

Book Reviews

Fortress Builder. Bernard de Gomme, Charles II's Military Engineer

Andrew Saunders, 2004

Exeter, Devon: University of Exeter Press

382pp. 128illust. £45

ISBN 0-85889-7516

Britain has produced no military engineer of the standing of Vauban, Coehoorn or Dahlberg, but Sir Bernard de Gomme - who became the principal Royalist military engineer by the end of the English Civil War, and the leading figure in the rebuilding of England's fortifications following the Restoration - probably comes closest. Dutch by birth, De Gomme came to England in 1642, aged only 22 but already no stranger to war. He arrived as a fortification expert in the military entourage of Prince Rupert, himself only a few years older and already an expert in siege warfare as well as the cavalry tactics that brought him fame. During the war De Gomme served at the two sieges of Bristol in 1643 and 1645 - first as besieger, then in defence - and at the siege of Oxford in 1644 where the best drawing of this key operation is in his hand. Evidently functioning as both engineer and staff officer, De Gomme drew Prince Rupert's battle plans (records of the engagements at Edgehill, Marston Moor, Newbury II and Naseby during the first Civil War). Then as now, war represented a ladder of opportunity which was open even to those without noble blood. De Gomme ended the war with an English knighthood, and the rank of Quartermaster-General of Fortifications (his patent confirmed by the exiled Charles II at Breda in 1649). De Gomme was also a refugee, of course, but now back in his native country.

In 1660 he was still claiming back pay for his Civil War service in the Royalist cause from 1642 to 1646. By then, however, he had joined the throng of hopefuls seeking preferment at the court of the restored Charles II. Although the King was unable to deliver on all of the promises made in 1649, De Gomme received a life pension of £300 per annum. A year later he was appointed Chief Engineer to the King, which was not the equal of the military post he had held during the Civil War, or the position of Surveyor-General of Fortifications which he had been promised in Breda. But it carried a daily fee of 13s. 4d. and jobs with further allowances (such as the "riding charges" of 20s. a day) followed: first the rebuilding of fortifications at Dunkirk (England's new foothold in Continental Europe, the prize from a French alliance with the Commonwealth), then a posting to the English bridgehead at Tangier (part of the dowry from Charles's queen, Catherine of Braganza, but already under more or less constant siege by the Moors). It was the outbreak of the second Anglo-Dutch War in 1665 which brought the émigré Dutchman home to oversee the fortification of England's naval ports - Plymouth, Portsmouth, the Medway positions and Tilbury. The last two bases were particularly vulnerable to Dutch raids, but the first three were massive projects which would last for decades and involved De Gomme - often it seems single-handed, but only ever with a very small team of assistants - in urban and maritime surveys and chart-making, and the design of barrack blocks, senior officers' housing, gunpowder magazines, and military hospitals, as well as fortifications.

Eventually De Gomme secured the long-promised post of Surveyor-General of Fortifications in the Ordnance Office, an organisation with its Medieval origins in the Privy Wardrobe, but much expanded to organise military supplies following criticism of the arming of the fleet for the Armada campaign. Under the Stuarts it expanded again to embrace all forms of military construction, as well as weapons procurement and logistics - everything not covered by the Office of Works. Under its Master-General, the Board of the Ordnance Office comprised five principal officers: the Lieutenant-General, Surveyor-General, Clerk of the Ordnance, Storekeeper, and Clerk of the Deliveries and in 1683 the Rules, Orders

and Instructions for the Government of the Office of Ordnance were revised under Lord Dartmouth (Master-General) and included detailed job descriptions - which called for the Surveyor-General to possess the qualities of Renaissance Man combined with those of a Quantity Surveyor. Training in continental methods was evidently also part of the agenda. The young De Gomme probably secured his original opening as a military engineer with Prince Rupert on the strength of his portfolio of drawings of fortifications and sieges in the Netherlands, some of which indicate personal familiarity with places and events. England at peace provided site experience but not the campaign experience which set the military engineer apart, and Andrew Saunders cites instructions from the Board Minutes which despatched Jacob Richards - a future Chief Engineer - on a study tour "towards HUNGARY" to observe fortifications, artillery, siege operations and military manoeuvres of all kinds, to keep a journal and to make drawings "having first obtained permission" so that on his return he may render himself "fit to be employed as one of His Majesty's Engineers for his service in England." Architects by then were beating a path to Italy, but for De Gomme's trainee engineers it was a study tour to the seemingly endless Hapsburg campaigns against the Ottomans in central Europe.

