MAISIE TAYLOR & FRANCIS PRYOR, **Bronze Age Building Techniques at Flag Fen, Peterborough, England,** *World Archaeology*, 21, 3 (February 1990), pp.425-434. The waterlogged Late Bronze Age wooden platform at Flat Fen, Peterborough, has yielded a number of well-preserved structural timbers – including some thought to be *in situ* which offers a unusual opportunity to investigate and reconstruct the details of prehistoric timber roof construction and its carpentry.

PRISCILLA WEGARS, **Who's been Workin' on the Railroad? An Examination of the Construction, Distribution, and Ethnic Origins of Domed Rock Ovens on Railroad-Related Sites,** *Historical Archaeology*, 25, 1 (1991), pp.37-65. Interesting light on the ethnic origin of railroad construction teams, as well as the transfer of vernacular building forms, has been shed by the analysis of small domed rock structures recorded throughout the western United States and Canada, and associated with railroad construction camps (and, to a lesser extent, with mine workings). There is reason to believe that these were built and used as bread ovens mainly by Italian and other southern European immigrant labourers.

ANDREW WHITE, **Stone-masons in a Georgian Town,** *The Local Historian*, 21, 2 (May 1991), pp.60-65. Lancaster is predominantly a Georgian town, with many of its central buildings built in stone following a disastrous fire in 1698 and the port's rise to prosperity on the West Indies trade in the 18th century. White's paper uses local archival sources to explore the activities of Lancaster's builders (architects, mason, carpenters) during the construction boom of the 18th and early 19th centuries.

MICHAEL ANN WILLIAMS, **Pride and Prejudice: The Appalachian Boxed House in Southwestern North Carolina,** *The Winterthur Portfolio*, 25, 4 (Winter 1990), pp.217-30. The stud-less vertical-plank or 'boxed' house was essentially a cheap form of construction which nevertheless depended on the availability of sawn planks and boards. It had its American origins in 17th and 18th century New England but, when powered sawmills became plentiful, was widely employed in company towns and mining camps as recently as the 1930s, and in southern Appalachia became very much part of the local vernacular.

Book Reviews

Light, Wind and Structure — The Mystery of the Master Builders
ROBERT MARK, 1990
Cambridge, Massachusetts & London. The MIT Press.
209pp. illust. (70 b/w photographs; 42 line drawings) £22.50
ISBN 0-262-13246-X

It is always a pleasure to encounter a new book on the history of structural engineering; however on this occasion it is a disappointment to find that a book which promises so much adds little to our knowledge or understanding of the subject. Moreover it is a minor outrage that it should so mislead the reader concerning the uses to which engineering science can legitimately be put.

Mr Mark's book forms part of the Alfred P. Sloan Foundation's New Liberal Arts Program which aims to 'involve undergraduates in meaningful experiences with technology', to understand 'the scientific and cultural settings within which engineers work' and to make them (the undergraduates) 'much more comfortable... with reasoning with numbers and applying mathematical and physical models'. These are laudable aims and Mr Mark's book certainly provides the general reader and students of architecture and architectural history with a good introduction to several structural achievements of three great eras of masonry construction – Roman, Gothic and Renaissance/Baroque. These three chapters are preceded by two which, respectively, deal with problems of technological interpretation of historic architecture and introduce some of the technical concepts and language relating to building structure, interior illumination and the use of scale models for representing actual structures. The author concludes with a number of philosophical generalization drawn from his study of masonry structures which he applies to several other buildng types and periods of history not covered in the three central chapters. The book is copiously, if sometimes irrelevantly, illustrated, though the three-dimensionality of the buildings would probably have been easier to appreciate in the television programme 'The Mystery of the Master Builders' which appeared in conjunction with the book.

Unfortunately, the book suffers from two fundamental flaws. These flaws are the more serious since it is aimed principally at a readership which, in general, will lack the specialist technical knowledge needed to detect them.

