisters in the original manufacture.’\textsuperscript{239} Such blistering would have severely affected the galvanising, rendering the iron liable to rapid corrosion.

At Pembroke dock, reports suggested that there had been no deterioration in the corrugated iron, despite that fact that it had been in place for nearly four years.

Corrugated iron, as well as its predecessor flat iron sheeting, seems to have had a mixed level of durability. It would appear that this depended primarily on the care exercised during manufacture.

The mixed results of the 1850 inspection clearly suggested that early corrugated iron had not proved to be a perfect material, but its performance

\textsuperscript{237} Evans, \textit{Building the Steam Navy}, 129.
\textsuperscript{238} Evans, \textit{Building the Steam Navy}, 129.
\textsuperscript{239} Evans, \textit{Building the Steam Navy}, 129.
was still sufficiently impressive to persuade Greene to specify it for the Sheerness Boat Store. There is no direct evidence of his, or the Admiralty’s, thinking but perhaps concerns over manufacturing quality were outweighed by the advantages of light weight and low cost.

The use of cast and wrought iron made it possible to build wider roof spans, and the invention and manufacture of corrugated iron allowed these structures to have a lightweight roof covering. As well as this, the slender iron columns allowed greater access to the ships. Despite the change of materials from wood to iron, the basic design of the slipways remained little changed; form continued to follow function.\textsuperscript{240} The underlying construction of the new slip roofs was almost as innovatory as the technology of the new iron ships. Their development had a profound influence on all later buildings engineered in cast, wrought and corrugated iron, as noted by David Evans: the ‘slip roofs were of enormous significance in the development of free-standing iron frames… many of the technical steps… were worked through in the dockyards…’\textsuperscript{241}

The modern, commonly held, perception that corrugated iron is a temporary material was not shared by the nineteenth century Navy. The new covered slips were not conceived as temporary structures but were built to last indefinitely. The survival of the covered slips at Chatham is abundant proof of this, especially since the original corrugated iron cladding survived till the restoration in the 1990s.

At the time they were built, the massive roofs of the naval slips were not possible without corrugated iron. The navy took full advantage of its strengths, and utilised corrugated iron in a large number of buildings, dispensing with boarding and battens and using trusses and purlins instead.

\textsuperscript{240} Evans, \textit{Building the Steam Navy}, 44.
\textsuperscript{241} Evans, \textit{Building the Steam Navy}, 45.
2.6 The Kensington Gore Museum

Built in 1856, the Kensington Gore museum was the direct predecessor of what is now the Victoria and Albert Museum. It was intended to be an educational resource, housing the treasures of the new Empire and displaying the genius of British design.

Victorian wealth and education widened and deepened the British public’s demand for culture and knowledge. Colonial exploitation, an increasing fascination with the world, all supported by Queen Victoria and consort Prince Albert, produced large volumes of valuable material. Public spirited visionaries recognised the opportunity that this vast quantity of material presented, and set about creating major public museums. This, in turn, created a need for new public buildings to house museum collections.

Figure 2.21. Kensington Gore museum, otherwise known as the Brompton Boilers.

One of the earliest new museums was the corrugated iron building erected to house the Victoria and Albert (V&A) collection. Much of the inspiration behind the creation of the V&A derived from the success of the Great Exhibition at the Crystal Palace, which proved and reinforced the public hunger for a celebration of art, design and manufacture. The Crystal Palace also proved the benefits of
standardised and pre-fabricated construction and demonstrated the feasibility of constructing large public exhibition spaces using new materials and techniques. It was thus natural that the new V&A building should embody the lessons learned at the Crystal Palace.

The profits from the Great Exhibition, plus further funds from the government, were used to purchase a large area of land in Kensington, and the new museum was intended to be one of several buildings which would become the public educational hub of London. Albert, the Prince Consort, was personally involved in the initial design, working with German architect and art critic Gottfried Semper. But the scheme was abandoned, being seen as too expensive, with Semper no longer involved in the museum’s design. A temporary building was proposed and in only four days, and Charles Young and Company, who were already familiar with building such structures, were appointed. The building was to be temporary, inexpensive and reusable, being constructed with an iron frame and clad with corrugated iron. The museum building would be constructed ‘266 feet long, 126 feet wide, and about 30 feet high, to the eaves.’ Inside there were to be three galleries, each 42 feet wide.242

But unlike the Crystal Palace, the V&A, which was first known as the Kensington Gore Museum, did not win a favourable response from the public. It was a deeply flawed design which failed to create a satisfactory internal environment, was ugly externally and soon acquired the derogatory nickname of the Brompton Boilers.

