# Book Reviews

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**Techniche Costruttive Murarie Medievali**
DONATELLA FIORANI, 1996
Rome. L'Erma Di Bretschneider s.v.l.
292pp. Illust.
ISBN 88-7062-935-X

This book is a massive technical study of medieval masonry in the southern half of Lazio - that is, in the area of the region roughly south of Rome. Existing studies tend to be based on archaeology or art history; by contrast, this volume explores aspects of technological, constructional and architectural history. Its aim is to make a scientific contribution to the history of building technology which will at the same time be relevant to the conservation and repair of masonry structures.

The first chapter gives a general introduction to southern Lazio, with a geography which includes geomorphology, geology and topography; a brief medieval history from the eleventh to the fifteenth century; a synoptic view of the styles of religious and civil architecture; and a more extended study of fortified construction in the heart of Lazio. The second chapter deals with materials: stone (three main types of limestone are considered, namely hard limestone, travertine and tufa); and mortar. Basic wall construction is next discussed: rubble masonry, coursed roughly-worked blocks, and squared ashlar.

Chapter Four assembles this material in a description of building construction, including foundations, two-skin walls and rubble fill (together with reconstructions of necessary scaffolding and falsework), and arches and vaults. The three remaining short chapters attempt to order the technical material both historically and geographically, and trace the interactions of variations of style and technique within the region studied (say 40 km x 50 km). An extended appendix deals with the difficult problem of recording site observations, and a second appendix deals with some problems of the conservation of masonry.

The book is clearly one of enormous scholarship, with copious reference and footnotes, but it is at the same time very readable. It lays down a methodology for the analysis of masonry construction which should provide the basis for many future studies.

JACQUES HEYMAN, University of Cambridge

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**Civil Engineers and Engineering in Britain 1600-1830**
A.W. SKEMPTON, 1996
Aldershot, Hants, Variorum.
338+ xxivpp. Illust. £59.50
ISBN 0-86078-578-5

Re-defining the Industrial Revolution, or even asking whether that expression is still an acceptable description of the economic and social changes which took place in Britain in the eighteenth and nineteenth centuries, has for some years been a preoccupation of historians. The concerns of econometricians about the language used in discussion of the national economy should be respected. At the same time our understanding can be increased by the clarification of the terms in which other aspects of the period are described. One feature of

Britain's 'industrial revolution' which unquestionably had consequences throughout the world was the growth of engineering knowledge and competence. Between 1750 and 1850 the British learned how to make iron machines, and the ability to do so had percolated to every town of consequence by the latter date. Over a somewhat longer period they gained new skills in the management of rivers for navigation, they learned how to build embankments and cuttings, and to create wet docks; and they began to use iron to sustain multi-storey buildings. In short, they came to practice civil engineering. This historic learning process is the theme of this book.

Alec Westley Skempton was Professor of Civil Engineering at Imperial College for nearly a quarter of a century. He became a Fellow of the Royal Society before he was fifty, and has received numerous other distinctions from academic and professional bodies in Britain and overseas. The papers reproduced in this volume represent his achievement not as a civil engineer but as an historian of civil engineering. In the 20-page introduction he describes how he was drawn to historical studies in the early 1950s, inspired by a meeting of the Smeatonian Society, and by the work of Esther Wright, L.T.C.Rolt and T.S.Willan. He sets his work soundly in its historiographical context, showing how astonishingly little was added to popular understanding of the growth of civil engineering in the century after Samuel Smiles. The book consists of twelve papers, previously published between 1953 and 1982, seven of them in *Transactions of the Newcomen Society*. The principal subjects are the construction of harbours, docks and river navigations, the drainage of fens, and industrial buildings, notably Albion Mill in Southwark and the cotton mills of William Strutt. Skempton constantly returns in publications which appeared over a 30-year period to a range of important and rewarding themes; the identification of engineers, the ways in which civil engineers managed projects, and the emergence of the civil engineering profession. Historians of many sorts will be grateful to have so much information and so much wisdom available in a single volume.

The publishers have not wholly done justice to their distinguished author. The standard of production does not justify the high price. The papers are reproduced by a photographic process, and are paginated, rather clumsily, chapter-by-chapter. The numbering of some of the illustrations, notably the plates in Chapter One is confusing, and the reproduction of the maps and pictures can scarcely be judged a triumph for late twentieth century scanning technology. Some chapters have footnotes and some endnotes, and the references follow the varied house styles of the journals in which the paper first appeared.

A common thoroughness of approach characterises all the papers in the volume. It exemplifies the very best the traditional involvement of the engineering profession in the investigation of its own history. Nevertheless the approach is sometimes rather narrow. Except for a passing reference to Howard Colvin's work on architects, Skempton shows no awareness of the work of other historians on the emergence of the professions, not even to Penelope Corfield's *Power and the Professions in Britain 1700-1850* (Routledge, 1995) which has a particularly perceptive section on the Institution of Civil Engineers. More consideration might have been given to patronage as a factor in the growth of the engineering profession, and in particular to the skills acquired by estate stewards and agents. In some respects the stories told in this volume, some based largely on reports and minutes, tend to be rather too neat and tidy. It is fortunate for everyone's safety that civil engineers are accustomed to working in a disciplined manner, but there is a chaotic element in every sequence of historical events which is rarely glimpsed here. Charles Hadfield, Professor Skempton's co-author in the biography of William Jessop, has shown in *Thomas Telford's Temptation* (Baldwin, 1994) how skilled linguistic analysis can reveal untold subtleties in the apparently straightforward prose of civil engineering writings.