The first flaw concerns the scientific technique which the author has used to conduct his anaysis of the structural behaviour of masonry buildings such as the Pantheon and Gothic cathedrals. Masonry buildings derive their stability from the geometrical shapes of the components (stones) and of the structural elements (walls, flying buttresses etc.) which these stones make up. The strength and elasticity of the material are virtually irrelevant since stresses are both very low (typically only 10% of strength) and also only compressive (since a joint has no tensile strength). The problem of stability and structural safety in a cathedral is thus closer to that of a dining table (with stresses well below danger level and stability decided mainly by the spread of the table legs) than it is to that of a modern building structure in which the material is loaded well up towards its yield strength and columns are loaded nearly up to the load at which they would buckle in compression. Mr Mark, however, has chosen to make and test models of masonry structures using the technique of photo-elasticity. This technique uses a homogeneous elastic material which fails to represent masonry adequately in one absolutely crucial way – masonry is non-homogeneous. While the technique itself is an extremely powerful analytical tool when used appropriately, such as with structural components of aircraft and their engines, when applied to masonry it yields results which are, literally, meaningless.

The second flaw upon which Mr Mark's book is based is a logical one. He purports to use the results of his experiments to deduce conclusions about the design skill and structural understanding of ancient designers. The logic of this argument is, quite simply, incorrect – by analogy, a modern chemical analysis of a sample of Roman wine tells us nothing of all of how a Roman wine maker understood the process of fermentation; nevertheless the Romans built excellent buildings and, I suspect, made excellent wine.

The author is quite explicit about his methodology. In the preface he states it as follows:

> *'The application of modern engineering tools has clarified the technological underpinning of (the development of new large-scale building types during three historic eras) and provided new insights into the design techniques employed by early builders. Hence, another theme... is the reinterpretation of technological precedents that are often misunderstood in contemporary architecture.' (pp. xv-svi)*

The problem is that Mr Mark chooses a selection of misunderstood 'interpretations of technological precedent' which have been made by people clearly inadequately equipped to understand them at all. He consistently refers only to the vague and often inaccurate technological views of architectural historians. The Pantheon dome is a typical case. A 19th century professor of art claimed, apparently, that 'Roman concrete was quite devoid of any lateral thrust, and covered its space with the rigidity of a metal lid'. Now, every engineer I know would be able to argue convincingly in a few minutes that this statement is incorrect. Mr Mark, however, seems to need to resort to the building and testing of photoelastic models, and to the use of finite element analysis in order to disprove it. He also finds 'the extent of the meridianal meridian cracking in the actual dome... agrees remarkably well with the simulated cracking in the full model' – a turn of phrase which conveys the impression that it is the theoretical model which is correct and the real structure which behaves only nearly correctly. These are utterly inappropriate applications of useful scientific tools of analysis.

The author repeats this same process in testing photoelastic models of several Gothic cathedrals, Wren's dome at St Paul's and his roof over the Sheldonian Theatre, and the medieval timber roof over Westminster Hall. Each time he sets up a view which some architectural commentators but few engineers might have suggested and then proceeds to knock it down with invalid scientific argument – a process which reminds me of the commuter who reputedly threw his screwed-up newspaper out of the window each day as the train approached London in order, he said, to keep the elephants away. When challenged that there were no elephants in England, he simply replied 'Effective, isn't it'.

I share with Mr Mark his twin aims of seeking to correct the many misconceptions which architects and architectural enthusiasts have about how structures, both ancient and modern, work as structures, and how people might have understood their behaviour at the time they were built. While seeking to expose the poor arguments used by many architectural historians, however, the author often introduces as many confusions as he would wish to remove. Also he often seems to be trying to blind the reader with science, or to rely on the reader's poor knowledge of the history of engineering and building design. Although Mr Mark is an engineer, I doubt if he would talk to fellow engineers in the way he expresses himself in this book. Three of many possible illustrations will suffice:

> *When talking of the results of the photoelastic analyses of a Gothic flying buttress he claims (p103) that it revealed 'some unanticipated critically stressed regions'. Overlooking, for a moment, the fact that the elastic material of the model cannot properly represent the behaviour of masonry, nearly any engineer familiar with stresses and loads would have been able to identify, without the need for model testing, the locations of likely stress concentrations. On the other hand, a person not familiar with stresses would have no justification at all for anticipating either a stress concentration or, indeed, the absence of one.*
>
> *The author refers to 'the 'mystery' of how the early master builders created great architecture without resort to modern analytical theory' (p17): yet there is no mystery, just as there is no mystery about how a child learns to walk without knowing about engineering science.*
>
> *After the observation that '(A pinnacle's) effect on the overall stability of the buttress is small and often appears to have been ignored in design' (p119), the uninformed reader is left in no doubt that Mr Mark appears to know exactly how the Gothic masons designed their buttresses: he does not.*

