CIVIL ENGINEERS' COMMEMORATIVE PLAQUES

Biographical notes on the civil engineers whose
names are commemorated on the façade of the
Civil Engineering Building

CIVIL ENGINEERING DEPARTMENT

IMPERIAL COLLEGE

LONDON
1995

FOREWORD

The term *civil engineer* appeared for the first time in the Minutes of the Society of Civil Engineers, formed in 1771. In using this title, founder members of the society were recognising a new profession in Britain which was distinct from the much earlier profession of military engineer. John Smeaton, whose name appears among those on the plaques, was among the founder members. The Society, which still exists, was later renamed the Smeatonion Society of Civil Engineers after principal founder, John Smeaton, and was the precursor of, but distinct from, the Institution of Civil Engineers, which was formed in 1818, with Thomas Telford as its first President.

The transformation of Britain from an agrarian to an industrial society during the eighteenth and nineteenth centuries was made possible only through the skill and ingenuity of civil engineers. From the beginning of the eighteenth century the quantity and range of engineering work gained momentum, encompassing river navigation schemes, drainage of marshes, work on docks and harbours, the building of bridges, and the surveying and laying out of a large canal system. The last involved tunnels and aqueducts on a hitherto undreamt of scale. As the Canal Age gave way to the development of the railway system during the nineteenth century, the challenges which engineers had to meet became even greater. The building of the railway track and bridges called for rapid advances in iron technology and an understanding of behaviour of both wrought and cast iron. Many contributions were made to this subject during the nineteenth century, and some very large complex iron and steel bridges were built. Advances in tunnelling techniques made possible the construction of large tunnels and the first deep 'tube' railway at the end of the century.

Engineers also devoted themselves to water supply and the provision of sufficient clean water for the growing population. At the same time the creation of good sanitation received attention and the science of public health engineering was born. Many engineers made their contribution through service overseas or international advice. This century has seen further advances in materials science and in all branches of engineering.

The names we have chosen for our commemorative plaques reflect some of this activity in Britain. To choose only nineteen to represent this long and important period of engineering achievement was difficult. Our earliest engineer is John Smeaton, born in 1724; our latest, Sir William Glanville, born in 1900. Between these two, we give a selection of great names representing advances in different branches of engineering, and including engineers from the universities and research institutions as well as practising engineers. We are keenly aware that a list like this will be controversial and it was with much regret that we had to set aside some names in favour of others.

The plaques are arranged on the façade in chronological order of date of birth of the engineers, but they may be thought of as forming several groups:

1. An early and ‘great’ group, active in the late eighteenth century and the first half of the nineteenth century: Smeaton, Jessop, Telford, Rennie, Stephenson, Brunel

2. Theorists contemporary with this group: Tredgold, Hodgkinson

3. Practising engineers of the mid-century and the second half of the nineteenth century: Cautley, Hawksley, Bazalgette, Binne, Baker

4. ‘Academic’ engineers of this period: Rankine, Unwin, Reynolds

5. Engineers working in the century: Gibb, Freeman, Glanville

The arrangement of this booklet follows these groupings.

Nowadays a civil engineer’s work many encompass practice, teaching and research, but in earlier times his role was more defined. Three descriptions are therefore used on the plaques:

Civil Engineer (a practising engineer)

Professor of Engineering (an engineer in a university or college)

Engineering Research (an engineer in a research institution or whose main contribution has been a fundamental research)

The idea of having civil engineers commemorative plaques came from Professor P.J. Dowling, F.R.S., F.R.Eng., (Head of Department 1985–1994), in discussion with Mr W.D. Evans, then Chief Engineer, Maintenance Services Section, Imperial College. The names were selected by Emeritus Professor A.W. Skempton, F.R. Eng., F.R.S., Dr. L.G. Booth (Reader in Timber Engineering) and myself. The plaques were designed by the Walker Wright Partnership at the request of Mr Roy Loveday, then Departmental Superintendent, and executed by Marbles Ltd., West Wickham. They were put in position in July 1987 during refurbishment of the façade under the direction of Mr D.S.B Burtenshaw of Maintenance Services.

This booklet was first produced in 1987 at the request of Professor Dowling, I am grateful to those who helped at that time: Dr L.G. Booth, now Emeritus Reading in Timber Engineering, who wrote the biographical entries for Brunel and Tredgold; Dr N.A. F Smith, now Emeritus Reader in History of Technology, who supplied biographies for Baker, Bazalgette, Rankine, Reynolds and Stephenson; Emeritus Professor Sir Alec Skempton for editorial, comment on the draft; Mrs Kay Crooks, then Civil Engineering Department Librarian, for bibliographic assistance; the late John Cooper of Dalbeattie Printers Ltd. For advice on the design; Mr Richard Green, then Departmental Administrator, for the cover design.
The booklet was revised in 1995 to incorporate new material on Sir Alexander Binnie supplied by his grandson and the late Mr G.M. Binnie and Mr J.G. Eldrige of Messers, Binnie and partners, and on Sir Ralph Freeman supplied by his son, the late Sir Ralph Freeman, C.V.O., C.B.E. This edition reprints the 1995 version and was expertly typed and produced by Fionnuala Donovan.

Joyce Brown
Formerly Senior Lecturer
Environmental Studies

February 2000

An early and 'great' group of engineers

JOHN SMEATON, F.R.S. (1724-1792)

John Smeaton is generally recognised to be the founder of the profession of civil engineering in this country. His work belongs to a period when innovative schemes on a grand scale were just beginning to be called for, and he was without question the leading engineer of his day.