Andrew Saunders - a former Chief Inspector of Ancient Monuments - knows the works in a way known only those who have walked and crawled over them (or toured the battlefields of Hungary). He has succeeded marvellously well in using Sir Bernard De Gomme as a window into the Stuart world of official construction, despite the lack of private papers, diaries, or the treatise that so often reveals a subject to posterity. Gruff, dogmatic, and perhaps never very accomplished in his adopted tongue, De Gomme nevertheless left a wonderful legacy of revealing drawings which Saunders has used to extraordinarily good effect in piecing together the works recorded in Ordnance Board minute books. For readers with an interest in fortification, this book provides a splendidly informed but highly accessible account of 17th century theory and practice; but there is also much here to interest those whose primary concern is in the construction history of some of England's most extensive building and engineering operations before the Industrial Revolution.

Simon Pepper
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Conserving the Enlightenment: French Military Engineering from Vauban to the Revolution

Janis Langins, 2004

Cambridge, Mass. & London, MIT Press

532 pp. 30 illust. £35.95

ISBN 0-262-12258-8

This book is a masterpiece: dense, but every page worth pondering, not just for the compelling story the author tells but for the insights he brings to the tangle of relations between science, technology, construction and war.

The historiography of construction in France during its halcyon years of power and influence tends to focus upon institutions, chiefly the two government corps and royal buildings agency which took shape under Louis XIV, and the schools each of them spawned. The senior of the two corps, the military engineering body, was fully defined as the Corps du Génie in 1691. Swollen to substance and status by continuous war, and to something like coherence by the incomparable Marquis de Vauban, the Génie can be claimed as the first permanent building organization of truly national scope. But after 1750, as France's fortunes in war wavered and Enlightenment priorities put peaceful infrastructure before fortification, the Corps des Ponts et Chaussées, created on the explicit model of the Génie, stole the limelight. The sweep of its roads and grandeur of its bridges captured the contemporary imagination. At the same time the Ponts et Chaussées worked out a method of engineering education often extolled as exemplary, most recently in the eloquent scholarship of Antoine Picon.

From the practical standpoint, by contrast, the pre-revolutionary Génie looks recessive, building little, squabbling a lot. Its own school at Mézières, set up in 1749, soon went theoretical and mathematical. It fostered great scientists like Coulomb, the father of soil mechanics, great teachers like Monge, the inventor of descriptive geometry and founder of the Ecole Polytechnique, and one great military planner, Carnot, who saved France from its circle of enemies in the 1790s, only to be eclipsed by Bonaparte the artilleryman. By then the Génie had peaked as a body of building engineers. Too aristocratic for its own good, it had to be taken to pieces and remade at the Revolution, while the Ponts et Chaussées sailed on unscathed.

While confirming this account of institutional developments in French construction, Janis Langins elaborates richly upon them. His early pages on Vauban offer the best account of that great engineer's powers and achievements available in English, often exceeding recent French scholarship in subtlety. For Vauban fans who care to look beyond the enticing spectacle of specific fortifications, Langins is now the place to start. As he begins, so he continues to shed light on issues of national construction. Later on, for example, he shows us the Génie struggling to hold on to the development of French ports but losing out to the Ponts et Chaussées, in a symbolic duel between defence and trade. Even at Cherbourg, one of the few places where the Génie was able to spend substantially on fortifications in the 1780s, the harbour works went to the rival corps.

But construction represents only a tithe of Langins' broad interests. The basis of his approach throughout is to hold fast to the fundamental purposes of the Génie. French military engineers, he insists, were in the first place neither builders nor scientists nor educators; they were technicians on the fringes of the army or navy, there to support and further the arts of war. Attack, for instance, mattered as much as defence. Only a minority of Vauban's 'Archimedean band' were engineer-builders. Most were engineer-soldiers, many of whom died in the siege-assaults that dominated land warfare between the middle ages and the tactical innovations of Frederick the Great.