In the final chapter of the book Mr Mark seeks to build upon several conclusions about the design and behaviour of structures – conclusions with which, in general, I concur (it is the invalid logic and deceptive rhetoric to which I object). Yet here again, unfortunately, I am not persuaded by the author's argument. He seeks to generalise from a number of masonry structures, all designed before our modern structural science was available for use by designers, to a range of structures built of different materials and designed in utterly different ways – structures such as the works of Gustav Eiffel and the John Hopkins Center in Chicago. It is to perpetuate architects' misunderstandings about the way buildings work and how they are designed to compare a 20th century steel-framed, 330 metre high skyscraper (John Hancock Center) to a masonry Gothic cathedral (Bourges) (p177). I am able to see only differences – materials, live and dead loads, foundation type, structural forms and principles involved, the influence of safety requirements and passive protection against fire loads (nor, incidently, am I able to find the 'arching action' which, according to Mr Mark (p179), is to be seen in the Hancock Center's exoskeletal structure).

Thus, while Mr Mark's principal quest – to rid the world of technological misunderstandings – is admirable, his method and argument are both based on invalid reasoning. Curiously, at no stage in the book does he refer to the wealth of engineers' analyses of ancient structures which have already argued successfully against the architectural historians' frequent misunderstandings.

Finally there are a number of curious and, perhaps, telling omissions. Considering Mr Mark's concentration on masonry structures it is a particularly severe omission not to mention the definitive work by Professor Heyman on arches, vaults and domes, which is well-known to all engineers interested in the history of such structures. Similarly it is odd that an engineer has managed to write a book on masonry structures without once using the concept of the *line of thrust* – a concept which is fundamental to the understanding of such structures. Finally, in the light of Mr Mark's total reliance on the supposed validity of using photoelastic models to investigate masonry structures, it is difficult indeed to understand why he only choose to mention, a few pages before the end of the book, the 'forgiving nature of typical masonry construction... (in which) small changes in the geometry of masonry have far less effect on stability that similar changes in modern construction' (p170). It is precisely this fact which invalidates the use of the photoelastic method. It is with great regret that I am unable to recommend this book, for there are so few on the subject. While Mr Mark's book contains much that is interesting and thought provoking, I fear it will only succeed in seriously misleading the non-technical reader and infuriating the technical one. On the subject of masonry structures (despite some poorly argued philosophy, the book is about little more) I would still refer the general reader to the works of Professor Henry J. Cowan and the specialist to Professor Jacques Heyman.

BILL ADDIS, *University of Reading.*

Structural Engineering. The Nature of Theory and Design
WILLIAM ADDIS. 1990
London, Ellis Horwood
258pp. illust., £45.00
ISBN 0-13-850611-6

I suppose the history of engineering is susceptible to three sorts of interpretation. There is the socio-economic approach so strongly advocated in the United States and often resulting in what quite simply *is* social and economic history and should really be recognised as such. There is the history of hardware – the study in other words of historic machines, structures, processes and mechanisms in themselves – which has held sway in Great Britain and is well represented by the work of the Newcomen Society and the industrial archaeology movement. And thirdly there is the rarely undertaken attempt to explore engineering history as a body of ideas, in other words to treat engineering as an intellectual and creative activity in its own right and to see its historical development as something other than a facet of the history of mathematics, science or art. Dr. Addis's book is such an enterprise and is exceptionally welcome for that reason alone, to remind the engineering history fraternity that it can and should be done.

Structural Engineering is above all about design, and it is essentially philosophical. Historical considerations manifest themselves in two ways: concepts of design are used to explore historical structural developments and, conversely, historical issues and information are resorted to in order to illuminate the philosophy of design. The book is not a history of design as such and at times the discussion as between design history and structural philosophy is rather inclined to revolve in circles, or so it seems to me.