These are minor quibbles about a book which brings together research which over four decades has helped to revolutionise our knowledge of industrial and engineering history. When Professor Skempton presented his paper on William Strutt's cotton mills in the early 1950s the President of the Newcomen Society enquired, without apparently receiving a reply, if any early water-powered cotton mills survived in the Cromford area (Chapter X, p203). That this question would now seem ludicrous and that it could be answered, not just from reports and learned articles produced by the Royal Commission, but from numerous cheap publications prepared for tourists and schoolchildren, is due to a transformation of our understanding of so many aspects of our industrial past which has come about through the kind of research which appears in this book.

BARRIE TRINDER, Nene College

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**The British Building Industry Since 1800. An Economic History**
CHRISTOPHER POWELL, 2nd edition 1996
London, E and F.N. Spon
276pp. 48 illust. £19.99
ISBN 0-419-207309

This second edition of Christopher Powell's work (first published in 1980) has been extensively revised and rewritten, with two new chapters to cover a further period to the middle of the present decade. The result is a pioneering achievement, a systematic economic history of building in Britain since the time of the Industrial Revolution. For any substantial industry this would be a long period for satisfactorily detailed treatment. In the case of building its close involvement with the population across the whole country, together with the great variety of its products, modes of organisation, technological methods and materials make it an exceptionally difficult subject. Furthermore, the history of building displays no revolution such as can be seen in industries which have been in the forefront of industrialisation, from cotton to computers. This absence of rapid, radical change is an interesting and important feature, but of its nature provides a less sharply defined field of study. Such features as growth of output and productive efficiency and changes in products, organisation and technology have been comparatively slow, diverse and evolutionary, as the author remarks. Even so, the industry today is, as he also observes, very different from what it was like two centuries ago.

Powell explains in the *Preface* that his system for ordering this complicated subject was to aim to '*introduce and describe nearly two centuries of buildings as an agency of change in the national building stock*'. (p.ix) He continues: '*Two related groups of simple questions are addressed. First, who decided to build, why, and what was built? Second, who built and how did they do so?' By these means he aims to 'focus and unify a fragmented historical picture*'. (p.ix) Since he takes building to be the provision of shelter, purely engineering construction is not dealt with. England and Wales are the areas covered unless otherwise stated, Scotland being left, with regret, '*to others*'. (p.x). The industry is defined to include its allied professions as well as the building firms and their workers. A temporal framework is provided by five historical periods which are distinguished from one another by particular features of the industry and its relationships with the economy, the state and society. Two chapters cover each period. The first deals with demand and building promoters, additions to the building stock, and building form. The second, character and influences, the professions, firms, building materials, components and processes. This

approach, of course, strengthens the ordering of information within each period. Also, as the author says, it means that '*common threads may be traced through them all*'. (p.x).

The building of 'Coketown' between 1800 and 1850 begins the history. Dickens's name for a northern factory town in *Hard Times* serves well to signal the break with the past by which building became involved in providing the factories and housing of the new industrial system, and infrastructure, in a development without precedent in terms of pace and characteristics. Yet, as this opening chapter makes clear, there was another England, much longer established and with London at its centre, with which the building industry was stimulatingly involved. London, much the largest and wealthiest city not only in Britain but in Europe and itself growing fast, was particularly important for developments in the building industry. It was there, rather than in the North, that the first great building contractors in the modern sense emerged. Large, but small in numbers at first, they brought the trades with their medieval craft origins under unified control in single firms and offered customers what they evidently increasingly looked for, a contract for the whole building at a fixed price. It is of interest that this innovation did not spread to all parts. As late as the present century it was not established in some areas of north of England nor in Scotland. In this first half-century architecture, too, underwent significant changes. As Powell points out, its organisation as a profession in the modern sense helped to meet the needs of an increasing diversity of clients, many of whom lacked experience of procuring buildings.

The history concludes - except for an *Afterword* - with a chapter in which '*The industry recasts responsibilities: after 1973*'. Circumstances both internal and external were calling into question the efficacy of the system of procuring buildings which had developed in the nineteenth century in the ways so well traced in this book. For the architects the task of comprehending the technological complexities of buildings had greatly increased, suggesting the need for closer involvement of the contractor in design and specification and as a consequence the development of new forms of contract. Customers, especially property development companies, but also other large public and private bodies, were seeking greater speed and reliability at a time when the merits of competition were being heavily emphasised. The Government's concern about the industry's efficiency in terms of costs and quality of product reached a high point in the 1990s. The Latham Report to the Department of the Environment in 1994 on *Constructing the Team* made important recommendations for reducing the industry's costly adversarial character and encouraging a culture of partnership together with faster increases in productivity.

In the short but very perceptive *Afterword* Powell reflects on a number of aspects of change and continuity over two centuries. He suggests, for instance, that whereas the pioneers of the new form of contracting in the early nineteenth century gained prestige from the large scale of their operations and their technological progressiveness the opposite is today the case for the industry's leading firms because '*they no longer command notably great or advanced resources*'. (p.231). If so, that may change if such firms succeed in the radical transformation which is being attempted. However, the industry's nomadic character as it moves from site to site, each having potential for costly surprises, together with its generally bespoke transactions with its customers, will endure. It is probably these features more than anything else that have constrained growth of productivity over the long term. If so, it may be inferred that good building in the end requires acceptance of costs which can be reduced only slowly compared with those of industries at the forefront of economic development. This book provides a sound basis and encouragement for such reflections.

