Smeaton Lecture

July 2020

Slide 1

Well good evening ladies and gentleman, and welcome.

This is the extraordinary story of British consulting engineers. It's based on the research which Mike Chrimes and I did for our book The Consulting Engineers, published earlier this year. Mike I believe is in our audience, and will join me to help answer any questions at the end.

This slide shows a selection of some of the great consulting engineers – John Smeaton, Thomas Telford, Robert Stephenson, John Fowler, Alexander Gibb and Ove Arup. Smeaton, as we shall see, spent *all* his career as a consulting engineer (though he never called himself one). Others, typically, were not consulting engineers for *all* of their careers, and sometimes combined consulting with other activities.

For example, Stephenson was also a locomotive manufacturer and a railway company employee; Gibb was a contractor, military engineer and civil servant, and Ove Arup was a contractor until his mid-40s.

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I'd like to divide this talk into two parts. First, we'll run through a roughly chronological story of the profession and how it developed and changed, up to the present day. On the way I'll address some of these questions:

What *is* a consulting engineer?

Why were *British* consulting engineers so much more successful internationally than any others?

And I'll try to justify the outrageous claim in the subtitle of this talk, that 'British consulting engineers created the world's infrastructure.'

The answers to these questions, as we'll see, have changed over time.

Then we'll take a look at a selection of the Great Consultants, and the firms they created.

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So let's start in early times in Britain. Before the mid 1700s, there were always people who acted from time to time as 'consulting engineers' - though the term had not yet been invented. But when there was a difficult job to do, the norm was to import expertise from overseas. When in the 1620s the Fens of Eastern England were to be drained to create agricultural land, Dutch consulting engineers – notably Cornelius Vermuyden - were called in. Similarly in the 1730s when Westminster Bridge was being planned – the first Thames bridge in London after the mediaeval London Bridge –

the expertise was seen to lie in France, and the Swiss émigré engineer Charles Labelye was employed: this shows the centring in place for constructing one of the stone arches.

But this was probably the last major project in England designed by a 'foreign' engineer. From then on, the tables were turned: as we'll see, British engineers were not only responsible for many works in Britain: through the 19th century their services were in demand all over the world.

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So what made an engineer a 'consulting engineer'? The first answer can be found with this man, John Smeaton, perhaps the greatest of all the early engineers. By his words and deeds, he showed what a consulting engineer should be, and his example – in the second half of the 18th century - created a model for consulting engineers over subsequent centuries.

He called himself a 'civil engineer' – the first do so in Britain: the term 'consulting engineer' was first used later, in 1804. But Smeaton's model embraced the basic tenets of consulting engineering, a model no doubt based on his knowledge of the legal profession, inherited from his lawyer father and learned from his own early training in law.

He described himself as a professional man, as distinct from a tradesman or an employee. He worked always for a fee, and never held a financial interest in projects on which he advised. He considered himself independent, always able to give independent advice. He was probably the first engineer to live out the whole of his career in a professional fee-earning capacity.

Few of his successors who acted as consulting engineers followed Smeaton's example so exactly – as we saw for example on the opening slide. Meanwhile, the civil engineering profession, formalised with the establishment of the Institution of Civil Engineers in 1818, took a much wider view of professionalism – embracing (for example) engineers who worked for contractors, suppliers, client bodies or the civil service.

The canals of the 18th century and the railways of the 19th century brought plenty of work for consulting engineers in Britain. But it was the 19th century which was the first Golden Age for British consulting engineers overseas.

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This included, naturally enough, most of the infrastructure for the British Empire – dams and reservoirs, roads and railways, ports harbours and lighthouses, waterworks and sewerage, and (later) power stations and large buildings. Here's a few examples.

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In mainland Europe too, British consulting engineers were in demand. Joseph Locke created France's first trunk railway – the Paris-Rouen-Le Havre – here he is with his great Barentin Viaduct - ; William Lindley created an extensive practice including water and sewerage schemes over much of Germany and eastern Europe: here's a remarkable scroll commemorating his heroism during the Great Fire of Hamburg, leading to his appointment to rebuild the city. This is Charles Vignoles' great Kiev suspension bridge over the Dnieper in Russia.