Nor in warfare was geometry or progressive science often a decisive factor. Generally, the military engineer found experience more helpful. That might mean anything from tradition to an understanding of the psychology of behaviour under fire, or the effect of smoke within the controversial cannon chambers known as casemates. Experience informs Langins' telling discussion of Bélidor, whose wonderful sourcebooks of the 1720s and 30s both codified Vauban's construction practice and

introduced his readers to the latest in engineering science. The scientific side of Bélidor's work is what has interested most scholars. But Langins points out that he never expected practical military engineers to take in much of it. To get a handle on the Génie, he steers deftly between the Scylla of building design and the Charybdis of science and technology: 'The fixation on design and engineering science as the defining essence of engineering has led many ... to downgrade project management and administration.' Not such an attractive haven to make for, one might think. But Langins' focus and breadth of reference make it so.

Why did the Génie become more conservative (hence the book's rather flat title) as the Ancien Régime went on, despite the liveliness of its scientific educators? That is the author's main question. Cost and political priority apart, his answer points to the declining status of fortification. On the one hand, Vauban had built most of the forts a retrenching France required; his professional successors found few radical improvements to make to his 'system'. On the other hand, Vauban's siegecraft had 'virtually banished the concept of impregnability', says Langins. Strongholds might still be necessary, but if they could only hold out for a while they lost some of their strategic status. France's defeats during the open battles of the Seven Years' War (1756-63) plus the increasing power of artillery (and therefore of the French artillery corps) exacerbated this trend.

The upshot was a crisis of confidence in the Génie, and an Enlightenment-style debate as to its purposes. The protagonists, military thinkers and engineers such as Guibert, du Portail and Le Michaud d'Arçon are unfamiliar names today. But their arguments as set out by Langins transcend the banal fortification treatises, armchair or otherwise, that had been the bread and butter of previous military publishing, and open the door to the fresh strategic thinking which was to help renew the glory of French arms. Guibert, a predecessor of Clausewitz in the age of Rousseau, believed that fortification softened men and that morale and hardness were the key factors in war. Du Portail, a subtler thinker, wanted the Génie to get out of construction and science altogether and concentrate on tactics and the study of 'military space'. D'Arçon, on the other hand, embraced the pragmatic ideal of maintenance and routine, and saw discipline, not flair or innovation, as the key to the true engineer.

The second half of the book is dominated by a story which casts a sidelight on the Génie's internal crisis - the long duel between the corps and Marc-René, the Marquis de Montalembert. In the hands of a lighter author than Langins this might have been presented as farce. Montalembert was a clever, well-connected, very persistent, insufferable dilettante, wishful thinker and, to put it bluntly, fraud. An army officer of some experience but never an engineer, he used his rank to procure contracts for casting improved cannon for the French navy. Having failed in that, he embarked unabashed upon a prolonged campaign against the Génie, contending that it should be deprived of its monopoly over fortification. The main vehicle of Montalembert's attack were the eleven polemical and ultimately ridiculous volumes of his *Fortification perpendiculaire* (1776-97), handsomely illustrated by Charles-François Mandar, later an influential teacher at the Ecole des Ponts et Chaussées. They aimed to prove that impregnable fortresses could be built at low cost, if France would only try out Montalembert's personal system of bastions and guntowers. In fact consistency of principle is well nigh impossible to discern in his ragbag of ideas, says Langins.

The Génie fumed and objected, d'Arçon with special articulacy, but Montalembert was allowed to have just one practical go at fortification. The guinea pig allotted to him was the little Ile d'Aix on the approach to Rochefort, which the British had briefly occupied in 1757. Montalembert neglected the job, failed to finish it and treated the workforce abominably, while claiming it as a success. Adding insult to injury, he asked for the eminent Coulomb to be sent to inspect the work. Three times a week Coulomb shuttled out from Rochefort, suffering from seasickness every time but keeping his mouth shut as he was conducted round the works. Another notable proved more amenable. This was Choderlos de Laclos, artillery officer and future author of the scandalous *Les liaisons dangereuses*, who acted as Montalembert's deputy at Ile d'Aix. In due course Choderlos was to add to his notoriety by penning an attack on Vauban, to the disdain of the military establishment.

Montalembert the aristocrat survived the perils of revolution, still arguing for his innovations and siring a first child at 82, before dying at an advanced age in 1800. By then Napoleon was in the process of administering the coup de grace to normal siege warfare. That is beyond the scope of this exceptional book. Its provocative general thesis is that engineering tends to conservatism not revolution. Be that as it may, Langins has made a backhanded case for believing that though French military engineers of the Enlightenment were 'dispersed and atomized', probably indeed often rather depressed, through their efforts to address their plight they became as much the harbingers of the nineteenth-century engineering world as the luckier technicians of the Corps des Ponts et Chaussées.