Prior to construction of the museum, the Builder magazine, which was normally very supportive of new designs and structures, commented that it ‘regretted that no professional architect had been consulted about the building.’243 Nevertheless, the commissioners liked the proposed building, citing its merits:

243 Physick, The Victoria and Albert Museum, 23.
Irrespective of its simplicity and cheapness, and the remarkable facility with which it can be constructed, it enjoys the great advantage from a pecuniary point of view, of being designed of a material which possesses a permanent pecuniary value, to which the cost of labour employed in its construction bears only a small proportion. While, therefore, it could on the one hand be at any time taken down and re-erected, if necessary, on another site, or in another form, at a very trifling expense, it could, on the other, be re-sold…

Clearly the perceived advantages of cost and movability were paramount, regardless of the overall design. A grant of £15,000 was allocated towards the building, and in early 1856, work began. But in April of that year, the *Builder* again crushingly complained that:

> Its ugliness is unmitigated: never was a beautiful sward, where daisies blossom and trees and shrubs put forth their branches… so vilely disfigured…

This criticism was continued in the following month's edition, noting that the new building: ‘is in three equal spans, all at the same height from the ground, like huge boilers placed side by side.’

This is undoubtedly where the nickname ‘the Brompton Boiler’ originated. An attempt was made to make the building more aesthetically acceptable by painting it in green and white stripes and adding an iron portico, but even this did little to stem derisive public comment.

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244 Physick, *The Victoria and Albert Museum*, 24, quoting a letter to the Chancellor of the Exchequer, 30th June 1855.
Appearance was not the only problem. The building leaked, despite additional caulking, because rainwater disposal was poorly designed. Lack of insulation meant that condensation that formed on the interior of the corrugated iron ran down the walls and dampened the exhibits. As if these problems were not sufficient, the upper floors were too weak to hold the plaster casts they had been intended to exhibit. It is no wonder that the Brompton Boilers were universally unpopular. The Builder magazine again exhorted: ‘… the Brompton Boilers, a loud speaking disgrace to the Country.’

The buildings continued in use until 1866, a short lifespan of ten years, before they were moved to become the Bethnal Green Museum, a branch of the Victoria & Albert, specifically designed to improve the working classes, who were presumably not considered deserving enough to be given materials such as stone or brick.

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The replacement the original concept of a design inspired by the Crystal Palace with a building made from corrugated iron not only made the building dark and leaky but also gave the structure a shabby industrial aspect. There was no attempt to add decoration. A series of quick and rash design decisions, the loss of the visionary architect and a severe lack of funding meant the outcomes were not what had been anticipated. This failure of vision and lack of money created a disastrous start for corrugated iron as a material for polite buildings. The very public failure of the Kensington Gore Museum to fulfil any of the requirements of a successful museum appears to have been a decisive first step in shaping longer-term public assessment of the cultural significance of corrugated iron.

Figure 2.23. Kensington Gore, or as it was more popularly known, the Brompton Boilers (1897). Their utilitarian shabbiness is all too obvious. Photograph from the V&A.

The failure of the Kensington Gore Museum to perform technically, and its failure to win public sympathy are both of key importance. Whether fairly or not, corrugated iron became strongly associated with the creation of an ugly and unsatisfactory public building. It has struggled ever since to shake off this association with cheapness and failure. The Brompton Boilers symbolised a form of building which was unacceptable to both an educated architectural elite.
and to the general public. This public reaction suggests that middle class Victorians were not ready to accept the use of a utilitarian material such as corrugated iron as a building material for public buildings. They were, however, perfectly accepting for its use in railway stations, warehouses or naval architecture.

2.6.1 The Reaction against Industry

The cultural tensions stemming from social, economic and technological change that had so characterised Victoria’s early reign did not abate during the twentieth century. The growth of industry continued, the pace of innovation and mechanisation accelerated and domestic life became increasingly urbanised. Education and medicine attained recognisably modern forms. These developments combined to produce a society that was unquestionably richer and more comfortable than any that had gone before.

Industrialisation had created a moneyed and leisured middle class, but it had also created grotesque inequalities of income. This was noted by a diverse range of social commentators including Karl Marx, Henry Mayhew and in fiction by authors such as Elizabeth Gaskell and Charles Dickens. Industrial development from the 1880s onward did little to invalidate the rhetoric of nineteenth century romantic commentators and continued to sustain a significant body of nostalgic anti-industrial sentiment.

250 Wilson, The Victorians, 14.
253 Elizabeth Gaskell, North and South (1855; London: Penguin, 1995).
The continuing process of urbanisation produced an intellectually driven reaction akin to that of anti-industrialisation. The National Trust is a conservation organisation, founded in 1895 as a pressure group dedicated to protecting parks and open spaces. It describes itself as a charity which directs its funds ‘towards keeping places special for ever, for everyone.’255 The Trust has a large collection of about 200 English country houses, out of a total of about 250 historic properties.256 It also protects historic landscapes such as the Lake District. More recently, it has diversified into conserving increasing numbers of vernacular and urban buildings.