Some description of the contents of this impressive and complex book is perhaps worthwhile at the outset. Early chapters are concerned with the nature of design in theory and practice, the problems of studying structural history and the styles of the approaches which have been adopted, as well as matters of research and education. Much is made of the conventional emphasis on theory as one thing and practice as another and the consequent urge to meet the challenge of 'bridging the gap'. The spectre of applied science is scrutinised and I must say I agree fully with the author that the real point is to see engineering as an autonomous activity whose central and distinguishing characteristic is *design*.

Design is defined and examined and we are introduced to Addis's key proposition, the 'design revolution' based on the author's extension of ideas first worked out in Thomas Kuhn's famous study of scientific revolutions. Kuhn's concepts of 'normal science' and 'scientific revolutions' are held to have engineering parallels, 'normal engineering' and 'engineering design revolutions'. To be honest one needs a more than passing acquaintance with *The Structure of Scientific Revolutions* not to mention a later Kuhn book, *The Essential Tension* to get the best from this methodological analogy: it is extremely interesting and not too far removed from Michael Duffy's ideas of technomorphology and the effects of *design impasse* which have been worked out and tested in other contexts, notably the history of railway traction.

That engineering follows steady development based on routine procedures which ultimately lead up to some point or moment of crisis or challenge is indeed comparable to Kuhn's picture of paradigmatic science. But I have one reservation. As I understand Kuhn a consequence of a revolution in science is that a new theory or view or analysis really does replace its predecessor. The conclusions of Copernicus, Newton, Darwin or Einstein simply could not co-exist with what had gone before, they were mutually incompatible and that is central to Kuhn's thesis. I am not clear that the separation is so complete in engineering design revolutions. A key example of Addis's is the replacement of elastic design theory by plastic theory. While one can follow the nature of the normal engineering which led to an anomaly in the Kuhnia sense it is not altogether convincing that the upshot was to render elastic theory invalid. Indeed it is a good question as to whether the nature of engineering which Addis explores can ever allow the paradigmatic shift which is so fundamental to Kuhn's position. Perhaps I can exemplify this by referring to an example which Dr. Addis explores, albeit from a different angle.

In modern times debate has gone on as to how best to structurally analyse Gothic cathedrals – and no substantial degree of agreement is very evident. If by some freak of modern decision-making it was decided to build, today, a Gothic cathedral one suspects that the best choice of designer would be a medieval architect. At least we know he could do it by a method – whatever it was – which has not been satisfactorily replaced by any subsequent design revolution of the last thousand years. However – and the contrast is important – there were scientific theories in vogue a thousand years ago which are now simply invalid.

Chapter 12 of Dr. Addis's book deals with two major early design revolutions, the Greek and the Gothic, embodying respectively ideas of proportion and geometry. Between the two I am not entirely convinced that we should not also credit Roman building with a design revolution based on arcuate construction which could be held to represent a profound dislocation between the concepts, problems and techniques of Greek and Gothic. All the same historians of structural engineering will enjoy the Greek/Gothic chapter and also the one which follows, an extremely good review of the development of the design of beams, arches and vaults, the truss bridge and suspension bridges. Whether or not the design revolutions identified within these structural systems are of the same order of magnitude, indeed of a sufficient order of magnitude, to stand alongside what is claimed for the Greek and the Gothic is too lengthy a matter to go into here.

For the 19th century Dr. Addis properly draws attention to the radical change which occurred in structural materials. The transition from traditional building in stone and wood to a new era of iron building has always seemed to me to be the most profound of all structural developments not least because the more rational behaviour of an elastic material, both isotropic and homogeneous, allowed mathematics to be deployed with confidence, eventually if not immediately. A closely related 19th century issue is also treated, namely the emergence of concerns about safety and the critical impact of failures then and more recently; the Tay Bridge, Tacoma Narrows and Ronan Point amongst others are considered. One of the most telling remarks ever made at a meeting of Victorian engineers was by Robert Stephenson when, apropos the particular problem of fatigue failure in railway axles but pregnant with implications for all and sundry, he said, 'the breaking of an axle has on one occasion rendered it questionable whether or not the engineer and superintendent would have a verdict of manslaughter returned against them.' That faulty design might have such grave consequences for an engineer was not in Britain, I think, a legal option that was ever tested; but it was at the time a real fear which worried the engineering professions no end as the performance of potential of iron and then steel were pursued. It helps to confirm just how instrumental in hastening design revolution the arrival of iron and steel really was.