Andrew Saint,
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The Small House in Eighteenth-Century London: a Social and Architectural History

Peter Guillery, 2004

New Haven and London, Yale University Press in association with English Heritage

vii, 351 pp. 278 colour and b & w plates and figures. £40

ISBN 0 300 10238 0

This book is about once-common houses to which artisans and some better-off labourers would have aspired: houses for the second quarter of the population (the bottom half of the top half). Above were houses in the more customary hunting ground for architectural historians while below households had to make do with parts of old buildings or long-gone shacks or cabins. For many readers it will be a pleasant surprise to learn of the survival today of fragments of a once-sizeable stock of small London houses, some dating back as far as the late seventeenth century. The author's aim 'is not just to show that some of these houses do still exist [but] also...to show that they matter...they cast new light on eighteenth-century London and its people.' They matter because they once formed a significant part of the largest city in western Europe. That city has enormous importance as having been 'a cauldron of cultural modernity' now offering a fuller understanding of the world since the eighteenth century. For construction historians much of the interest of the book lies in its dealing with a shift from building by artisan masters, journeymen and apprentices, to building by contractors, sub-contractors and building labourers. The shift marked a change from urban vernacular buildings to polite ones or, at any rate, more standardised and regulated ones.

From surviving evidence, small eighteenth century London houses were heterogeneous in form. They embodied many different combinations of staircase and chimney positions and numbers of floors. Many were of brick, some were timber framed (and timber clad, too) while others were pragmatic mixes of the two. By definition none were large; some were suited to multiple occupation and some to working at home. Predominantly found in east and south London, they were also scattered thinly elsewhere. Different districts had different characteristic house forms: as James Boswell noted, one end of London was like a different country from the other.

Guillery sets about describing building form, influences, processes and change, in a clear and ordered way, one of the many merits of the book. The first chapter gives essential context on social, economic and topographical matters and housing conditions. *Background to the district case studies* (which make up much of the book) follows in the shape of a survey of seventeenth century forerunners. Important themes are drawn out and equip the reader for a series of forays across London. The first destination is the former silk weaving district in Spitalfields and Bethnal Green. Workshop tenements with distinctive wide upper floor windows lighting loom shops were once common. Next the reader crosses the river to Southwark and Bermondsey to confront a contrasting and more varied housing stock which arose from a quite different set of influences. Northwards again, on major routes out of London along Kingsland Road and Mile End Road, the vernacular and the polite jostled one another. From this early ribbon development the focus moves east to other carefully chosen and distinctive locations. Distinctive, that is, both in house form and in the local social and economic influences which moulded it. Deptford and Woolwich were key naval shipbuilding centres which Guillery dubs a military-industrial satellite. The tour concludes in one-time outlying settlements such as Hampstead, Hammersmith and Peckham where there were small scatters of houses. The case studies are followed by brief comparisons with small urban houses elsewhere in England and east coast North America.

Taken together, the case studies yield a picture of a housebuilding tradition which was local and variable. Artisan housing was largely based on precedent, generally unsystematic and often overlaid by an influence of classicism. The small scale of the speculative developments did not support much standardisation. Today the vernacular metropolis made up by such houses has been largely forgotten, drowned out and swept away by the polite developments which followed. This demise is attributed to three forces. First was the eclipse of artisans as a distinct social class. Second was building legislation

or, often, its tighter enforcement. Third was the shift from building by artisan masters to contractors. From the end of the eighteenth century housebuilding became increasingly paper based and standardised. The time marks a crucial transition both in the way construction activity was organised and in its products. It would appear that typical space standards dipped at that time, although such trends are problematic.

Guillery ranges widely across the whole spectrum of his subject from the social and economic origins of housing demand, through the means of supply, to house form, materials and appearances, and on to the cultural significance of it all. This wide-horizon, joined up history may be said to leave less space for dealing with the archaeological minutiae of buildings. But the avowed aim of the author is not to provide such fine detail. Rather, it is to convey a rounded picture in which artifacts (houses) are viewed as being rooted in human experience and capable of being interpreted to shed light on that experience. Thus construction history is regarded as being instrumental in the better understanding of society, rather than as a series of successive technical solutions to problems of shelter.