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Elsewhere, for example, Sir John Wolfe Barry's firm was consultant for the Shanghai Nanking Railway in China – seen here on its opening day. In South America – despite stiff US competition – British engineers designed most of the railways, with the firm of Livesey & Henderson being the most successful. This is a lovely picture of Valparaiso Station in Chile, on the Santiago & Valparaiso Railway, engineered by Englishman William Lloyd.

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The profession thrived, with most of the ambitious engineers gravitating to Westminster where Bills for their projects had to be negotiated through Parliament. Great George Street became the centre, later spreading west along Victoria Street.

So let's pause to reflect on why consulting engineering was so appealing to engineers, and why the British were so successful at it around the world?

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The first reason was undoubtedly the Industrial Revolution which had created unprecedented demand for engineering works in Britain – primarily (but not entirely) canals, followed by the railways. Initially this was demand at home, but later, other countries wanted to emulate Britain's engineering success, and they wanted to consult British engineers who were the people with the expertise.

The second reason was finance. London was a financial centre of the world, and for a large proportion of the world's infrastructure during the 19th century, capital was raised in Britain. And British investors felt more comfortable if there was a respected British consulting engineer's name on the prospectus. This applied (for example) to Joseph Locke's Paris-Rouen railway, through most of the railways in South America, to the first Aswan Dam in Egypt (Sir Benjamin Baker) at the end of the century.

The third reason, I suggest, is cultural. Despite (or perhaps because of) the success of the Industrial Revolution, there was in the 19th century (and to some degree still is) a deep mistrust and abhorrence of grubby industry. Earning money from the profits of industry was distinctly distasteful. No wonder that so many aspiring British engineers saw their future as professional, fee-earning gentlemen.

Although consulting engineering thrived during the nineteenth century, it was a somewhat ill-defined profession . The great railway engineers – the Stephensons, Brunel and Locke – practised as consulting engineers, but only when it suited, though some of their successors such as Fowler and Baker were more like the firms that developed in the 20th century.

The call for more clarity for the role of the consulting engineer came in the early 20th century, not from the traditional disciplines, but from the new and rapidly expanding electrical engineering industry, and in particular, from the conflict of interest of the many electrical engineers who were advising clients while tied to particular manufacturers: of course, they would always recommend their own firm's wares!

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This man, Alfred Dykes, together with Henry Handcock, his partner in the Westminster electrical engineering consultancy of Handcock & Dykes, were the leaders. They brought together the leading lights in electrical (and water) engineering to try to persuade ICE to establish a group within ICE of consulting engineers who had signed up to a strict code of conduct. But ICE was unmoved, seeing the proposal as elitist. So they established the Association of Consulting Engineers, which held its inaugural meeting in July 1910.

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Two years later they produced this definition of a consulting engineer. It will win no prizes for its brevity – but it does encompass the defining characteristics – expertise, independence and professionalism - and it survived unaltered as the ACE's definition for three quarters of a century.

Members of ACE had to be members of one of the leading Institutions, and their strict code of conduct contained three primary obligations:

- No fee competition
- No advertising of services
- No limit to legal liability.

Originally, all ACE members were individuals, but later, partnerships (or 'firms') were also included.

And so the profession of consulting engineering was defined, and it served the profession pretty well for more than half a century before the wheels started to fall off.

A second 'golden period' came with a surge in overseas activity by British consultants after World War Two. From a standing start – there were probably no more than two firms with more than 100 staff in 1945 – they managed to win an extraordinarily large proportion of the infrastructure work for developing countries.

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By 1961 the Association of Consulting Engineers was boasting that the capital value of overseas work in hand by its members had risen to more than £650M.

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This figure doubled by 1967,

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doubled again by 1972,

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and by 1974 it was £5bn.