Structural Engineering is a wide-ranging (almost too much so) and important book. The probability that not everyone will agree with all of Dr. Addis's ideas, in general or in detail, is less important, much less, than his ability to raise issues, provoke thought and discussion, and overall to illuminate and explore my earlier observation – that enginering is a creative and intellectual discipline in its own right and demands to be studied as such. In the longer term, and in different hands presumably, it would prove interesting, if and when someone is willing to undertake the task, to see how far Dr. Addis's ideas, however modified to suit, can cope with other branches of engineering, such as mechanical.

NORMAN SMITH, *Imperial College, London*

Brick Building in Britain
R.W. BRUNSKILL, 1990
London, Victor Gollancz in association with Peter Crawley
208pp., illus., £18.95
ISBN 0 575 04457 8

Ron Brunskill has up-dated and expanded his 'English Brickwork', written jointly with Alec Clifton-Taylor and published in 1977. The new book combines Brunskill's expertise in vernacular recording with a sensitivity to the aesthetics of building materials in the Clifton-Taylor mould.

The chapters on materials and manufacturing draw upon recent research by members of the British Brick Society. A geological overview of malms, marls and shales leads into a consideration of different types of fuel. Brickmaking techniques are explained by culinary analogy, contrasting the 'butter-pat' and 'pastry' methods with what could have been referred to as 'spaghetti' style extrusion. The tools of handmoulding and different types of kilns are illustrated. Neither the text or the drawings convey the transformation in the scale of the industry brought about by the Industrial Revolution, with sprawling brickworks drawing clay and coal from a common mineshaft, and advertising an encyclopaedic variety of bricks, pipes and pots through lavish catalogues.

The chapter on the use of bricks considers bonding in some detail, but also has a welcome section on structural matters. Illustrations of mathematical tiling emphasise the broad geographical range and time span over which this equivalent of modern 'sticky-stone' cladding was used. It is a pity that Brunskill's excellent research into cavity construction is consigned to an unillustrated appendix. The glossary provides a virtually definitive coverage of different types of brick bonding, the descriptions being accompanied by exemplary line drawings.

The chronological survey highlights the colours, size and texture of bricks and their most likely usage in terms of building type and location. Crisp photographs help recount the highly indulgent use of brick in Tudor and Elizabethan East Anglia, the geographical spread of the material through the Jacobean and Stuart periods, and the increasing reserve shown by the Georgians. The regional coverage is skewed towards the east of England, Scotland being covered by an appendix.

The coverage of the nineteenth and twentieth centuries concentrates on ceramic high points such as Keble College, Oxford and Guildford Cathedral, to the neglect of terraced or semi-detached houses. Photographs of Ruabon 'reds' or the silver bricks of Reading could have been used to demonstrate how the Victorian period, far from marking a decline in regional variety and vernacular sensitivity to locality, saw an increased range of brickwork available and, often, a close geographical relationship between claybank and client.

A book on building materials has to embrace geology and industrial archaeology as well as architectural and construction history. Differing brands of historians might quibble with the emphasis and arrangement of this volume. Nevertheless it offers a valuable coverage of this ubiquitous material, another economically priced volume in Gollancz's series on building materials, and marks a step forward in integrating different approaches to the study of building construction.

MICHAEL STRATTON, *The Ironbridge Institute*

100 Years of the Forth Bridge
ROLAND PAXTON, Ed., 1990
London. Thomas Telford Ltd.
166pp. illustr. £12.50
ISBN 07277 1600X

When completed, the Forth Bridge had the longest span in the world and was the first major structure built using mild steel. It was much visited both during and after construction and came to stand for Scotland in the way that Tower Bridge stands for London and the Eiffel Tower for Paris. It has been used continuously for its original purpose for 100 years with negligible distress and now carries heavier and more frequent trains then expected by its designers.