E W COONEY





**L'Art de L'Ingenieur: Constructeur, Entrepreur, Inventeur**
An Exhibition at the Centre Pompidou, Paris, 26 June - 29 September 1997.
Catalogue of the same title, Edited by Antoine Picon
Paris, Editions du Centre Pompidou et Editions du Moniteur.
598pp. Illust. 540 Francs.
ISBN 2-85850-911-5

Any exhibition of engineering work is bound to be significant, since the work of engineers is too rarely displayed, but what makes a successful exhibition and how can the art of structural or civil engineering be presented within the confines of small space? For compared with the material shown even the Centre Pompidou is a small space. Moreover, how is one to encapsulate all of engineering art within the single volume that an accompanying book must almost inevitably be? There are simple practical answers to these questions. First of course, some limit has to be placed on the scope of the material shown, and here the title of both the exhibition and the accompanying book is a little misleading since they deal only with structural engineering. Secondly the scale of space available in the Centre Pompidou did make possible some dramatic presentations that contributed to the outstanding quality of the displays.

An exhibition may be considered successful if it absorbs one to the extent that fatigue does not become an issue. Another measure of success is if one makes new discoveries, either by discovering things that one knew little or nothing about or by seeing the familiar in a new light. *L'art de l'ingénieur* succeeded in all of these ways. There was so much to look at that advice to make more than one visit to avoid visual overload was sensible - but never were the attractions of the bar or café greater than the next display. There was also material which must have been new to most of those interested in the history of engineering,if only because the exhibition went so far beyond what one finds normally presented.

The exhibition was divided into different spaces covering different aspects of the engineer's art but also providing different opportunities for the curator. It was the first two of the galleries that perhaps contained material of most interest to historians, the rooms dealing with iron and with concrete rather the current lightweight structures of the third space. But what was called contemporary research in the fourth room also had material of historical interest since some of the exhibits looked back nearly half a century and covered developments that may be a memory to some but will be history to others.

To concentrate on structural art, buildings and bridges rather than civil engineering projects such as canals and tunnels, was a perfectly reasonable choice for the curator: some limitation was obviously necessary. But it was not a completely rigid division and one was left wondering why some items were included: the Great Eastern Steamship for example. Its inclusion raises one's awareness that a major aspect of engineering is to facilitate trade and transport and thus something on canals or harbour works might have been equally appropriate. The same might be said of the section dealing with concrete dams which included a huge wooden model of the concrete Daniel Johnson dam. This is a dam without water, looking at the forms of the structure which are largely invisible once the valley has been flooded. Attention was drawn to this because of its visual structural form while the rest system of which it is a part was ignored. What the exhibition did not address is the part that engineers play in society.

In the first room concerned with iron structures it was British developments that predominated, something that has not escaped the notice of the French, while in the second room the reinforced concrete structures were predominantly Continental, as one would expect since that is where the early development took place. But even when it comes to

later shell structures continental examples predominated and British visitors might have noticed that it was fascist aircraft hangars rather than socialist bus garages, but then the former are much more dramatic. Such were the impressions left by the powerful visual images that remain in the memory that one wonders how well any attempt to present themes within the structure of the exhibition succeeded. A link between the Brompton Boilers and Jenny's Home Insurance Buildings because both are examples of 'Préfabrication et industrialisations du bâtiment à l'heure americaine', which is the way the catalogue informs me that they were arranged, was quite unconvincing. In actually viewing the exhibits, it was simpler just to see the American buildings as part of 'Le temps des gratte-ciel'.

One of the tasks of presenting the art of engineers is to convey the scale of the works that they carry out. One way of doing this is through models but (and I can only speak personally here), for all that they formed a prominent part of this exhibition this is one medium that for the most part leaves me cold. I see only the model-maker's art, although I know that this was a delight for some who saw the exhibition. The more interesting models were those used to explore the working of a piece of engineering or the processes of construction. Thus, I was immediately captivated by a model close to the entrance of the iron exhibition of a timber structure, the falsework that was built to erect the iron-ribbed dome of the Halle au blé, Paris. In the concrete gallery there was the structural model for Trorroja's Fronton Rocolletos with a complex assembly of cords and pieces of wood that produced the distributed load to test the behaviour of the structure.

It is generally impossible to convey the sense of scale except by having the real thing, but there were examples that came close to this. In the Iron Gallery there was a piece of Stephenson's Menai bridge, part of the lower chord flame-cut out of the structure and presented just as it was, with nothing more than a coat of paint: perhaps it would have been more dramatic without that coat. In the concrete gallery was the end of a bridge segment, presented like a three dimensional cut-away drawing with the reinforcing bars and the prestressing anchorages. What both of these demonstrated in their different ways was the nature of the medium with which the engineer works, riveted iron in one case, still visible in the final product, but the steel eventually hidden within the concrete in modern structures.

Another way of showing the scale of engineering works is to use very large images and this was done by projecting them onto the wall of the gallery. This was particularly effective in the Iron Gallery where the whole of the side wall was used for this. Thus one saw Telford's project for the iron bridge over the Thames at London spanning the full length of the gallery: something like the size that it would have been. Similarly one might glance up from an exhibit in one of the cases to see the whole of the hull of the Great Eastern. Never mind if one had seen these images before in a book, there can be nothing like the experience of seeing them projected at this size. For some reason similarly projected images in the concrete gallery had a less dramatic impact. It may have been that they were at one end of the gallery and so separated from the main part of the exhibition, so that one had to make a conscious decision to stand and watch them with the all too solid three-dimensional material a more urgent draw. But it may also have been that these were structures whose drama was in their interiors, structures like aircraft hangars which can be captured less well from the outside or, even as interiors, by projecting onto a flat screen.

The theme suggested by the exhibition's title remains a puzzle. Is art simply what we find beautiful or are there real artistic intentions behind engineers' work? It is difficult to imagine Stephenson had any artistic intentions when designing his tubular bridges. And was it not simply the logic of topography, ground conditions and the mathematics of water pressure that produced the curves of an arch dam, no matter how beautiful we may find the result? That some engineering products may be thought beautiful is no more art than the





product of the mindless working of spirograph. At the same time there are those engineers who clearly do have artistic intentions. This is surely true of the bridges of Maillart or Calatrava, the concrete work of Torroja, Nervi or Morrandi and perhaps of many of the lightweight structures that were displayed. There is also the question of the extent to which building structures can be considered an aspect of the art of the engineer: what was the contribution of engineers to early skyscrapers? In general how is one to tell without some knowledge of the process of design? This is something that is difficult to address in an exhibition: it might have been addressed in an accompanying book, but not one of the form which was adopted.