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By 1976 it was approaching £15bn,

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and by 1978 nearly £32bn. Even allowing for high inflation, this was staggering growth – unequalled by consultants from any other country - , creating much-needed overseas earnings at a time when the British economy was in serious difficulties.

So what created this great boom? Part of the reason was that there wasn't much work at home. Post-war austerity had delayed long-planned infrastructure projects such as the great estuarial crossings and new roads, and there was a shift of work to the public sector – for example, through nationalisation of rail and electricity.

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A principal reason stemmed from Smeaton's example, and from ACE's definition of consulting engineering. For a time this was seen as a handicap. British consulting engineers had positioned themselves – more so than those from other countries – as impartial professionals who would always advise in their clients' best interests, with complete integrity, independent of any contractor or supplier and not overtly promoting suppliers from their home country. This approach was not always easy to explain to customers who thought they could avoid the cost of professional fees by dealing directly with suppliers. This slide shows how the ACE put it in the 1950s:

This may have been a difficult idea to sell, but fortunately, it was believed by the three most important groups of clients promoting infrastructure works in the developing world.

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First were the international development banks, led by the World Bank, which were funding much of this development. In particular, the World Bank adopted the FIDIC Conditions of Contract which were based closely on the UK's ICE Conditions which enshrined the independent 'Engineer' in the heart of the contract. This gave UK firms a huge advantage. The largest (at the time) and perhaps the greatest was the mighty Mangla Dam in Pakistan, designed by Binnie & Partners and built in 1961-65, funded by the World Bank and the Asian Development Bank.

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The second important group of clients were those from the newly oil-rich Middle East, where Britain had important historic links through its main trade route to India via the Persian Gulf. The construction boom really took off – in Iran, Iraq, the Gulf States and Saudi Arabia – after the quadrupling of oil prices in 1973. And British consulting engineers were predominant across most of the region. Almost all the larger firms were quickly involved, and the work included every form of infrastructure development.

Perhaps the most successful was Sir William Halcrow & Partners, who had the foresight (or good luck) to establish the first consulting engineer's office in Dubai from 1950 – well before oil was discovered there. The firm's close personal relationship with Sheik Rashid, the Ruler of Dubai, led to a string of giant projects – Port Rashid, Dubai dry dock, and Mina Jebel Ali. All were signed with a handshake and a minimum of paperwork, and all had to be completed in impossibly quick time. By

the end of the 1970s Halcrow was in charge of work worth a million pounds a day, and 95% of the firm's revenue was coming from the region.

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The third important group of clients was in the British colony of Hong Kong, which enjoyed a spectacular construction boom in the 1970s and 80s. One of the first consulting engineers to make a mark there was Scott Wilson) with Kai Tak airport and, later, the first cross-harbour tunnel . Other firms followed, and the boom lasted for a generation – till the hand-over of the colony to China in 1997,and beyond. At times Maunsell – certainly – and probably Arup and several other large firms were generating more profits from Hong Kong than the rest of the world combined – including the UK.

Things started to change again from the early 1980s, with greater competition for work overseas – but much more of it, and much more work at home. One startling effect was the huge growth in size of firms.

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Look at this slide. Before the war there was probably only one firm with more than 50 staff. By 1979 – despite huge international growth - there were just seven firms with more than 1000 staff; 35 years later there were at least six with more than 10,000. Today there are several close to the 100,000 mark – though with a much more diverse portfolio of work.

In the process, most firms changed out of all recognition. How and why did this happen?

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The first and perhaps the most important reason was a simple consequence of growth. As firms grew larger they became large businesses, requiring business management skills which the greatest consulting engineers did not always possess. They required substantial working capital which had to be raised by the partners (or through bank loans). And they became valuable businesses, which magnified the problems of succession. In a traditional partnership, a retiring partner would sell his share in the firm to a new partner who would finance the investment perhaps with a bank loan plus deferring his share of the profits for a few years.