Real as the anti-industrial sentiments of the late nineteenth century were, they were as nothing to the social and economic tensions created by the twin disasters of the First and Second World Wars. The human deprivation and loss, directly stemming from mass warfare, was added the pain of economic depression and the uncertainty of declining religious faith. These changes were not confined to Britain. The wars of the twentieth century fundamentally challenged nineteenth century assumptions on Britain’s role in the political and economic world order. Even the Victorian certainties of empire were proved to be illusory. In short, British society during the late nineteenth and the twentieth century was assailed by change and insecurity.

In politics, nationalism became a strident voice, largely, but not exclusively, driven by the increasing economic power of the newly united Germany in 1871. This generated an increasingly unstable competition for world influence amongst the European powers.

Nationalism in Britain was expressed in many ways. There was a determined effort to define a historic national culture by collecting folk songs, led by Cecil Sharp, and by creating fictional literature that sought define national identity.

256 Hugh Mellor, Manager of Knightshayes Court, National Trust Property, email message to author, 25 June 2020.
In art and music, consciously British styles developed. British architecture also developed a distinctive style. Whilst architectural scholars may look to modernism to characterise European architectural style from the 1880s, the defining British style of late nineteenth century and twentieth century architecture was really the semi-detached villa. This is important because it reflects the conservatism of the house buying middle classes, who had no desire to desert the terraces of the mid-Victorian period for adventurous design using modern materials: they wanted the same bricks but fewer neighbours.

The rise of rail networks and bus routes meant that people were able to live at some distance from their work. This allowed the development of the English suburb, where self-contained spacious housing was designed for families. In Victorian times, the streets were straight, but with reasonably sized gardens. ‘English character of a kind was usually made. Before about 1875 that meant a faintly picturesque mixture of materials, styles and planting. Houses and front garden boundaries tend to have Italian touches and to be stuccoed or in brick.’ After the war the architecture ‘took on a consciously vernacular character. The visual model for this was the traditional English cottage, modernised almost out of recognition, a trend exemplified by the emergence of the garden city or suburb development.’

Corrugated iron fell victim to this popular conservatism. At no stage between the late Victorian era and the present day has corrugated iron made a serious impact on British domestic architecture. The cultural significance of corrugated iron had been permanently diminished by the conservatism of the general public and negative associations with war and industry.

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2.7 Military Use of Corrugated Iron

2.7.1 The Crimean War

The development of the British Empire during the nineteenth century was accompanied by near constant military activity, and much effort was required to maintain British rule and subdue rebellions. Outside the Empire, British foreign policy was frequently based on military intervention, for example, as part of the Great Game, where Britain fought with Russia for control of the Crimea. What is relevant to the history of corrugated iron is that the planning of the war was over-optimistic. As with most British military adventures, initial expectations of an easy victory in the Crimea proved illusory, leaving the British Army ill-equipped to deal with the Crimean winter. Their response took advantage of the newly developing concept of prefabricated buildings.

The principle of prefabricated building design was well established by the time the Crimean war started in 1854. The machinery needed for mass production of the timber parts was already extant. In mid-November 1854, the contracts were signed for the supply of 1,000 wooden huts and by the end of the year, not only were they made but delivered to the Crimea: an exceptionally speedy response that emphasised the advantages of prefabrication. However, although the army was undoubtedly persuaded of the advantages of prefabrication during its experience in the Crimea, it was cautious in uniting the concept of prefabrication with use of corrugated iron. An excellent example was Brunel’s Crimean war hospital at Renkioi, on the Dardinelles, which was based on a prefabricated modular design.\(^{259}\) However, despite the relatively plentiful supply of corrugated iron and Brunel’s familiarity with the material, the main hospital was built of timber. Corrugated iron was, however, used for auxiliary buildings. An 1857 report stated that they included: ‘An iron kitchen,

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slightly detached from the wooden buildings… a similar building of iron… fitted up with all the machinery needed for washing and drying.'

Further evidence of the use of corrugated iron buildings is shown in an engraving made in 1856, which shows three barrel vaulted corrugated iron buildings at Balaklava. Certainly, corrugated iron was used, but most buildings appear to have been constructed of timber.

The hesitant adoption by the Army of corrugated iron in the Crimea is hard to interpret. It may signify a culturally driven resistance to any adaptation to circumstances, for which the Army has justly been notorious. Alternatively, it may represent a rational desire to restrict experiment in the field of battle. In other words, the army specified wooden prefabricated buildings in the Crimea because they knew they would work, even if corrugated iron offered theoretical cost and deployment advantages.

Figure 2.24. Illustration showing Balaklava in 1855. The corrugated iron building can be seen at the top right, identified by the curved roof. Image from Illustrated London News (1855).