What engineers produce most directly are their drawings and the general visitor would have found more of these for iron and steel structures. Here the visual impact was sometimes stunning, sometimes intriguing. There were some sketch-books of Brunel (although I felt that more interesting pages could have been displayed)and later production drawings of the Woolworth building: drawings of the wind bracing that are more frustrating than visually attractive because without a plan it is not possible to see where these frames fit into the structure of the building. The much later concrete drawings are interesting for the quite different styles in the manner of handling the reinforcing details.

The other meaning that we give to art is simply that blend of knowledge and skill that the engineer brings to the work. This is an art that is developed through experiment and theoretical analysis. The engineer as artist is, like any other artist, exploring the possibilities of the medium while developing it at the same time and, just as the fourth room in the exhibition considered the wind-tunnel experiments that have been necessary for the development of long-span bridges, so the earlier rooms displayed early treatises on construction in iron and concrete. Here is the engineer as inventor and entrepreneur.

Between the theories and the final construction comes the art of making without which there would be no engineering, the engineer as constructor. Beyond the design is the process by which the building is to be put up and one wonders if it was deliberate that what visitor saw immediately on entering the first room was a model of the falsework for the Halle au blé while the first model in the concrete gallery was of falsework for a concrete bridge? Next to the drawings of the Woolworth building was a film of the construction of the Empire State Building, fascinating as we watch the erectors' vertiginous acrobatics in bringing the steels to their place and fixing them. But it is in the dramatic concrete structures that this marriage of art and artifice occurs, or at least is shown to occur. Of course the construction of iron bridges in the nineteenth century required the same kind of attention to the process of erection. The drawings of the chains and hydraulic presses for the erection of the Menai bridge are there so that one can work out exactly how the spans were lifted into place. What one wonders is whether the lithographs of the spans being floated out into the river would have been as powerful to a nineteenth century audience as the films of the erection Pont Albert-Louppe, or of Freyssinet's hangars at Orly were in the exhibition.

These films, projected onto the wall, were powerful as much because their size and perhaps because there was no sound commentary. What was shown was the moveable centring for both of these structure being manoeuvred into position. Each were considerable structures in their own right but ones which had to be lowered away from the completed concrete work, moved and then lifted into position to make the next section. For the hangars the placing of the steel and the construction of the top of the formwork was shown and then the pouring of the concrete. This was film footage that conveyed the drama of construction as no drawings ever could.

The catalogue of the exhibition is simply an appendix in the form of a giant book which

accompanied the exhibition; the largest volume with which I have ever been burdened as I staggered away from an exhibition! As is common today the book is far from a catalogue of the exhibition and so needs to be treated separately. It is set out in the form of an encyclopaedia with articles contributed by a number of specialist authors. One would therefore hesitate before commenting on the content of these articles. No one would presume to have the encyclopaedic knowledge to make a balanced criticism across the full scope of subjects covered which deal with different engineering forms, the biographies of engineers and even explanation of particular techniques, such as prestressing. There are articles on soil mechanics and the strength of materials as well as on individual materials. What one can comment on is the balance and structure of the collection as a whole and perhaps whether this was an appropriate form to use.

Here again the structural bias of the exhibition is seen, although there are articles on some other kinds of engineering. Perhaps it would have been better had the bias been as thorough in the book as it was in the exhibition because the result is a rather token inclusion of some of the subjects. For example, there is an article on tunnels, although nothing on individual tunnels: there is an article on canals, although nothing on particular canals - not even the Suez. In contrast, there is an article by Skempton on the Eddystone Lighthouse, and an article on the Roche Douvres lighthouse but nothing on lighthouses in general so that their inclusion seems a little arbitrary. Nor would it have been possible to discover that these articles were there by looking under lighthouses in the index. There are then some subjects which seem to have little connection with structural engineering or whose connection is perhaps more imagined than real. Biomechanics scarcely seems important as a contribution to structural engineering.

The real problem for an editor must be ensuring a consistency of approach when soliciting contributions from a wide range of authors. What brief were they given? Many of the articles do take an historical bias, even some that might have been handled in other ways. This is true of Frank Newby's contribution *Architectes et ingénieurs* which begins by considering the origins of the engineering professions in France and Britain in the eighteenth century before considering the collaborations of this century. In contrast, the article on laminated timber provides an account of the material as it is today but says nothing about its history. There is no mention of Emy's nineteenth century work on the subject nor of the German inventor of glued laminated timber. The issue here is not simply the extent to which it is desirable to describe the historical background to the present day engineering phenomenon but the consistency of treatment which one should like to have seen.

The article on dams again shows a structural bias because it deals with arch dams rather than any other kind. The author of this article is concerned to recognise the contribution of François Zola, pioneer of this type of dam in France, whom he seems to feel has not received due attention. Readers may feel that they learn more about the biography of this man than they wanted to know compared with more technical issues that might have been covered. There is nothing on gravity masonry dams or earth filled dams in this article in spite of the article on soil mechanics being illustrated with a section through one of the latter.