But as firms got bigger, they became more valuable and the sums needed to buy-out retiring partners became impossible. One major firm had to sell its freehold property in central London and relocate to rented property outside, largely to pay off a retiring senior partner.

A second reason was the increasing litigiousness of business. As clients and others saw suing the consulting engineer as a legitimate way to recover losses, unlimited liability became unsustainable. Many partners prudently transferred their assets into the names of family members. Most large firms created more complex structures, retaining the fig leaf of unlimited liability practices while sheltering behind limited liability. Others simply left the ACE and became more commercial companies. As one of the early resigners, Terry White – later of White Young Green - , put it in 1976: 'Any prudent consultant splits his assets up amongst his relatives anyway. To be a consulting engineer today you have to be a technically brilliant, economically conscious man of straw'.

A third came with a tax regime which could be punitive for profitable partnerships compared with companies. Under UK law partnerships could not retain profits, so they couldn't build up working capital. And when tax rates peaked under the Wilson government in the 1970s, partners could be paying tax at 83%. Again, the response was more complex business structures, including the use of offshore companies: such as Halcrow's international partnership established in Geneva in 1977.

All of these factors made firms increasingly vulnerable to takeover. The reasons could be many, including limited assets to weather a difficult period or the problems of raising capital to expand quickly as a partnership. But a major factor was that takeover was the simplest way for partners to solve the succession problem and get paid off. For founder-partners, this might be reasonable enough, but for long-established firms the sight of the current partners cashing in (largely) on the efforts of their predecessors caused some disquiet.

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On top of everything else came Margaret Thatcher's victory in the 1979 General Election, which brought about profound changes. The first two of these were both surprising and unwelcome: public spending cuts, including major cuts in infrastructure projects as revealed in this cover from New Civil Engineer.

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And a completely unexpected attack on professional privilege, not aimed at consulting engineers but – eventually – forcing ACE to relinquish – one-by-one – all three of the founding principles of its code of conduct. Fee competition was introduced in 1984, advertising for services was allowed from 1989, and restrictions on how firms managed their affairs – including unlimited liability – were swept away in the 1990s.

But there were other Thatcher initiatives with a much more positive side for the profession, and by far the most important was privatisation.

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The period from 1918 through to the 1970s had seen a steady growth in the public sector in Britain, at the expense of (among others) consulting engineers. This was all reversed by the Thatcher Government.

When Transport Minister Norman Fowler announced the scrapping of the government's Road Construction Units and their sub-units, he announced. 'My major aim is to give more work to private consultants'. 'They already carry out an enormous amount of export work, and it makes a great deal of sense to give them a home base.' This was music to consultants' ears, and all of the sub-units with their staff were transferred to consultants. Much more followed in the late 80s and 90s with, for example, 'externalisation' of local authorities' technical services departments, and privatisation of British Rail, including its large regional design offices, all of which went to consulting firms. The size of firms increased threefold during the Thatcher years, and the principal reason was privatisation.

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This was also a period of merger and acquisition which saw many small and medium sized firms being swallowed up by larger ones, and the larger ones becoming acquisition targets for large overseas companies, mostly from the US and northern Europe – you can see some examples here.

By now consulting engineers – at least at the large end – were unrecognisable from the firms of a generation earlier: more commercial, more multi-disciplined and much, much bigger. Even the ACE had changed its name, to the Association for Consultancy and Engineering.

So let's go back to the beginning and examine who some of these consulting engineers were, where they came from, and what became of the firms they founded.

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This is James Brindley who trained and worked as a millwright before branching into canal surveys, which led to his 'big break': the Duke of Bridgewater commissioned him to survey a canal to transport his coal to Manchester. Within a year of the opening of the Bridgewater Canal in 1761, the price of coal in Manchester had halved, and the benefits of canals were evident to all. The success heralded the Canal Age, and secured Brindley's career as a consulting engineer.