The book originated with the Royal Commission on the Historical Monuments of England in 1997, continued by English Heritage. The result is excellently produced and richly illustrated with numerous house plans (presented so as to help size comparisons), sections and perspective reconstructions, together with early street plans and the like. Many of the carefully chosen photographs date from the early twentieth century or before, with some superb, detailed, large format views which capture the surrounding social scene. The whole is rounded off with extensive notes on sources and a very full bibliography. The high quality of production is complemented by an approach and literary style at once clear, penetrating and stimulating, and which no doubt benefits from profound knowledge of period and place as well as buildings. Evidence is carefully weighed, and measured conclusions are presented without fuss. Occasional minor digressions provide well-judged relief, as with the extraordinary case of housebuilder Mary Lacy, alias Slade (1740-95), a doughty lady who went to sea disguised as a man before completing a shipwright's apprenticeship and an autobiography. Not all housebuilders were, or are, such. Part of 'Slade's Place' still stands in Deptford High Street as her memorial. The book in which she fleetingly features is a very valuable study of a hitherto-neglected subject and is a pleasure to read.

Christopher Powell,
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The Old Iron Bridge, Spanish Town, Jamaica

Suzanne Francis Brown & Peter Francis, 2005

Kingston, Jamaica: University of Technology, Jamaica

115 pp. 1 colour and 68 b&w illustrations. £7

ISBN 976-8027-23-1

This is the second in a proposed series of monographs to describe and celebrate the variety of structures in the Caribbean. It deals with a cast iron bridge, designed and fabricated in Britain in 1800, shipped to Jamaica and erected there in 1802. The bridge is therefore the first of its type in the New World, an early and fine example of prefabrication and one of the oldest surviving cast iron bridges anywhere. It was designed by Thomas Wilson (1751-1820), who had been closely involved with the great Wearmouth Bridge at Sunderland in 1792-96. That bridge had suffered problems from lack of rigidity and the Spanish Town bridge showed significant development in its detail design.

The authors are respectively a journalist and an architect, with strong interests in history and conservation. The book deals very fully with all aspects of the subject. The chapter on the technological context relies heavily on information from British institutions and individuals and, in the absence of archives that have not already been investigated, provides a useful summary of existing knowledge. Details of the shipping and erection have been found in contemporary newspapers in Britain and Jamaica and there is detailed analysis of the reasons for the choice of this location and structure. The book is liberally illustrated with views of the bridge, both historic and modern, and maps of the area, from a wide range of sources. There is a series of drawings by Oliver Cox (co-author of the first monograph, about the Old Naval Hospital at Port Royal) showing an erection sequence starting at the crown of the arch and working towards the abutments. This is based on knowledge of the Sunderland bridge and detailed investigation at site, an outstanding feature of this work.

There are one or two minor inaccuracies in the description of the work in Britain, where the authors do not appear to have had access to the most up to date information, but this detracts hardly at all from a most valuable book. The treatment is comprehensive and well presented. The text is given in parallel in English, Spanish and French.

The iron bridge at Spanish Town is one of only three by Thomas Wilson that remain today. Although ultimately the form of this bridge, with cast iron voussoirs, would prove to be a technical cul-de-sac, but the series of eight that he designed between 1792 and 1810 demonstrates vividly the development of thinking and practice in the early days of cast iron bridges. Some aspects of the bridge at Stratfield Saye, the second of the three survivors, look forward clearly to the more satisfactory designs of Telford and Rennie in Britain. The bridge at Spanish Town is clearly a monument of significant international importance, and the book ends with a chapter on current repairs and plans for its refurbishment. It is a welcome addition to the literature, particularly in its wide ranging approach, and it is to be hoped that it will find a wide readership.

Peter Cross-Rudkin,
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Edward Cressy 1792-1858. Architect and Civil Engineer

Diana Burfield, 2003

Donington, Lincs.: Shaun Tyas

240pp. 55 illust. £24.00

ISBN 1-900-289-652

Edward Cressy will be known to readers of this journal mainly as the author of *An Encyclopaedia of Civil Engineering*, which first appeared in 1847 and went through two new editions in 1856 and 1861. This was one of the most widely known early textbooks of engineering, covering history, geometry and mechanics as well as specialist topics such as piling, dredging and masonry construction. Cressy's encyclopaedia may not rank with its French equivalents published in previous decades, but the fact that it was reissued twice shows that it served its purpose well.