This article on soil mechanics is one of a number that seek to explain engineering phenomena; examples of others being structural behaviour or strengths of materials. But it is difficult to know how much of these things can be satisfactorily explained in this kind of text and it is difficult for a reviewer who has his own way of explaining such things to approach impartially the explanations of others. However, here again there is the question of balance. There is no attempt to illustrate the mechanism of prestressing which I would like to have seen, the article concentrating on the history and a description of techniques,





and yet this is something that can be explained as vividly as the *modéle vivant* which explains the cantilever mechanism of the Forth Bridge. Providing some simple sketches and a text to illustrate the behaviour of so fundamental an engineering device as an arch, which receives no treatment, also seems more important that a drawing to illustrate the meaning of Poisson's ratio.

The book is copiously illustrated with some magnificent pictures, although again one is tempted to be critical because there are many that one could have managed without while wanting pictures that are not there. There are no illustrations of structures by Calatrava, although opposite the article on his railway station at Zurich is an illustration of precast concrete window frames purporting to illustrate standardisation that conveys nothing to me. All readers will probably find their own gaps in both the text and the illustrations. To be all things to all men is a hopeless task, and just as one had to be grateful for the films of construction work in progress in the exhibition there are some excellent and dramatic photographs in the book.

The advantage of the encyclopaeda format is that one has a reference work where one can look up individual projects or the biographies of particular engineers. What one cannot look up directly are the various institutions and societies: these only appear as mentioned in other articles. This format enables articles beyond the simple factual; the discussions of the influence of nature on the thinking of the engineer or the aesthtics of engineering works. But it does not allow more discursive pieces, perhaps on such subjects as the ways in which engineers have developed within society (the article *Formation des ingénieurs* does not do that), their influence as entrepreneurs or inventors.

If one imagines the wide range of visitors that must surely have come to an exhibition of this kind, one might imagine a range of material that they might wish to buy: a dictionary of projects and personalities, which this encyclopaedia is in part; something that explains the forces in a wide range of structural types; some essays on the phenomeon of engineers as artists, as entrepreneurs or as agents of change in society. What the teachers of history and the teachers of engineering will surely want are those films that show the scale and the drama of the art of engineering to inspire the engineers of the future. What I should like to have been able to buy, far more than an encyclopaedia, would have been films, videotapes or CDs which explained aspects of this art and which showed these dramatic works of the past under construction. The exhibition showed considerable imagination in its presentation and considerable variety in the material used. The encyclopaedia format simply misses out on that.

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**Constructing a Bridge. An Exploration of Engineering Culture. Design, and Research in Nineteenth-Century France and America.**
EDA KRANAKIS, 1997
Cambridge Mass. and London, MIT Press.
454pp. 44 illust £38.50
ISBN 0-262-11217-5

*Constructing a Bridge* looks at engineering in France and the United States during the early years of the nineteenth century at three levels. First the design of suspension bridges, particularly the ill-fated 1826 *Pont des Invalides* in Paris, and a series of chain bridges which James Finley, farmer-politician and inventor, patented in 1808 for a rural 'do-it-

yourself' market in Pennsylvania. Secondly the educational and professional structure within which engineering design developed in the two countries: the already mature system of education at the *École des ponts et chaussés*, Paris, and the largely, but not entirely 'training on the job' in the young United States. And finally the related social and cultural environments within which engineering and technology flourished.

Professor Eda Kranakis of the Department of History, University of Ottawa, admits her book had been 'long in the making'. Its long-making has been worthwhile. Having dug deep on numerous sites in Britain, France and the United States, including the French national archives, and those of the *École des ponts et chaussés*, Kranakis' 44-page bibliograpy, listing special collections and mss, periodicals, and primary and secondary sources in Britain, France and the United States is a valuable guide for others planning similar studies. Missing from the list is one important document, recently chanced on the Côte d'Or *départemental archives*, an 1804 *Decret Imperial portant organisations du Corps des Ingénieurs des Ponts et Chaussées*, signed by Napoleon from his invasion base at Boulogne not long before the Emperor abandoned his plan to invade England, and marched the *Grande Armée* across Europe to the gates of Moscow. After the debacle which followed, the Napoleonic Empire soon came to an end at Waterloo. The *Corps*, whose organisation was established under this Napoleonic decree, survives, with few major changes.

The French bridge designer, whose social background, education and career as an engineer-scientist Kranakis uses to illustrate her thesis, is Claude-Louis-Marie-Henri Navier (1785-1836). From the age of sixteen, when Navier left his Dijon home, he stayed in Paris with his uncle, Emiland Gauthey, a distinguished senior member of the *Corps*. Except for a few years in Napoleonic Italy and two short visits to England, his youth and professional life were spent in a world where science and mathematics ranked above work in the field. During that time Navier was to update and edit standard publications like Belidor's *Science des Ingénieurs* and *Architecure Hydraulique*, becoming a member of the theoretical mechanics section, *Académie des Sciences*, at the age of 39.

An account of the ill-fated *Pont des Invalides*, has already been published in less easily seen Dutch journals. It is a subject which merits a book on its own. Navier's career, and his approach to the design of the Paris bridge, highlight the strengths, and weaknesses, in the education of *École polytechnique - École ponts et chaussées* graduates. The Invalides bridge may be an extreme example of what can happen when an academic, with no previous experience of the kind of work involved, is called on to design a novel kind of structure, in this case a 70m span suspension bridge crossing the Seine at a place where there was no need for the bridge other than to demonstrate 'the character of grandeur'.

Navier, a 'high-flyer', held mathematical theory to be a necessary foundation for good design. But in its application he largely ignored the practical experience of British bridge builders. While British designers built models and did tests, Navier chose to develop a design method based on mathematical analysis. He used theory to proportion various structural elements of the bridge, and to maximise the structure's stability. Guided by a belief that heavy bridges were relatively more stable, the dead weight per linear foot of the bridge which he designed was to exceed that of other suspension bridges being built at the time.