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John Smeaton was born eight years after Brindley, and we've already heard of his role in founding the profession. He also established the means of organising a civil engineering project which survived until at least the late 20th century: the 'Engineer' who designs and supervises construction, separated from the Contractor who builds, and the Resident Engineer – the Engineer's representative supervising works on site. A system which he employed successfully on his great Forth & Clyde Canal across the breadth of Scotland.

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Smeaton trained William Jessop – whose father had assisted Smeaton with construction of his Eddystone lighthouse – and Jessop became the greatest civil engineer of his generation, with a string of canal projects and culminating in his great docks – West India in London, and Bristol's floating dock. But unlike Smeaton, he didn't work *only* as a consulting engineer: he worked also as a salaried engineer, had shares in commercial companies – notably the Butterley Ironworks, and even toyed with a career as a contractor. This was typical of the times.

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Jessop bridged the gap to the greatest engineer of the next generation – Thomas Telford – who worked under Jessop on two of their greatest projects – the Ellesmere Canal including Pontcysslte Aqueduct, and the Caledonian Canal through Scotland's Great Glen.

The last of Telford's great works was the Menai suspension bridge - with the longest span in the world when completed in 1826. This was one of the wonders of the world. Telford is also remembered as the first President of the ICE, the man who secured the Institution's Royal Charter and thereby established civil engineering as a respected profession.

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A generation later, James Meadows Rendel is remembered largely for his great harbours at Grimsby, Portland and Holyhead - and also as the first engineer to found a firm which carried his name into the 21st century. Despite his limited involvement in the early railways, he was appointed as engineer-in-chief to the East Bengal Railway in India, and this provided a base for the firm's development after his death by his son Alexander and (later) by Sir Frederick Palmer, former chief engineer to the Port of Calcutta and the Port of London. Rendel Palmer & Tritton thrived for most of the 20th century, being one of the first firms to develop, post-war in the Middle East, and culminating in London's Thames Barrier in the 1970s.

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Incidentally, as part of the work for our book, Mike and I produced a 'timeline' tracking the development , mergers and acquisitions of many firms from earliest times – and two firms emerged as contenders as the earliest continuous chain to the present day. The first was from Thomas and James Simpson, the great 18th century water engineers, through John Taylor & Sons, Acer and Hyder to Arcadis. The other started with the distinguished Douglass family of lighthouse designers in the 18th century, through Lewis & Lewis, Posford Duvivier to another Dutch Company: Royal Haskoning DHV.

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Now we've got all this way without mentioning the great railway engineers – George and Robert Stephenson, IK Brunel and Joseph Locke. Their lives have been well charted elsewhere, so I'll be brief. Here's a couple of quotes which make clear that a 'consulting engineer' was sometimes seen at the time merely as a name to be attached to a Railway Bill to give it credibility. This is IK Brunel in 1851, and FR Conder was an engineer and author who worked under Robert Stephenson. Despite Brunel's protestations, he and the others worked frequently as consulting engineers.

It's also worth noting that Robert Stephenson provided something of a model of the consulting engineering firms that were to follow, stemming from his success with the London & Birmingham Railway. He chose and developed able assistants who pursued successful careers after his death, and his methods of organising projects, his contracts and specifications provided a model that was copied by others – including Brunel.

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This is Thomas Hawksley, one of the greatest of the water engineers. His works included this, the Vrynwy Dam in North Wales to supply water to Manchester. He also fought a tireless campaign against the encroachment of publicly funded engineers , notably under the General Board of Health, into what he considered to be the rightful territory of private-sector consultancy – a forerunner of battles which would rage through most of the 20th century. The firm of T&C Hawksley (later Watson Hawksley) continued to thrive until a US merger in 1992 to form what became MWH Global.

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Not everything went well for every consulting engineer. This is Thomas Bouch who built his reputation on 'economic railways' including lightweight iron structures, such as this Belah Viaduct in Cumbria. His design for the Tay Bridge – at 2 miles, the world's longest - was similar, but significantly simpler, lighter – and cheaper. On 28 December 1879 the 13 'high girders' collapsed as a train was crossing, killing all 75 passengers and crew. Popular myth blamed the furious storm that was blowing at the time. But as my grandmother – who happened to be out beside the Tay that evening – confirmed, the storm was not that unusual. The Commission of Inquiry found a chapter of errors and concluded that 'the bridge was badly designed, badly constructed and badly maintained'. Bouch was ruined, and died soon after.