Six lectures were given in Edinburgh as part of the celebration of its centenary and at a late stage it was decided they should be published. This book is the outcome, and the awkwardness which occurs when the spoken and illustrated word is transcribed too directly into print has, to the credit of the editor and lecturers, been very nearly eliminated.

The book is designed on a small square format, awkward in a bookshelf and unimpressive on a coffee-table, which brings the text too close to the top and bottom of each page. The resulting size of the illustrations and the quality of their reproduction lose some of the detail. These aside, I wish the book had been the first aim, rather than an afterthought to the lectures, as the knowledge and understanding of the authors deserve a more developed argument than a single public lecture allows.

Roland Paxton's first lecture dealt with the means used or proposed for crossing the Forth before the construction of the bridge. After a conjectural Severan pontoon bridge around 208AD and the more mundane improvements to jetties and ferries, the early 19th century saw a succession of tunnel and bridge schemes which Paxton shows were premature. He then recounts the prolonged efforts to carry railways across the Forth, including Thomas Bouch's invention of a train ferry for the Granton to Burntisland crossing and his design for the North British Railway Company of a bridge about 2¼ miles long near Charlestown. He finished with Bouch's double suspension bridge on the same site and for the same client as the present bridge, of which construction was actually begun in 1878, but which was abandoned after the notorious collapse of his Tay Bridge in 1879.

A criticism of the Bouch proposal was given in J.S. Shipway's next lecture, before going on to recount the development of the design of the present bridge, relating it to other cantilever bridges. The present bridge is shown to be conservative in that, although the design works at the full stresses allowed on the new material of mild steel at that day, these stresses were lower and the loads applied were greater and applied with greater factors of safety than we would now require. The Tay collapse had resulted in Parliament giving the Board of Trade a responsibilty for overseeing the design and construction of bridges, reflecting public concern, and the North British Railway Company had to regain public confidence in their bridges: so the conservatism is understandable.

Benjamin Baker, in weighing the criteria for the design of a bridge, had written that 'none are more important than those affecting facility of erection', and in the third lecture W.R. Cox showed how Baker and William Arrol planned and carried

out the immense task of the bridge's construction. He included Arrol's remarkable contribution in the development of machines; for hydraulic riveting at unprecedented pressures and speed, and for drilling the 12′ diameter tube sections whilst pre-assembled.

As the civil engineer responsible for the maintenance of the bridge, D. Grant's lecture was reassuring on the continuing serviceability of the bridge, which has essentially only needed protection against corrosion and occasional replacement of the rails and their supports, albeit at a cost of around £1m annually. Modern health and safety requirements are influencing the sequence and frequency of maintenance, but that fabled team of painters still works incessantly in the same colour red paint. The continuous employment of 40 men on the bridge raises parallels with a cathedral works organisation: would we still maintain the bridge if trains no longer rumbled across? Has the century seen the bridge slowly transform from utility to historical symbol? Not entirely, and iconoclasm would be expensive.

Ronald Birse then discussed some of the men who provided the intellectual and entrepreneurial power from which the bridge sprang, successfuly resisting the tendency to identify heroes and showing how events and people remote both geographically and in time helped to build the will and capacity for such an exceptional endeavour.

Finally Ted Happold talked about the changing preoccupations of structural engineering in 'Crossing the Forth in 2090', about the engineer as 'conservator', rather than conservative, of the Earth's resources and about the possibilities opened up when the edges of engineering overlap the edges of other disciplines. He concludes that we have not learnt anything since 1890 which invalidates the bridge and that it will be there in 2090, but if we started afresh then, the diminishing resources of the Earth would require us to use a material which was less energy expensive, and hence probably organic rather than metallic.

It seems to me that the bridge is pivotal in the development of engineering and its relationship to society because of its scale, its position in time, and because it was conceived and constructed in the aftermath of the Tay Bridge collapse. As Ted Happold points out, '1890 was almost the end of the period when the public was highly aware of the great civil engineers and their triumphs.' But not of their failures. The Forth Bridge stands at this turning point of attention.