As construction proceeded, cracks began to appear at the base of each tower, widening to 5 centimetres as the roadway was completed. There was a second mishap when water, from a broken main, flooded the area around the anchorage buttresses on the Right Bank, one of which tilted 40 cm. Work was stopped while damage was inspected by the executive council of the *Corps des ponts et chaussées*. Initially, they thought it would be a





straightforward repair job. But, failing to agree which party should pay for the repair work, construction was abandoned. In the end, contractor, Desjardins, and the project investors were compensated. Desjardins was allowed to provide his own designs for three other Seine bridges, the only stipulation being that they passed load tests supervised by the Corps. Eventually they were built - to make a profit, rather than demonstrate the merits of mathematical analysis. One, the *Ponts des Champs-Elysées*, a suspension bridge having a 72m span flanked by two half spans, described as 'truly a villainous thing', stood for 25 years until replaced by a masonry structure.

Among critics of the Invalides bridge debacle were the '*ingénieurs civils*', men trained at institutions like the *École centrale* and working in the private sector as *constructeurs*. Like their best known member, Gustav Eiffel, they were 'design-build' engineers, constructing under contract magnificent iron structures such as the Garabit viaduct and the Eiffel tower. Their role within French engineering merits further study as it would help to understand why engineering design in France is largely in the hands of *bureaux des études* and not of consulting engineer, as in Britain and the USA.

The debacle dealt Navier's career a devastating blow, and he died a few years later, a sad if not broken man. A mathematical rather than practical approach to structural design was not unique among engineers trained in the *École polytechnique - École ponts et chaussées* tradition, but there are reasons why Navier's work was at the extreme end of a range of appoaches.

James Finley's scheme for constructing suspension bridges in rural Pennsylvania was in sharp contrast, representing the vitality of a pioneering entrepreneur in a new country with few traditions and little sources of technical information other than that drawn from the article 'Bridges' in Rees's *The Cyclopædia; or, Universal Dictionary of the Arts, Sciences and Literature*. Published in London while Finley was working on how to meet a need for a bridge design '*economical to build and maintain....uncomplicated enough to permit construction and maintenance by blacksmiths and carpenters without specialised training*', it showed the value of the kind of simple experiments Finley needed to determine the lengths of hangers and links of a suspension bridge of a specified span.

Kranakis describes how Finley worked out how each element of a bridge - chains, hangers, roadway, towers and anchorages - were fabricated and how he dealt with the safety factor problem empirically. Like other American bridge designers in the early 19th century, Finley patented his design. For this among other reasons, the exact number of bridges built is now known. Initially the system was adopted with a burst of enthusiasm. Out of 22 know bridges, eighteen were built before 1812, and the remaining three after the Finley patents had expired. Two built on Finley's plan remained in service for a century or more. Three others collapsed when chains in their main structure ruptured less than twenty years after completion, in each case during the winter under the influence of extreme cold weather and a heavy snow load.

However, *Constructing a Bridge* is much more than an interesting account of Navier's and Finley's bridge-building. Its main purpose is to explain how the '*social structure of the French and American technological communities and their distinct systems of training*' shaped engineering practice and the processes of design and research in these two countries. In an early Chapter, 'Theorising the Suspension Bridge', Kranakis refers to the work of such British engineers as Barlow, Brunel, Telford and Robert Stevenson. To extend the Kranakis thesis to the quite different technical and social environment in which British engineers were trained and practised in the nineteenth century would be a worthwhile venture.

GEORGE ATKINSON

**The Liverpool Dock Engineers**
ADRIAN JARVIS, 1996
Stroud, Glos, Sutton Publishing Ltd.
288pp. 50 illust £17.99
ISBN 0-7509-1093-3

Liverpool, docks, engineers - prosaic enough, and a straightforward title, but somehow these words combine to have a romantic allure. Sure enough, the dust jacket sets out a bigger stall - '*out of Liverpool came a string of famous engineers who spread the skills they had learned there literally around the world*', and '*the development of [Victorian] dock engineering was almost synonymous with the work of the Liverpool dock engineers*'.

Adrian Jarvis tackles his subject with enormous verve and an enjoyably conversational style - a huge plus given that a book on dock engineering could so easily be direly unreadable. He has fun with demonic anecdotes. For instance, an account of difficulties with shifting sands in the Mersey contrasts a revetment built by G F Lyster to the door erected in the desert by the Roadrunner - the Coyote knocks on the door, the tides just went round the revetment. A characteristic description of Lyster as '*confident, authoritative and garnished*', might also be applied to Jarvis's writing style.

This reviewer joins the author in making a clean breast of having no engineering training. Naturally, therefore, this is not a point of criticism here; nor should it be elsewhere. It is not just that the historian may be more at home with prose, but as so few historians have been able or willing to bridge the disciplines, engineering has been too little subject to the analytically historical mindset. As Jarvis reminds us, Samuel Smiles is still absurdly current.

The core subject, Liverpool's dock engineering in the period 1824-1913, is stoutly addressed. Through extensive research and an array of publications Jarvis has acquired a well-earned ownership of this subject. The book's structure is not immediately intelligible, but in the end it works. A 'project management' approach has been adopted, taking the reader from planning to fitting out. This has particular value for its emphasis on the engineering as against either the engineers or the docks. There is some discursiveness, with biographical material scattered, and some basics are missing. We are not given the dates of the main protagonists, and there is a need for a handy summary table setting out Liverpool's docks, with building dates, engineers and costs.

A strength of the book is that, as the blurb tells us, '*particular attention has been paid to "finding" the usually neglected men at third and fourth tiers in the structure*'. This reflects an overall regard for the 'corporate' nature of the subject and represents considerable scholarship. The reader gains a sense of having visited the Dock Yard, the unique in-house base for Liverpool's engineering. The book has numerous insights into the nature of large institutions. It is good on the management and processes of major construction projects, of interest well beyond a dock context. The discussion of the shipping context is solid.