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At the time of the Tay collapse, construction had already started on Bouch's ambitious design for a slender suspension bridge over the Forth, seen here. Not surprisingly, work was suspended and this man was brought in as a 'safe pair of hands' to take over.

John Fowler had set up as a consulting engineer in Westminster in 1844 and built up a (for the time) substantial practice. By his competence, tenacity and persuasiveness in front of Parliamentary committees, he had managed to deliver the world's first underground railway – the Metropolitan Line in London – which had been the basis of his future success. His trusted assistant, and later his successor as head of the firm, was this man Benjamin Baker, who was 23 years his junior.

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Their triumph was the Forth Bridge, a pioneering work in the 'new' material of steel. Baker went on to be a pioneer of tube railways in London, and to design the first Aswan Dam across the Nile in Egypt – which on opening in 1902 was by far the largest ever British-built overseas construction project.

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This is Sir John Wolfe Barry, best known for his Tower Bridge in London – disguised as a stone structure but actually another early use of structural steel. He built a substantial practice with his partner Henry Marc Brunel, IK Brunel's son, which trained many engineers of the next generation – including Sir Alexander Gibb.

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Sir Alexander Binnie had a distinguished career in India and as chief engineer to London County Council – effectively Joseph Bazalgette's successor – before aged 62 founding what became one of the great water consultancies of the 20th century. The firm thrived on major water projects before and after the war, and the high point was undoubtedly Geoffrey Binnie's Mangla Dam in Pakistan – mentioned earlier .

A major setback came in May 1984 with a fatal explosion in a valve house at Abbeystead on the Lune-Wyre water transfer scheme in Lancashire. Binnie had designed the scheme to vent through the valve house, rather than a more usual vent shaft. But a build-up of methane coincided with a party of visitors, and a spark triggered an explosion which killed 16 of the party. Four years later the

Court of Appeal found Binnie wholly negligent – a finding most knowledgeable commentators thought grossly unfair. But the decision, and the uncertainty in the intervening period, did great damage to the firm's reputation. In 1995 Binnie was taken over by Kansas-based Black & Veatch.

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Sir William Halcrow was another great name of the 20th century. The firm was founded in 1867 by Thomas Meik and developed by his son Charles, specialising in harbours , marine works and water. Halcrow joined Meik's firm in 1921 and made his name in charge of the huge Lochaber hydroelectric scheme in Scotland, later steering the firm into other fields, particularly tunnelling. A generation later – as we have heard - Sir William Halcrow & Partners enjoyed a golden period in the Gulf, though later things became more difficult, In 2011 Halcrow was taken over by CH2MHill, who were in turn taken over by fellow US firm Jacobs in 2017.

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Mott Hay & Anderson was founded by Sir Basil Mott, a pioneer of early tube tunnels: he was joint engineer with Sir Benjamin Baker for the Central London Railway, the world's second tube railway. And he also developed expertise in large bridges. His greatest work was the first Mersey Road Tunnel with its extraordinary 44ft-diameter, seen here under construction in 1931. High points after the war included Tamar Bridge, Britain's first long-span suspension bridge, and design for the British section of the Channel Tunnel

In 1989, Motts merged with the successful international firm of Sir Murdoch Macdonald & Partners, which specialised in water supply drainage and irrigation. Mott Macdonald is now one of only two of the largest firms still to be owned and run by its employees.

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Most ambitious consulting engineers established their headquarters in Westminster. The most notable exception was Scotland's greatest firm, Babtie Shaw & Morton, founded in 1895 by John Taylor Babtie, which expanded in the post-war period with modernisation of Clydeside's shipyards, major hydro-electric schemes, early Scottish motorways and (later) the Kielder Water scheme in Northumberland impounding Europe's largest man-made lake. Rapid expansion in the 1990s was followed by a merger with US firm Jacobs, who had earlier taken over Gibbs.