On the titlepage, Cressy classed himself as 'Architect and Civil Engineer', for although by training he was an architect, he was one of those who regretted the increasing split between architectural and engineering skills. Like others, such as Alfred Bartholomew (the second editor of *The Builder*), he believed that the two should be united through their common interest in the mechanics of building. He was convinced that the sense of shared purpose which characterised the work of medieval masons should serve as a model for contemporary practice. But if forced to make a choice between them, Cressy favoured the engineers, for being better educated and organised and for having a clearer sense of their professional role.

There are some obvious parallels between the position which Cressy adopted and the stance taken by the Munich architect Jakob Kreuter, whose biography was reviewed in Vol. 19 of this journal. Like Kreuter, Cressy distanced himself from the architectural profession, in his case by declining to become a long-term member of the (Royal) Institute of British Architects. His stated reason for remaining aloof was that the Institute was too exclusive, specifically that it refused membership to those who were merely measurers: 'to Professor Donaldson, Barry, Hardwick, and some others we owe this state of stupidity in not having a Basis sufficiently capacious to embrace all'. Yet, although he looked to the engineers as a model, they were no more liberal in outlook, and he also declined to join their institution. Like Kreuter, his refusal to acknowledge the growing division between the different design professions led to his being partly left out in the cold.

Diana Burfield is Cressy's great-great-granddaughter, and perhaps out of a residual loyalty to him, she seems reluctant to confront the point that his increasing commitment to engineering in the last twenty years of his life was the result of his lack of flair as an architect. At the outset, everything looked much more promising. He and his friend George Ledwell Taylor went on the Grand Tour together in 1817-19, from which resulted their *Architectural Antiquities of Rome Measured and Delineated* (1821-2) and *The Architecture of the Middle Ages in Italy* (1829). Both of these were path-breaking, scholarly works which took the understanding of Roman architecture, and aspects of medieval architecture, such as constructional polychromy, to a new level. But their subsequent project on the architecture of the Renaissance fizzled out, and their architectural reputations never benefited from these publishing activities in the way that the careers of Adam or Wilkins once had done. Cressy ultimately turned to more modest antiquarian studies such as his book on the church at Stone in Kent, published in 1840, praised in *The Builder* as a work of 'quiet, manly literature'.

The architectural commissions which Cressy received never gave him the chance to develop a distinctive style or approach. Perhaps his most interesting project was a group of artists' apartments in Paris, arranged around a garden square, but it remains unclear how that work came his way: it led to nothing else for him in France. Back home, he had to content himself with modest residential projects, amongst them alterations to Charles Darwin's house at Down, an estate surveyorship in Knightsbridge, and local improvements near his home in Kent.

Diana Burfield acknowledges that Cressy's architectural output was disappointingly slender, yet her

interest in that aspect of his life leads her to downplay perhaps its most interesting aspect, in which his engineering skills came to the fore. In 1848, he became one of the five inspectors working for Chadwick's General Board of Health, responsible for reporting on the condition of towns which had submitted plans for sanitary improvements. Over a three-year period, he dealt with sixteen towns, including Derby, Gloucester and Hastings. Given the bureaucratic nature of Chadwick's organisation, his reports must yield much about the work he had to do, and how he undertook it. Yet only one of his reports is discussed in any detail.

Cresy died at his home from a stroke in 1858, his copy of Vitruvius open before him. Although his labours for the General Board of Health may have been his finest hour, it was his time in Italy forty years earlier which still mattered most to him.

Robert Thorne

Engineering Architecture: The Vision of Fazlur R. Khan

Yasmin Sabina Khan, 2004

New York and London: W. W. Norton and Co.

416pp. illust. £35

ISBN 0-393-73107-3

Among several eminent Kahns and Khans in the history of American construction, none better deserves a full study than the subject of this book. Fazlur Khan was the brilliant in-house engineer within Skidmore, Owings and Merrill's Chicago office who re-energized high-rise design in the 1960s and 70s, revolutionizing its structural style and scale. His evolving system of tube construction broke with the customary steel frame, dominant for three generations, and paved the way for the superskyscrapers we have come to live with today, for better or worse.

From that summary it might be thought that Khan was an American technologist of the purest hue. The truth is more inspiring, and therein lies the value of this meticulous study of his career, written by his daughter. It ranges far beyond the filial piety which is certainly one of its ingredients. Yasmin Sabina Khan is herself a structural engineer, well equipped to expound the technical side of her father's work. But technique is only part of it. As her father did, she is at pains to make constant linkages between engineering, architecture and wider human issues. In both scope and detail her study therefore supplants the only previous book-length study of Khan's work, Mir M. Ali's rather unfocussed *Art of the Skyscraper: The Genius Of Fazlur Khan* (Rizzoli, New York, 2001).