A keen interest in human relations and organisational dynamics has led Jarvis to uncover the Board members who didn't read the minutes, the engineers who failed to keep up with professional reading, the cockups over units of measurements, and the massive expenditure on pointless dredging while pipes in the lavs were being painted rather than polished to save money. This is familiar messy reality. Far from trivial, it is part of charting the path from robust success to inefficient complacency.

As so far described the book is essentially a good and valuable local study. The use of local history as an exemplar for general history needs a dispassionate touch. The local, even when the subject is a great port, is rarely an adequate platform for conclusions of a national





or international nature. Jarvis acknowledges his dilemma by admitting that his focus on Liverpool is '*an apparently foolhardy narrowing of the subject area*'. Of course, it is not, so long as the subject is Liverpool's dock engineers, but it is once something wider is intended. At this point it would be best to declare an interest having read the book as one whose knowledge of the subject is London based. Through the 19th century Britain had two great general ports - Liverpool and London. In so far as this book draws conclusions about dock engineering beyond Liverpool the absence of reference to London, in the text and bibliography, is an important omission.

A tendency to see the world as spinning around Liverpool has many distorting effects. We are desperately ignorant about 17th and 18th century dock engineers. The fact that Liverpool led in the building of commercial wet docks in the 18th century is insufficient basis for the presumption that it provided a lead in dock engineering. As Jarvis recognises, '*the contribution of Thomas Steers strictly to the technology of dock-building does not seem to have been very notable*'. We know too little about work in the Royal Dockyards or by Ordnance engineers, and even less about early 'engineer/carpenter' dock contractors.

Early 19th century developments in dock engineering cannot be understood without reference to London. Jarvis considers Jessop's and Rennie's Liverpool consultancies, but without mentioning that at the time that they were engaged in unprecedently massive and innovative dock works in London. The Aydon & Elwell type cast-iron 'swivel bridge', which derives from designs by Ralph Walker made in 1800 for use at the West India Docks, had been made in Bradford for use in Hull, London and Liverpool by 1809. It became a standard type in both London and Liverpool and was used elsewhere through the first half of the century. The survival of one of these bridges at Liverpool and its detailed analysis by Jarvis are therefore all the more valuable. This bridge tells us that the development of dock fittings is not port specific; ideas and innovations shifted around, a fact that is given insufficient emphasis.

Undoubtedly Liverpool had a mid 19th century period of pre-eminence, when the quality and quantity of its dock engineering was superior to that elsewhere. However, it can be argued that Jesse Hartley stands at the end of a tradition of heroic engineers, rather than at the head of a new tradition. Some of his greatest achievements were late flowerings. His granite dock walls were built shortly before mass concrete came into wide use. The Albert Dock was the last of the major multi-storey dock warehouse complexes. The most obvious point against the idea that Hartley founded a dynasty is that his successor, G F Lyster, was a pupil of J M Rendel. Innovation occurred away from Liverpool and many important dock engineers had only passing acquaintance with the Mersey - to cite three 'dynasties', the Rennies, the Walkers and the Rendels. Liverpool had the Hartleys and the Lysters, with Hawkshaw and Rawlinson as protégés, but the '*string of famous engineers*' goes no further. The proposition that the Liverpool Dock Yard had a role analogous to that of L'École de Ponts et Chaussées is unsustained, even the lesser argument that it was in some sense a '*centre for the dissemination of expertise*' is unproven.

The desire to see Liverpool as the fount of all developments means that late 19th century diversification in dock engineering is inadequately reflected, though it is hinted at through the decline of the Liverpool establishment. Ingenuity had many sources. Liverpool was reluctant to invest in special-purpose equipment. There was a different approach at the Millwall Docks where a highly competitive situation stimulated innovative engineering based on American example in the form of F E Duckham's 1870s grain-handling equipment. A travelling roof crane devised by A G Lyster in the 1880s is presented as innovative, yet Augustus Manning introduced similar crainage at the East India Docks in the 1870s. When Liverpool's older docks were deepened the simple expedient of 'false' quays

used elsewhere was apparently avoided.

The layout and appearance of the book is attractive and there are some fascinating illustrations, but often too small, and eccentric in their range. Some topics, dock bridges for example, are well illustrated, others hardly at all. Some illustrations seem arbitrarily placed, without relation to nearby text. There is a single map, usefully bound as a fold out at the back, but murky in its detail. The text is generally well referenced, but the index is inadequate. Proof reading was sloppy; there is reference to '*the inconvenience caused by operating a movable bride on the perennially crowded Dock Road*' - are we suddenly back to John Bernard Hartley's marital problems?

This book is enjoyable and useful. It advances knowledge considerably - about Liverpool, about dock engineering, and about the products of that aspect of engineering. It is not, however, the bigger book that it purports to be. It contributes much to the study of a subject where more work is needed before that bigger book could be written. Here is what happened in Liverpool. How was it reflected elsewhere?

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**Building the Nineteenth Century**
TOM F PETERS, 1996
Cambridge, Massachusetts and London, England, the MIT Press
535pp., 178 illustr. £32.50
ISBN 0-262-16160-5

This is a fascinating though somewhat frustrating book. The title, the blurb on the dust jacket and the preface suggest a broad-brush analysis embracing building, engineering and technology. Peters aims to '*look at how builders' thought processes influenced construction, and particularly at how construction thinking changed, in the last century*'. He clearly pins himself to the progressivist mast. His preface defines three stages: a pre-industrial one when '*builders did not yet recognise the act of constructing as a process*', a transitional phase when contractors sought to develop '*technological thought in building*' and a third stage when projects demonstrated '*the breakthrough of mechanisation and a mature form of technological thinking*'. The reader should welcome an attempt to categorise an incredibly complex aspect of history, but might be nervous already about the use of generalisation and jargon.