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Sir Alexander Gibb had an extraordinary engineering pedigree, starting with his great- great grandfather who was a mason and contractor to Thomas Telford on early Scottish canals. Alexander was a pupil of Sir John Wolfe Barry and worked for Scottish consultant Foreman and McCall, before joining the family contracting business. He had a distinguished war career, ending as chief engineer to the Admiralty, later as a civil servant helping to form the new Ministry of Transport. In 1921 he left to form Sir Alexander Gibb & Partners, aiming to become Britain's largest firm of consulting engineers, an ambition he achieved before the Second World War with an astounding range of projects in five continents, including the Galloway hydroelectric project in Scotland in the 1930s.

Success continued during and after the war with projects such as the huge double-curvature Kariba Dam across the Zambezi in the 1950s. But by the late 1980s Gibb had cash flow problems, triggered at least in part by its troubled Lar Dam project in Iran, and was seeking a 'white knight' . Salvation came from Florida-based consultant Law in 1989, and Gibb was later sold on to fellow-US firm Jacobs.

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A long-time associate of Alexander Gibb was Guy Maunsell, an innovative engineer with a notoriously short temper. After working off-and-on with Gibb for more than 35 years, he set up as a consultant – short-lived after one row too many with his partners, before in the 1950s – aged 71 – setting up G Maunsell & Partners, with four bright and energetic young engineers as partners. The firm thrived, initially with projects in Australia including the concrete-arch Gladesville Bridge in Sydney, later in Hong Kong. Maunsell was taken over by AECOM in 1999.

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Freeman Fox & Partners started with Sir Charles Fox who was articled to Robert Stephenson and became his resident engineer on the London section of the London & Birmingham Railway – designing Euston station's roof - before leaving to co-found the leading engineering and metal-working company Fox Henderson & Co. His greatest achievement was the Crystal Palace for the 1851 Great Exhibition in Hyde Park. In just 10 months, he helped turn gardener Joseph Paxton's sketches into a design, and complete construction in time for the opening – a pioneering example of modular construction and prefabrication.

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When Fox Henderson failed, Fox set up as a consulting engineer with his sons, winning railway and bridge work all over the world- notably in southern Africa. A young Ralph Freeman worked on this spectacular railway bridge over the Zambezi with Victoria Falls behind. Freeman later became senior partner of Freeman Fox & Partners, and designed his most famous work, Sydney Harbour Bridge – the heaviest bridge ever built at the time and still the world's largest arch bridge.

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Freeman's greatest legacy was the team of talented bridge engineers he assembled, including his son Ralph, Gilbert Roberts, Oleg Kerensky and Bill Brown. They led a remarkable roller-coaster ride – including design of the great post-war suspension bridges: across the Forth, the Severn, the Bosporus in Istanbul, and the Humber – the latter with the world's longest span. There then followed two fatal collapses of the firm's large, lightweight steel box-girder bridges – the first at Milford Haven in Wales in 1970, and the second (here) at West Gate in Melbourne later the same year. The collapses prompted the Merrison Inquiry and a programme of strengthening box-girder bridges, and severely damaged the firm's reputation. In 1987, Freeman Fox merged with John Taylor to form Acer.

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Guthlac Wilson was a pioneer of soil mechanics in Britain. He set up Scott & Wilson in 1936, initially designing factories and bridges. After the war came a wide variety of projects in the UK including London's Royal Festival Hall, and an office in Nyasaland which was the start of the firm's long association with roads in Africa.

This in turn led to early work in Hong Kong. But in 1953, Wilson and his wife were killed in an air crash in Africa, while returning from Hong Kong. Largely to help with succession, the firm merged with Sir Cyril Kirkpatrick & Partners, which had been founded 30 years earlier by the former chief engineer of the Port of London Authority. Later distinctions for Scott Wilson Kirkpatrick & Partners included the section of M6 through the Lake District, widely praised for the way it was worked into the environment, and several of Scotland's early motorways.