260 Mornement and Holloway, Corrugated Iron, 108.
The apparent contradiction between the Army’s conservatism in the Crimea and the Navy’s enthusiastic experiment with corrugated iron on its slipways does have a rational explanation: the Army’s timber huts were known to work, whereas the use of timber for slip roofs was known not to work. The Navy was forced by necessity into the use of new materials, but no such necessity was felt by the Army.

2.7.2 The First World War

Apart from its adoption by the Navy, principally as a roofing material for the construction of highly specialised slips, nineteenth century military use of corrugated iron remained limited. After minor experiments during the Crimean War, the Boer War (1899–1902) saw a return to the use of canvas tents as the primary means of housing troops on active service. The climatic conditions experienced during the Boer War were markedly different from those in the Crimea, and the war itself was less static. It is possible that the continued use of canvass tents was a conscious and rational reaction to the style of the war rather than a conservative rejection of a new material. The army did experiment on a very small scale with corrugated iron building, producing an officer’s mess and a kitchen at the barracks at Aldershot.

The First World War forced a change of thinking. Military planners had not foreseen the reality of winter warfare in northern Europe. Protracted periods of cold, wet weather created exceedingly poor living conditions for the troops housed in canvas tents. The Army’s solution to the problem came in the form of the Nissen hut.
Halfway through the First World War, Peter Norman Nissen, possibly inspired by the design of the drill hall at Queen’s University in Ontario, invented the Nissen hut. Nissen was a mining engineer and inventor who registered 28 patents. The Nissen hut was a semi-circular structure made of corrugated iron sheets on a steel frame, with timber walls at each end which contained the door and windows.

The main success of the Nissen hut was the ease of transportation – it could be packed into the back of a standard army three ton lorry and erected by six men in four hours; it also made economical use of materials, which was important in wartime austerity. The ability to erect the huts quickly was paramount, and each hut came with a set of instructions – a set of drawings showing the sequence of construction. The manufacturers were not slow to start production and six months after the first order was issued, 20,000 huts had reached the French battlefields.\footnote{Mallory and Ottar, \textit{Architecture of Aggression}, 81.} It was mass production of buildings on a grand scale.

Figure 2.27: Cultibraggan Camp. Photograph by the author.

The Nissen, despite undoubted achievement, is an exemplar of how design success does not automatically win enhanced status. Perhaps more than any
other corrugated iron design, the Nissen hut has come to associate corrugated iron with the misery of war.\textsuperscript{263} The fact that it did its job so admirably was quite lost on the infantry, forced to endure its charms. When the infantry were demobbed, they carried all their negative associations for corrugated iron with them back into the civilian world. While precise measurement is difficult, it is highly probable that enduring (unfavourable) attitudes towards corrugated iron were enforced by the association with war.

The impact of First World War life in a Nissen hut was reinforced by the Second World War. Here again, accommodation in corrugated iron temporary Nissen huts and in American variants of the design (e.g. the Quonset hut) became the ordinary man’s experience of corrugated iron. Yet again, the memory of this experience was carried forward into civilian life, and has had an enduring impact on attitudes to corrugated iron.

Whilst life in a Nissen or Quonset hut was confined to military personnel, the British public directly experienced corrugated iron through enforced use of Anderson shelters. Anderson Shelters were designed in 1938 as air raid or bomb shelters, large enough to house six people and made from corrugated iron sheet. For some, memories of these buildings are mixed and sometimes nostalgic, but often Anderson shelters still present a starkly utilitarian use of corrugated iron. Despite its utility, the wartime use of corrugated iron has contributed to a strong association between the material and privation.

\subsection{The Second World War}

Nissen hut manufacture slowed down between the wars and at the start of the Second World War, as part of a general decrease in military spending. It did not recover immediately at the start of the Second World War due to steel

\textsuperscript{263} Mornement and Holloway, \textit{Corrugated Iron}, 7.
shortages. However, steel was the only material that could be used for huts that needed to be transported, concrete and asbestos being too heavy.\textsuperscript{264}

Nissen huts took on multiple roles during the Second World War. They continued to be the mainstay of housing for troops but they found a new use as housing for prisoners of war. When the prisoner-of-war camp at Cultybraggan, near Perth was constructed, Nissen huts were chosen in preference to other contemporary designs because of their simplicity of erection- ‘no nailing and hand fitting.’\textsuperscript{265}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2_28.jpg}
\caption{Nissen huts at Cultybraggan prisoner-of-war camp, photographed during a re-enactment of prisoner movement, c.2010. Note how the timber end walls of the First World War huts have been replaced with masonry. Also of interest is the extent of replacement corrugated iron, probably dating from the 1980s, when the camp was used for Territorial Army training. Permission given.}
\end{figure}

\textsuperscript{264} Mallory and Ottar, \textit{Architecture of Aggression}, 81.
\textsuperscript{265} Mallory and Ottar, \textit{Architecture of Aggression}, 81.
The Nissen hut ‘may have a claim to be the most replicated building ever designed,’ as its use did not end with the Second World War and has continued to the present day in all parts of the world. Post war civilian re-use of Nissen huts has emphasised their adaptability and versatility, with multiple applications as housing, workshops and farm buildings. Many Second World War huts are still in use though large numbers are deteriorating ruins, overgrown and abandoned on farms and in woodlands. The maintenance failures of civilian re-use has given the Nissen hut a strong association with ruin, war and death that often sparks a sense of revulsion for corrugated iron.