Looking at Paxton's and Shipway's account of Bouch's work, it seems that he understood gravity and vertical loading as they affected the design of an economical single span, but his designs show little grasp of the importance of lateral stability, or of loading from the wind and how its effects increase in importance with the aspect ratio of a structure. He seems also to have had an inadequate conception of multi-span bridges, regarding them as single span bridges laid end-to-end and not appreciating the need for robustness against accident or construction flaws. Both the Tay Bridge and the projected bridge from Charlestown have these flaws. In his Forth Bridge design he was forced to move away from the repetitive truss and pier bridges he knew most about and the initial conception of the bridge seems poor in both form and proportion.

Disasters usually occur only when several things go wrong at once: the first inadequacy removes most of the factor of safety that the designer intends, the second removes the capacities of the structure that he ignores and it is only after two serious inadequacies occur that nature is able to bring the structure down. Bouch based the Tay design on incorrect information about the ground conditions below the estuary, forcing a complete change of the pier design during construction, and he accepted inadequate advice about wind loads which underestimated them by a factor of about three. The redesigned piers were poorly designed and constructed; possessing inadequate bracing, providing insufficient linkage between spans and with serious flaws in the principal castings. It fell, Bouch was ruined and died within a year. It was sober men who set about designing the present bridge in 1881.

In the mid 19th century, engineering had been seen as a risky adventure; people lost lives and fortunes in it. But by 1879 rail travel was expected to be safe and reliable and engineers were increasingly required and able to justify their works. The Tay bridge collapse was unacceptable to society in a way that earlier 'accidents' had not been. A current parallel is perhaps the way in which we increasingly regard third world disasters as unacceptable; we can see that they are avoidable, not accidental. Public opinion in 1879 saw that the Tay collapse was also avoidable. After the Forth Bridge, civil engineering was seen as socially, and increasingly legally, accountable; and the focus of public interest in technological development gradually shifted elsewhere.

Kenneth Clark called the bridge a 'brontosaurus of technology' and Birse quotes Steinman and Watson, 'The Forth Bridge seems to scorn beauty, even seems to revel in a certain awkward angularity, for it boasts of invincible strength, in which it glories with superb indifference and insolent pride'. Mr Shipway sees it as 'slender and graceful, leaping like a greyhound over the vast span of water', but the 'Holbein straddle', the 1 in 7½ batter of the structure in section, does suggest a fear of some sideways onslaught that is more primaeval than even the Forth can muster; and the diplodocus spread of its feet and the high ratio of height to span, to 1 to 4¾, give it a degree of stability and stiffness, which visually verges on the obsessive and in engineering terms sets standards which later generations felt they could relax. Each of these stability measures was increased from the initial to the final design, indicating the general concern that, as Parliament put it, the bridge 'should gain the confidence of the public, and enjoy a reputation of being not only the biggest and strongest, but also the stiffest bridge in the world'.

Inevitably no single book can satisfy one's curiosity about such a great feat of engineering. These lectures have added to our understanding of this great and stiffest bridge and each raised questions and have stimulated me to know more. I wish the resulting book had allowed the authors to develop their subjects more fully.

ANDREW SMITH

Un Musée Retrouvé - Le Musée des Travaux Publics 1939-1955
BERTRAND LEMOINE AND JEAN MESQUI, 1991
Ministère de l'Equipment, du Logement, des Transports, et de la Mer (France)
156pp., illustr. (139 half-tone; 7 line drawings) FF 150. (approx £16)
ISBN 2-11-086893-7

This fascinating, and exquisitely produced little book serves several different purposes. It was born during the celebrations of the 50th anniversary of the magnificent Exposition Internationale des Arts et Techniques which was held in Paris in 1937. The Exposition had provided the stimulus to found a National Museum of Public Works and no less an architect than Auguste Perret was commissioned to design a permanent home for the exhibits – it is still to be found at Number 1, Avenue d'Iena. Some twenty pages of text, drawings and photographs celebrate the building itself, which is a great monument to the outstanding achievements of the French, and of Perret in particular, in the architectural use of reinforced concrete.