Only in the later twentieth century did architecture become reciprocally international and multicultural. Khan is a graphic example of what that has come to mean. A Muslim and a scholarship boy from what was then East Pakistan, now Bangladesh, he went to the United States in 1952 as a Fulbright scholar at the University of Illinois, without any intention of settling. Returning home, he saw no hope of advancement, and so was drawn back to SOM, where he had worked after graduation. He could not have timed his return better. The Chicago office of SOM was large, busy and humming. Its design side was run mostly by architects trained under Mies van der Rohe at the Illinois Institute of Technology and known as the Mieslings. Brought up believing in structural expression combined with experiment, they were headed intellectually by Myron Goldsmith - slightly underplayed in this book. Engineering, staffed increasingly by international recruits among whom Hal Iyengar should also be mentioned, was kept in-house, and collaboration between the disciplines taken as a matter of course. Khan, as he made his mark, embarked on a lifelong partnership with Bruce Graham, the architectural strongman of the office.

The sequence of fresh thoughts and bold experiments whereby that mark was made and the tall building transformed occupies many of these pages. It is necessarily involved, and not always easy to follow for the non-engineer. Grossly simplified, it consisted of concentrating structure on the building's perimeter in the form of closely spaced columns, sometimes complemented by equally close load-bearing beams at the perimeter (the framed tube), sometimes diagonally braced as at the John Hancock Center (the trussed tube), sometimes connected to a second such system in the core of the building (the tube-in-tube). Whichever the system, the relation of perimeter to core was crucial, in particular for coping with the shear factors due to wind. The consequences were radical. Interiors were released from the tyranny of regular column spacing, the curtain wall became optional or redundant, and the cost of building above a certain height plummeted. By the time Khan and Graham had got on to the Sears Tower in the early 1970s, they were able by means of the 'bundled tube' to subdivide a simple square plan into nine smaller squares each with its own tube structure, and then stop them off at different heights. The matchbox on end had been broken, albeit in ungainly form.

There are many more steps along this path than the John Hancock Center and Sears Tower, and the author takes us through all of them. The story starts with concrete, which interested Khan as much as steel, and SOM's plans for the Brunswick Building (1961-3). Nor is it confined to Chicago, to office

buildings, or to the frame alone. The tube system threw everything in the air. Many pages of this book are about foundations, the unsung because unseen portion of engineering works. Every great engineer must have courage in crisis. This Khan proved in abundance when he stopped the works on the Hancock Center after a slight shift in one of the caissons. A large void in the caisson's core was discovered, due to a faulty but widely used method of construction. The delay proved ruinous for the developer, but without Khan's resolution catastrophe could have occurred.

After the oil crisis of 1973-4, a shift took place in Fazlur Khan's career. It was a watershed for construction everywhere, which the author links to the advent of post-modernism. With the changing nature of SOM's business he found himself travelling more, especially to the Middle East. He had never forsaken his Islamic roots, and now plunged into all those issues of appropriate building in other cultures that skyscraper design ignored. In the process he turned into an architect-planner-manager almost more than an engineer. Two Saudi Arabian projects in particular absorbed his attention: a sensitive university campus at Jeddah, never built, on which he worked with Hassan Fathy and others; and the Hajj Airport Terminal for Mecca, celebrated for its multiplicity of cable-and-fabric roofs. There were many protagonists on the Hajj Terminal. Khan's structural input was probably not decisive, but as a Muslim he fronted and co-ordinated what was perhaps the most intelligent project ever built by an American firm in the oil states.

It was also in Saudi Arabia, by coincidence, that Khan died of a heart attack in 1982, while travelling. He was only 52. His daughter does not say so, but it seems a shame that he had spent the last ten years of his short career running round the world for a corporate firm which had passed its peak, instead of turning consultant and devoting his exceptional creativity and decency to other ends, maybe back in Bangladesh. It was typical of the generous and modest man portrayed in this absorbing book that he never put himself first.