Figure 2.29. Nissen hut in Dorset, now used as a workshop. Photograph by the author.

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266 Mornement and Holloway, *Corrugated Iron*, 112.
The Italian Chapel on Orkney is a good example of the adaptability of the Nissen huts. In May 1940, Italian prisoners of war were moved to Orkney to build the Churchill barriers and 550 prisoners were housed in Camp 60 on the island of Lambholm. The prisoners made huge efforts to improve their living conditions, of which the building of the chapel formed a major part. The chapel was made from two Nissen huts, joined end to end, with an interior elaborately decorated by the Italian sculptor Domenico Chiocchetti. Domenico Chiocchetti, a painter born Moena, Italy 1910.\textsuperscript{267} The Chapel demonstrates that all buildings, whether corrugated iron or not, have a structural skeleton, but how we perceive them depends not on this hidden structure but on the visible decoration and the story they tell.

When compared with canvas tents, the Nissen hut hugely improved the standard of accommodation offered to serving soldiers, and even provided relatively civilised accommodation for prisoners of war. The conversion of a Nissen hut by Italian prisoners of war into a chapel, shows that Nissen huts in themselves were not seen as objects of revulsion by the prisoners that they housed.

### 2.7.4 Airship Hangars Using Corrugated Iron

![Image of Cardington Hangars; Number 2 shed under construction](image)

The attention given to Nissen huts is justly deserved, however, they were not the only military structures of the First World War era to use corrugated iron. The largest corrugated iron buildings in Britain are the Cardington airship hangars. Extraordinary survivors from the early twentieth century, these
massive yet lightweight, steel-framed structures are so vast, they could 'accommodate the RMS Titanic... and... Nelson's column could stand inside them.' Airship hangar No 1 was built by AJ Main of Glasgow in 1915 to house rigid airships R31 and R32, was 700 feet long, required 4,000 tons of steel and an act of parliament to overcome wartime restrictions of production. The building was extended further in 1924–26 to accommodate building airship R101, its length increased to 812 feet. The No. 2 shed was moved from RNAS Pulham, Norfolk in 1928. October 1930 saw the R101 airship crash, and consequently all work on airships stopped.

Figure 2.32. Cardington Hangars. The shed to the left is under repair. Photograph by the author.

Until recently, the Cardington Hangars were deteriorating but have now been restored with a grant from Historic England and further funding from property developers. All the old corrugated iron has been removed and replaced with new. Films taken from an air balloon flight over the top of the building show

268 Mornement and Holloway, Corrugated Iron, 114.
269 Mornement and Holloway, Corrugated Iron, 131.
that this was necessary.\textsuperscript{270} The amount of money spent on repairing the hangars, and their grade 2* listed status, suggest that their cultural significance has been fully recognised. The cultural significance of the hangars is less to do with their construction than with the narrative of the R101; they are a good example of how cultural significance is bound up with intangible heritage rather than with physical structures. Given the cost implications of their maintenance and conservation, and more general institutional attitudes towards listing relatively modern structures, it is astounding that these enormous buildings have been listed. They are arguably the most striking example of official and public inconsistency towards the cultural significance of corrugated iron.

The successful military use corrugated iron, whether in the form of giant structures such as the Navy’s slip roofs or the hangars at Cardington, when contrasted with the small, lightweight and transportable Nissen hut, highlights the versatility and adaptability of the material, and probably the only material available at the time to allow such vast structures to be built.

\textsuperscript{270} ‘Virgin balloon flight from Biggleswade (Shuttleworth College) to Cardington, Bedfordshire,’ YouTube video, 19 April 2017, https://youtu.be/uRn-NmH7pKM.
2.8 British Twentieth Century Domestic Housing

2.8.1 Post-war Housing

The mid-twentieth century experimental use of corrugated iron in British domestic housing produced very few building types; some of these are built near Yeovil in Somerset. These Nissen-Petren houses, built by architects Petter-Warren, were an attempt to tackle a serious housing shortage in 1925.271 The steel framed houses, with their highly distinctive curved corrugated iron roofs, cost £350 each to build, which was £100 more than a traditional house, causing the project to be abandoned on cost grounds.272 However, these houses are now listed grade 2, recognising their design interest, but when the Petter-Warren houses were constructed there was no intention for them to be valorised as monuments; they were practical experiments in economical housing. Their listed status recognises their rarity value and is an example of how cultural significance can change relatively rapidly.