The book also gives the background to the birth of the collection, tells the story of the museum until its closure in 1955 and recounts the sad fate of the museum's contents since that time – they were put into some 1400 cubic metres of crates and moved hither and thither until, in 1966, they found a resting place in the dark basement of a government building on the bank of the Seine. This basement has nearly become a tomb, for many of the models are now in a state which prohibits moving them – indeed many of the book's photographs of the exhibits in their open wooden crates in a dusty basement remind me, with great emotion, of archaeologists' records of burial sites of ancient Egypt or Paracas in Peru. The book, then, is also part of a campaign to publicise the fate of this unique collection of artefacts and models and to stir up the enthusiasm necessary to secure their preservation and to find them a new home where they can be on public view. It was as a result of the formation of l'Association pour le Sauvetage du Patrimoine de l'ancien Musée des Travaux Publics in 1989 that permission was finally grated for the incarcerated models to be investigated. Some of the best preserved of these models and artefacts were displayed in an excellent exhibition in a subterranean gallery at la Défense in April 1991.

The book's main purpose is to record as full an inventory as possible of the exhibits of the original Musée des Travaux Publics and to match this to the inventory of models and exhibits which were found in the basement store when this was recently investigated under the direction of the two authors. The full list runs to over 400 items, of which about a half have been lost or, perhaps, loaned to this or that regional museum. Many of those which survive are virtually beyond repair. The exhibits which have survived are listed under nine headings – electricity and energy, machines and instruments, mining and geology, inland navigation, oil, bridges and viaducts, ports, road and motorways, and the slightly mysterious 'divers et inconnus'. Amongst those items which have not survived, some of which can be seen in interior views of the museum building, are many more within the same themes as well as a number of models of aerodromes and hangars, railway vehicles and bridges, and lighthouses and buoys.

Finally, a word about the exhibits themselves. The majority are models, yet a great many of them were not made for display in a museum; in this respect they are utterly different from the very few models related to civil and structural engineering that one finds in our own National Museum of Science and Industry in South Kensington. These models were built as part of the process of design and planning the construction of actual or proposed projects. Many of them came from the Ecole Nationale des Ponts et Chausées and are the three-dimensional equivalents of the incomparable engineering drawings which that school virtually invented in the 18th century, whereby the design, the method of construction and the operation of a bridge, fortification or canal lock were often shown on the one drawing.

The earliest models are four from the 1770s by Perronet including the proposed centering for his Neuilly Bridge. Surprisingly little seems to remain from the 19th century – a photograph of the few tangled remnants of what had been a 6 metre-long model of the longest metal viaduct in France (c1900) only serves to heighten the disappointment at what has so tragically been lost. Even Eiffel is represented now only by a rather mundane masonry bridge pier – the model of his Garabit Viaduct has sadly not survived. Most of the models relate to projects of the 1890s and the first half of the present century and many of the best models are of bridges and the centering used in their construction. Even two models of compressed-air caissons from 1880 and 1897 are included. One of the most surprising exhibits which survives is a 3.5 x 1.8 metre model of a very modern-looking motorway Y-junction just to the west of Paris: particularly interesting is the integral lighthouse (or beacon), which was not built, and the model cars which belie its age – 1938.

One last exhibit must be mentioned separately – Item No. 233, the reinforced concrete boat built by Lambot in 1849. As the photograph in the book shows, it was little larger than an ordinary rowing boat and the hull is about an inch thick and has approximately ¼ inch bars at 4 inch centres. Having seen it in the exhibition I fancy it would still float, although one of the seats is in need of patching. This exhibit must be one of the most important artefacts we have from the history of civil and structural engineering and it is little short of a scandal that it has remained hidden for so long from the public.

If this excellent book has one fault it is that many of the inventory entries do not give the age of the models – many have only the accession date, some no date at all. Although accurate dates are probably not known, in an inventory of works of such historical importance, even an acknowledged guess would have been better than nothing. It would have also been nice (but expensive) if there could have been photographs of the contents of all the crates in which the Musée des Travaux Publics has lately been stored. Nevertheless the book (and the exhibition) show without any doubt that the collection was, and still is, one of international importance. It is to be hopd that its publication will help to raise the concern and enthusiasm of enough people to ensure that as many of the surviving exhibits as possible are brought back on show – perhaps some of them might one day reach our own National Museum of Science and Industry.

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