The most curious aspect of this book, given its title and its agenda, is the choice of case-studies. None are conventional buildings with solid walls and roofs, though there are brief reference to the Albion Flour Mill in London and fireproof structures in the United States. Peters aims to unravel the '*genesis of the building process*' by considering some of the most exceptional and daring engineering projects, from Marc Brunel's Thames Tunnel to the Panama Canal, which was, of course, completed in 1913, well beyond the end of the century.

It is worth perservering with this 535 page tome. It opens up a fascinating subject area: innovations and failures in major engineering projects, and, more specifically how engineers and contractors pushed the boundaries of what men and machines could achieve when tunnelling under rivers and through mountains, or constructing bridges, towers and exhibition halls. Peters' starting point is that commercial pressures made engineers and contractors focus on speed rather than quality. The case of the Woodhead Tunnel (1839-45),





where Wellington Purdon justified 32 deaths by the speed with which he bored through the Pennines, is presented as an unsatisfactory starting point, dramatising the need for improvements in 'the building process'. Compressed air allowed railway engineers to work faster and more safely in challenging environments. The Mont Cenis Tunnel, the first to conquer the Alps and opened in 1871, involved experiments with new types of compressors and drills, pneumatic machines achieving a twelfth-fold increase in progress over hand drilling.

The section on the Conway and Menai Bridges explores how Robert Stephenson, Fairbairn and Hodgkinson worked as an engineering team, resulting in avant-garde approaches to site organisation, component manufacture and erection. Stephenson is credited with working through key issues - structural experiments, constructing the masonry piers and making decisions on the superstructure - in parallel, so using a '*primitive form of critical-path and matrix thinking*'. One could argue that canal engineers of the preceding century also had to resolve major problems - water supply, geological stability and major aqueducts - without the luxury of being able to resolve one before moving on to the next. Peters uses the example of the Menai Bridge to present the idea of an 'aesthetics of process'. Stephenson's bridge may have looked somewhat ungainly but the decision to raise the piers above the level of the beam supports was an 'elegant' means of allowing the tubes to be lifted into position.

The Suez Canal, opened in 1869, marks the shift from manual to mechanised construction, although the French engineers became clogged, literally, by pragmatic problems, as the fine sand clung to the dredge buckets. Lavalley combined steam-powered earth moving equipment with teams pushing wheelbarrows and mules working inclined planes, simple technology being justified by the availability of cheap labour.

Chapter Six focuses on buildings, starting in 1830 with the Sayn Foundry in Bendorf, progressing to the Palm House at Kew, the Crystal Palace, the Brompton Boilers and ending in 1889 with the Eiffel Tower and the Galerie de Machines built for the Paris Exhibition. Aided by crisp isometric drawings, Peters charts the simplification and mass production of components, the use of building sites as assembly lines and problems with stability and thermal movement inherent in metal-framed structures. A brief consideration of the American balloon frame shows a more pragmatic approach, ideal for unskilled labourers equipped only with saws and bags of nails, and with no worries over precise tolerances. Eiffel is credited with developing an 'open system', a kit of parts that could be applied equally to bridges and tall structures. The Galerie was built with a series of pre-assembled components, and is lauded by Peters as marking the point where analytical engineering became a key determinant of built form. His argument is persuasive, but it would have been helpful to have information on some prosaic matters, such as when and where Eiffel starting substituting steel for cast and wrought iron.

The two final case-studies are the Langwies Viaduct in Switzerland (1912-4) and the Panama Canal. With both of these organisation is presented as the key to success. Bar graphs were used to co-ordinate work on the Hennebique concrete viaduct, and to minimise the problems caused by the short summer and difficult terrain. The Panama Canal presents a fitting finale, the scale and political overtones of the project highlighting the problems of housing, health, recruitment and transport. Malaria and yellow fever were the worst nightmare, in an area long known as the 'pest hole of the world'. Such concerns are seen as being more daunting than the actual digging work, the designs of the French shovels, dredgers and cranes largely deriving from those used at Suez fifteen years earlier. Peters recounts how once the American government had move in on the project, huge Bucyrus shovels and double cableways brought the Canal to completion, despite the Navy ordering

changes in the width of the channel and the lock design after some plant was already installed. Credit is given to George Goethals, the American chief engineer, who directed the organisation, transportation and material supply with military precision. This section benefits enormously from being illustrated by photographs as well as drawings. The reliance on engravings and drawings elsewhere gives the volume a distinctive flavour, very much in the mould of the MIT Press, but it reinforces a suspension roused by the text that the author has never visited most of the structures discussed. In some cases the picture researchers have chosen off-beat and subjective engravings, such as of the Iron Bridge or the Tay Bridge.

In his brief concluding chapter, Peters brings together the idea of building as a process. He urges the importance of thinking in terms of structures rather than materials and in systematic problem-solving as opposed to experimentation and fortuitous discovery. British engineers pioneered the mass production of building components in the early Victorian period, but Eiffel took the concept of a building system into maturity. In his final paragraphs the author justifies his concentration on engineering projects by explaining that train stations, hospitals, banks and opera houses are not pure works of architecture but machine-buildings dependent on such technology as safety elevators and water pumps. Peters sees matrix or contextural thinking as the key to understanding the building process within the context of technological advance. There is a brief aside where he admits that building is rarely the vanguard of modern science and technology. This is the fundamental chink in his argument. While this book is inspirational in its approach and brings together valuable information on some of the world's greatest engineering feats, one cannot help feel as though his text would have been richer for embracing building as opposed to engineering more fully and if he had recognised the continued use of hand labour and traditional materials for the vast bulk of construction during the nineteenth century.

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