There were numerous post-war experiments in system-built domestic housing in Britain but most of these were based on the use of prefabricated concrete panels, and none made significant use of corrugated iron. One notable exception has been the development at Bean Hill in Milton Keynes.
At Bean Hill, Milton Keynes, Norman Foster used corrugated cladding for his design of low-cost housing. Between 1973 and 1977, nearly 500 houses, timber framed with corrugated aluminium cladding, were built, with the aim of giving homes to poorer families.273 Not only were the families sensitive to the corrugated appearance, which reminded them of temporary houses and shanty towns, but the leaks, condensation and high heating bills also made the houses unpopular with tenants who christened their estate ‘shantytown.’274 Refurbished less than 10 years after construction, some of the houses were given pitched roofs and mock-Tudor style details, though many still have the corrugated iron.

As stated by Mornement and Holloway, ‘Bean Hill is yet another unhappy chapter in British housing failures due to design, materials and system building.’ Bean Hill, like the Brompton Boilers, as discussed above, has marked a low point in the valuation of corrugated iron as a domestic building material in Britain. This is, of course, unfair; failures of detail design are the responsibility of the designer, not the material. Nevertheless, the perception of corrugated iron as ‘unsuitable’ for domestic housing has been strongly reinforced by the Bean Hill failure.

Both public and specialist architectural reaction, in Britain, to the use of corrugated iron in the late twentieth century has been muted. Its extensive use in industrial estates has drawn little hostile comment but neither has it attracted the attention of conservation minded professionals. This apparent indifference on the part of both the general public and the architectural profession may be because industrially produced materials, such as corrugated metal, now have the status of familiar-but-uninteresting. The success of the Town & Country

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275 Mornement and Holloway, Corrugated Iron, 170.
Planning Acts in zoning development, and thus hiding industrial buildings in ghetto estates, has significantly reduced public exposure of this modern use of corrugated iron. Where the public do come into daily contact with corrugated iron buildings is in out-of-town shopping centres, but here the true nature of the building is often hidden by brickwork and tile facades.

2.8.2 The Frontiers of Britain

The situation is different in Scotland, where the combination of climate, deforestation and clearances produced a geography of marginal human occupation not dissimilar to that experienced by the settlers in new colonial worlds and in twentieth century Britain’s only real frontiers were ends of railways in the Highlands and Islands.

Figure 2.36. Kinbrace, Sutherland, one of Britain’s remaining frontiers. Situated next to the railway station on the line running between Inverness to Thurso. Photograph by the author.
2.8.3 The Rural Vernacular

Since the mass production and mechanisation of corrugated iron sheet the material has been used as means to protect failing thatch. It was seen, and still is seen, by many farmers as an economical way of permanently covering buildings that would otherwise either never have been repaired or rather belatedly been rethatched. Because the practice is so commonplace, through sheer endurance of the habit, it has become part of an acceptable rural vernacular. This is recognised as a valid conservation technique by Historic Environment Scotland, Historic England and many conservation architects.
Figure 2.38. Blaenavon iron works where corrugated sheeting has been used to protect the top of an old blast furnace. It is also used to cover the casting sheds and painted red. Traditionally this would have been red lead paint, but a more acceptable modern finish is used today. Photograph by the author.

Figure 2.39. Wambrook in Somerset. This traditional Somerset cottage would originally have been thatched, but is now covered in tin as a cost effective method of keeping the building watertight. Photograph by the author.
However, there are architectural practices that encourage the use of corrugated iron in new build, such as House No 7 on the Isle of Tiree, built by Murray Kerr of Denzien Works architects.

![Figure 2.40. House No 7 on the Isle of Tiree, by Denzien Works architects. Originally a ruined blackhouse, the building was refurbished to reflect the original design, using the materials that were an accepted part of the rural vernacular. Photograph by the author.](image)

The Tiree house is not the only new built to follow the idea of using corrugated iron as part of the rural vernacular. The Tinhouse on the Isle of Skye designed by Nick Thomson of the Rural Design Partnership, and is described as:

> The Tinhouse celebrates corrugated metal sheeting, commonly used on the agricultural buildings of the rural landscape. It does so in a thoroughly contemporary way by using mill finished corrugated aluminium as the external cladding for both roof and walls. The external metal skin predominates as a protective layer against the often ferocious storms with minimal openings cut out for the view.
Figure 2.41. Corrugated iron house on Skye by Rural Design Partnership, who describe the house as: ‘The project is an essay in landscape, economy, construction and imagination… The Tinhouse celebrates corrugated metal sheeting, commonly used on the agricultural buildings of the rural landscape.’ Photograph by Rural Design Architects.