In 2002 the new chairman Geoff French led a major expansion through acquisition, which in turn led to a takeover by US firm URS Corporation, and in 2013 URS itself was taken over by AECOM.

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Many new firms emerged immediately after the war, the most successful of which were Arup and Atkins.

Ove Arup was born in Newcastle to Danish parents, educated in Germany and Denmark and studied philosophy for three years before switching to civil engineering. He worked for contractors before setting up Ove Arup & Partners in 1946.

His passion was 'total design' of buildings, a belief that the engineer and architect should work closely from the start as an integrated team to produce the best result for clients. His big break came with the Sydney Opera House, and the chance to turn architect Jorn Utzon's 'unbuildable' vision into reality. Its success demonstrated to the world the engineer's important role with designing modern buildings, and was the foundation of the firm's subsequent success. The firm remains in the ownership of trusts, effectively owned by its employees.

Ove's greatest legacy is the ethos he instilled in his staff - of 'total design', dedication to quality, and humanitarianism - which – uniquely - continues to inspire a generation of engineers, most of whom never knew him. He expounded his philosophy in his 1970 Key Speech. You can find it on Arup's website, and it's well worth a read.

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Another who started his firm after the war following a career in contracting was Bill Atkins, though their approach to consulting engineering was very different: Atkins was much more business-like. In late 1945, when WS Atkins & Partners was effectively just Bill Atkins, he was invited to be consulting engineer for the huge Abbey Steelworks in Port Talbot – a priority project for post-war reconstruction. Success gave him a market lead as one of the few firms with expertise in industrial development, and the only one with project management as a core discipline. More industrial projects followed throughout the world, including the world's first commercial nuclear power station at Berkeley in Gloucestershire, plus diversification into other disciplines including highways and tunnels.

Atkins was floated on the London Stock Exchange in 1996, Meanwhile, while its competitors were being swallowed up by overseas firms, Atkins was doing the opposite, completing a string of takeovers, notably of firms in the US. But in 2017, Atkins and its 17,000 staff was itself taken over by SNC Lavalin of Canada.

And so we're nearly up to date, and you can see that the larger firms have grown very large indeed, and divide themselves up between those that have remained British and employee-owned – Arup and Mott MacDonald – and those that have become parts of large, foreign owned multi-nationals such as these examples *AECOM, Jacobs, MWH, Black & Veatch, Arcadis, Sweco, SNC Lavalin and Tetra Tech.*

But there are many other medium-sized firms – such as Buro Happold – or small regional or specialist firms which remain much closer to the form of the traditional partnership of the early consulting engineers. And at the other end, there is one British firm which is right up there among the big multi-nationals.

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Chris Cole was a founding partner of building services engineers Williams Sale Partnership, aged just 27. He decided he wanted to turn the firm into a large multinational, but didn't have the time to do it organically, like Arup who he much admired. He took WSP to the stock market in 1987, and began a programme of growth, largely by merger and acquisition, mopping up many well-known British names such as Mouchel, and others including several great US firms - Parsons Brinckerhof - and Cantor Seinek, the renowned New York skyscraper specialist. The latter led to WSP's three landmark buildings – One World Trade Centre rising from the ashes of 9/11 in New York, and western Europe's two largest buildings – the Shard and 22 Bishopsgate.

After a reverse takeover by Canadian consultant Genivar, the WSP name was retained, with Cole as executive chairman. So it can still be seen as a British firm. Last I heard before lock-down, Cole was trying to arrange a merger with AECOM which would create a mega firm. He told me a few years ago: 'I always believed in consolidation, that consulting engineers would follow the accountancy model with eventually just four large firms- no numbers five or six'. It seems WSP in one form or other could be one of them. But I suspect that there will long be room for others.

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So there we are. Just a taste of who these remarkable consulting engineers were. If you'd like more, try our book!

ENDS