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Building Structures: from Concepts to Design

Malcolm Millais, 2005

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This is the second edition of a work first published in 1997, in which the author - himself a structural engineer - sets out to explain what the structure of a building is, what it has to do, and how it does it. So is this a textbook on structures? Yes it is, and as such any engineering student (and teacher too) will find here lucid explanations of what in the academic syllabus is called 'theory of structures'. But is the book also of interest to the construction historian? I certainly think so, for two main reasons.

Firstly, every building has a structure so that, to fully understand the building, we must understand that structure; this is rarely an easy task, even when the structure is visible and apparently 'obvious'. (Structural engineers themselves don't always get this right when working on an existing building!) The first half of the book is a comprehensive guide to structural behaviour. I gloss the author's definition, to the effect that the function of a structure is to carry loads applied to the building via load paths; these induce forces in the structure which generate stresses and movements that it has to carry while being strong and stiff enough, so that it doesn't fall down. It must also be stable, so that it doesn't fall over. Each aspect of this fundamental need is described, greatly aided by the abundant sketch illustrations, hand-drawn by the author, which complement the text and aid visualisation of structural behaviour. This use of drawings is the valuable printed equivalent of the teacher who quickly draws on the blackboard so that the spoken word is reinforced by the sketch.

Secondly, history and historic buildings are woven into the text. This is particularly evident in subsequent chapters of the book. Millais examines and explains the structural behaviour of a selection of specific major buildings (ranging from Durham Cathedral via the Palm House at Kew, closing with the more recent Bank of China in Hong Kong); he discusses the processes by which structures are conceived; and he considers how structures and the overall form of the building are integrated (or not), in a long chapter with enticing sub-headings such as 'Engineers, architects, decoration and theory' and 'Engineering as fantasy'. The final two chapters, new to this second edition, offer a simple approach to calculations and a somewhat more challenging derivation of the mathematical basis for key equations used by structural engineers. Even here, there is room for some history, with a paragraph on p.403 telling us when and by whom were devised the successive methods of analysing bending in continuous beams by hand calculation, before computers came on the scene.

Millais has very clear, not to say robust, views on important issues associated with structures - if there is a fence around, he is more likely to be on one or other side rather than sitting on it. He attacks the belief of some architects that they have, or should have, an 'intuitive' understanding of structures, quoting a dictionary definition of intuitive as "perception of truth without reason or analysis" and, in my view rightly, arguing that reason and analysis are the very tools needed to understand structural behaviour correctly (p.326). And he writes, perhaps provocatively, that "the idea of 'structural honesty', a Modern Movement edict, makes no sense to anyone who has a conceptual understanding of structural behaviour" (p.317).

He also challenges the belief that there is, for each building, a uniquely correct structure, i.e. one that somehow fits the building's structural needs better than any alternative. As he points out (p.258), provided that a structural design is both structurally sound and meets all the other requirements imposed by the building's design, then that structure is 'correct'. But so may other designs be too, and then the designer has to make an informed choice of which to adopt.

Innovation, sometimes elevated to be a major 'goal of design', does not escape Millais's notice. Possibly his most telling comment on this is camouflaged in the text under the sub-heading 'Prevention of axial instability'. He comments: "perhaps a 'good' copy is better than an ill-conceived 'innovation'"

(p.192). Three cheers for that. Three more for another observation in the same paragraph: “investigating the behaviour of existing structures gives the inexperienced designer important insights into how building structures are designed and built”.

This last comment prompts me to wonder what construction historians in the future will make of the present era, particularly in regard to the current practice of structural engineering. Today even the simplest structure may well be ‘put on the computer’ for analysis by a bright graduate engineer, without necessarily any thinking about how it actually works. The general abandonment of traditional contractual arrangements for building construction (a retrograde step in other ways also, in my view) means that opportunities for design engineers to gain practical site experience as assistant resident engineers are diminishing. The teaching of engineering history on undergraduate courses is also on the decline, under pressure from a crowded syllabus and anyway with fewer historically-informed younger lecturers apparently coming along. And, as Santayana wrote, those who cannot remember the past are condemned to repeat it - not an encouraging thought where the risk of structural failure through ignorance is concerned.

All of these changes represent a dissociation between theory and ‘the real’, and point to the need for tools that can counterbalance them, not least guidance on structural concepts and behaviour that can be studied, preferably in a portable, instantly-fully-searchable format (i.e. a book, not a laptop). This work by Malcolm Millais is valuable in this respect, as well as providing the historically-minded reader with an informative insight into structural matters, from which a better understanding of buildings should come.

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