2.9 Architectural Design with Corrugated Iron

In the first part of the twentieth century, growing pressures of social change created a potential market for an increased use of corrugated iron in standardised prefabricated housing. However, the design of new prefabricated buildings, though innovative, centred mainly on the use of concrete rather than corrugated iron. Up to the twentieth century in America prefabricated buildings were mainly constructed from timber. By the beginning of the twentieth century the new materials that had become available, which helped reduce installation times. A reduced labour force after the Second World War along-side less availability of materials, meant that it was more cost effective to make prefabricated buildings rather than to build on site. As a result of using cost effective methods of construction, prefabs developed a bad reputation. In America the Cemento house – made from prefabricated asbestos cement panels was made from 1941, and the Lustron house, made mainly from steel, factory made but put together on site.277 In Britain these buildings were made from precast reinforced concrete, bolted together with a steel frame, though many different styles of construction were eventually used.278

However, some notable architects, such as Walter Gropius and Buckminster Fuller, did design buildings incorporating the use of corrugated metals into prefabricated buildings. Walter Gropius, German architect and founder of the Bauhaus,279 after considerable research into prefabrication, designed a Copper-Plate house in 1931. The French designer and metalworker, Jean Prouvé was innovative in the design of factory produced and prefabricated buildings, working with pressed aluminium for export to tropical regions.280 Probably best known is Richard Buckminster-Fuller, an American architect well known for the creation of geodesic domes. Buckminster Fuller’s Dymaxion

277 Prudon, Preservation of Modern Architecture, 305.
278 Prudon, Preservation of Modern Architecture, 305.
280 Mornement and Holloway, Corrugated Iron, 145.
house, a combination of ‘dynamic, maximum and tension’ was first exhibited in 1929 and made in 1941. It was a low cost, hexagonal house and was wrapped around with corrugated aluminium sheets. Ahead of its time perhaps and certainly ahead of public taste, the corrugated aluminium was functional, acting as a structural element.\textsuperscript{281} It never went into mass production as the American government had to divert metal supplies to the war effort but some were made and used as dormitories in the Persian Gulf during World War 2.\textsuperscript{282}

It was not till the 1940s that corrugated iron began to throw off the stigma of being a material only suitable for industrial and military use. This significant change meant corrugated iron started to be used in individual buildings designed by architects. As suggested by Mornement and Holloway:

\begin{quote}
It was cheap, light and resonated with the enthusiasm for mass-produced machine-made components. On the aesthetic level, its shiny, streamlined appearance was suited to the times; it implied speed, flight and dynamism.\textsuperscript{283}
\end{quote}

In areas of the world where there is a frontier culture, such as Australia or the west coast of America, architects saw corrugated iron as a material integral to, and valorised by, their national historical narratives. Both Australia and America (especially the west coast and Texas) accepted corrugated iron as part of their cultural tradition, having played an integral part in the development of their early frontier culture. As modern versions of corrugated iron became readily available, a desire to use it in a modern building context developed.\textsuperscript{284}

\textsuperscript{281} Mornement and Holloway, \textit{Corrugated Iron}, 145.
\textsuperscript{282} Mallory and Ottar, \textit{Architecture of Aggression}, 272.
\textsuperscript{283} Mornement and Holloway, \textit{Corrugated Iron}, 146.
\textsuperscript{284} Mornement and Holloway, \textit{Corrugated Iron}, 146.
Modern architectural excitement with corrugated iron is particularly evidenced in the work of Australian architects; probably the most well-known is Glen Murcutt, who began designing corrugated iron buildings in the 1970s. As stated by Mornement and Holloway, Murcutt’s work is both a response to the ‘Australian emotional bond between the material and Australian vernacular buildings,’ but linked with developing new forms in modern architecture.

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Until recently the use of corrugated metal in the twentieth century architecture in Britain differs was very sparse and markedly from Australia, America and Japan. However, the Stathaven Airfield House in Lanarkshire had defied convention. This building is explored further in Chapter 3.
2.10 Modern Industrial use of Corrugated Cladding

Twentieth century architectural design in Britain using corrugated iron has concentrated on industrialised prefabrication, focussing on other corrugated materials such as copper and aluminium.

Corrugated iron has undergone a renaissance since the end of the Second World War. In the utilitarian world of factory-unit construction, profiled metal has become the standard material for roof and wall cladding. Not all of this is strictly corrugated iron – other metals are in use – but the bulk is formed in steel, protected with factory-applied plastic coatings, and the profile of the metal used is not always the traditional sinewave. The apparently flat panels used on many modern steel-clad buildings are deceptive: they may not have obvious corrugations but still have hidden flanges to provide stiffness.
The cultural significance of buildings on modern industrial estates is open to debate. They are easily ignored by architectural historians as being a design niche without architectural value. However, it is unfair to dismiss such buildings with simple generalisations, as some factory units display real attention to design detail, together with highly adventurous use of colour and texture.

Corrugated iron has never lost its popularity with industrial unit designers, because of its overwhelming utility, but its use outside industrial estates in Britain has been limited. The cultural significance of new corrugated iron buildings in Britain remains limited, with most perceptions limiting the material to a functional cladding element for industrial units.

By the end of the nineteenth century, corrugated iron was utilised across all building applications, and mass production and catalogue advertising made prefabricated buildings commonplace. Corrugated iron buildings were used to accommodate all forms of industry, housing and amenity uses in all parts of the world, as far north and south as the Polar Regions. The needs of the British Industrial revolution, and the mass production of iron that made it affordable, had made corrugated iron a success beyond all measure.
In the early twentieth century, corrugated iron became a victim of its own success: wartime, industrial and low status use began to generate negative associations for the material.

2.11 Conclusion

The cultural significance attributed to corrugated iron buildings has changed dramatically since the patenting of the material in 1829. An initial enthusiastic response to a bright, functional and innovative new metal changed by the end of the nineteenth century to a perception of the material as rusty, mass produced and utilitarian and suitable only for industry, the poor and the military. The cultural significance of corrugated iron was further diminished by its very success: it was everywhere.

Victorian attitudes to corrugated iron did not remain constant but evolved in response to changing economic pressures and opportunities, and reflected the markedly different needs and ambitions of the military and civilian worlds.

For the English country gentleman or the romantic anti-industrialist, corrugated iron was at best irrelevant and at worst ‘a pestilence.’ But for the colonisers of Australia and the miners on the frontiers of the United States of America, corrugated iron made life possible, and acquired a commensurate significance.

The architectural vocabulary of corrugated iron use in the nineteenth century was shaped by the economic and engineering practicalities of the age. For the newly prominent profession of Victorian engineers, corrugated iron almost immediately attained enhanced value and significance. It opened an array of structural possibilities that enabled new building designs to be realised at low cost. The relative strength and light weight of metal structures clad with corrugated iron permitted and encouraged new buildings of unprecedented
size and utility. These materials (together with concrete) have become the language of construction in the modern world.

The Chatham docks, Sheerness boat-store and Kensington Gore museum were remarkable for their age. They were built not with steel but with cast and wrought iron frameworks, and clad with manually rolled corrugated wrought iron. The production of all these materials was highly labour-intensive, and the buildings are examples of the high level of resource that experimenters were prepared to commit to new techniques.

By the end of the nineteenth century, mass industrialisation in Britain had generated fear and horror at the loss of countryside and historic landscapes. This, combined with the perceived cultural significance of the picturesque and pastoral, developed into an unprecedented rise in conservation awareness both of the countryside and the buildings in it. The cultural significance of historic buildings was recognised and elevated by the introduction of legal protection systems and the extension of state ownership to historic monuments. Pressure groups such as the National Trust, the Society for the Protection of Ancient Buildings (SPAB) and the other amenity societies contributed to both protection and valorisation of historic buildings. The status of these buildings was further enhanced by increased public awareness, in itself driven by mass tourism and the media. However, until recently, conservation values had a relatively narrow focus such as castles, abbeys, stately homes and Georgian townhouses, and served to restrict the cultural significance accorded to ‘new’ building styles and materials.

The value of corrugated iron is also developing a limited recognition when used in a picturesque setting. A corrugated iron shepherd’s hut, set in an overgrown garden, has become an acceptable face of a lifestyle magazine, such as Country Life. Tin chapels with architectural details in the Victorian style favoured by the Ecclesiological society are now a favourite subject of architectural and conservation journals.
Despite indications that the cultural significance of corrugated iron is continuing to evolve, negative associations continue to persist. The association with war is particularly damaging, as is the false assumption that corrugated iron is a temporary and short-lived material. If properly maintained, the direct evidence of physical survivals show that it is a durable material. The concept of temporary is itself problematic. Buildings intended to be temporary often become more permanent and are better described as transitional. This is particularly true when the possibilities of returning ‘home’ are limited, such as in colonisation, war and disaster situations. Perhaps more significantly, ‘permanent’ is a subjective concept: Britain has very few buildings of any construction that are more than 500 years old, and the oldest corrugated iron is now approaching 170 years old.

This is not the case in other areas of the world, where there are numerous architect-designed corrugated iron buildings that explore the design potential of corrugated iron. The perceptions that affect the values of corrugated iron buildings are traceable through the history of the development of the buildings. The values and perceptions ascribed to buildings advise us on which ones to conserve; this is explored further in chapter 3.