Originally intended by his father for the law, Smeaton left his home near Leeds and went to London where he set up first as an instrument-maker. He was soon, however experimenting with a variety of instruments and machines, and in 1759 he had the high distinction of being awarded the Copley Medal of the Royal Society for his paper on the power of wind and water. He had been elected a Fellow in 1753.

His first great civil engineering achievement was the design and building of the Eddystone lighthouse between 1756 and 1759. Built of extremely strongly constructed masonry, the lighthouse was 70 ft tall up to the base of the lantern and founded on rocks in the wild seas off Plymouth. It established Smeaton's reputation as an engineer and he was thereafter consulted on a wide range of subjects in England, Scotland and Ireland.

Typical work in this period involved designs to improve the navigability of rivers. Some of these, such as Smeaton's scheme for the Calder and Hebble Navigation, were elaborate works involving the construction of a large number of locks, an artificially channel and a feeder reservoir. A more challenging proposal was for a sea-to-sea canal, large enough for sea-going vessels, to join the Forth and Clyde rivers in Scotland. Such a canal would have to cross a watershed with a rise of 155ft and would involve very large locks, substantial aqueducts, and a reservoir. Smeaton worked on it for ten years from 1768, during which time it was largely finished. He also constructed harbours for St Ives, Aberdeen, Portpatrick and Cromarty and a fine fen drainage scheme at Hatfield Chase, while splendid examples of his masonry bridges can be seen at Coldstream, Perth and Banff. Added to all this was the demands for his mechanical skill in the design of numerous mills and works such as the great waterwheel for London Bridge waterworks. His improvements to the steam engine pre-date the work of Watt, while his research on hydraulic limes in relation to Eddystone lighthouse led to the first basic discovery in cement chemistry.

The range and quality of Smeaton's intellectual powers, combined with his practical ability, established him as the outstanding civil engineer of the eighteenth century, and one whom the profession is still proud to recognise as its father.

Bibliography:

A.W. Skempton, *John Smeaton, F.R.S.,* London, 1981

Samuel Smiles, *Lives of the Engineers*, Vol. 2, London, 1862

WILLIAM JESSOP (1745-1814)

William Jessop's name is one which has tended to be neglected in engineering history and yet he was one of the foremost engineers of his period, involved in a large number of engineering works, some of them on a massive and unprecedented scale. One of the greatest harbour engineers, he built three of the then biggest dock systems in Britain or elsewhere: Ringsend Docks (Dublin), the West India Docks (London) and Bristol Docks.

William's father, Josias, had had practical charge of building the Eddystone lighthouse under Smeaton's direction (q.v.), and it was therefore natural that William Jessop should become Smeaton's pupil, and later his assistant. Jessop was with Smeaton for several years, gaining valuable experience in harbour projects, drainage, canal construction and river engineering. Improvement of the inland waterway system was critical for industrial development, and Jessop, on setting up on his own, was to play an unrivalled role in creating a network of rivers and canals in the Midlands in the last thirty years of the century. The Trent, Thames, Shannon, and Don were all improved by him and he was involved in work on five great trunk canals: the Grand of Ireland, the Grand Junction, the Rochdale, the Ellesmere and the Caledonian – the last at Telford's (q.v.) special request.

As international trade grew, the need for improved harbours and docks brought work to engineers. Between 1792 and 1796 Jessop built the extensive Ringsend Docks in Dublin and went on in 1799 to the appointment of engineer to the West India Dock Company in London. He was thus responsible for designing the great Import Dock, 30 acres in extent and 29ft deep, and the 25 acre Export Dock alongside it. In the same period he engineered the brilliant scheme at Bristol to divert the River Avon in a 2-mile cut and thereby transform the old course of the river into a floating harbour 70 acres in extent.

Jessop was also involved in early railway work and was, for example, the engineer of the Surrey Iron Railway, the first public railway running from Croydon for 10 miles to Wandsworth, opened in 1803. His railway work involved him in improvements to the design of cast iron rails. He was a foundation partner of the Butterley Iron Works, a company which was to establish a famous name for itself in the production of iron for mechanical and civil engineering.

Jessop's skill, particularly in canal and river engineering, brought him the respect and admiration of his fellow engineers, and a deservedly high reputation.

Bibliography:

Charles Hadfield and A.W. Skempton, *William Jessop, Engineer*, Newton Abbot, 1979

THOMAS TEFORD, F.R.S. (1757 – 1834)

Thomas Telford stands as one of the great engineers of all time for the huge number and the daring scale of several of his works. His outstanding achievement must be the suspension bridge over the Menai Straits.

Telford was the son of a shepherd in Westerkirk in Eastern Dumfriesshire. His early training as a stone mason took him first to Edinburgh and ultimately to London. There he was fortunate in coming under the patronage of another Scotsman, William Pulteney (later Sir William), who put building work in his direction at Portsmouth and later in Shrewsbury. No doubt it was also Pulteney's influence which secured for him the office of Surveyor of Public Works for the County of Shropshire. This post brought him an important engineering commission in 1793, to build the Ellesmere Canal to connect the Mersey, the Dee and the Severn. This work has on it two stupendous aqueducts. The Chirk aqueduct carries the canal 70ft above the level of the river in a valley 700ft wide; the Pont Cysyllte aqueduct employs and iron trough 1,007ft long and 125 ft above the river level. There are many other instances of Telford's canal works; he was, for example, involved in the construction of the Gotha Canal in Sweden to connect the Baltic and the North Sea, for which he received the Swedish order of knighthood.

An opportunity to benefit his native land came in 1802 when he was commissioned to draw up and extensive report of the improvements to harbours and communications that were needed. As a result, government money was poured into the building and renovation of some 920 miles of good roads and 120 bridges, as well as engineering work on many harbours, and the construction of the Caledonian Canal, a large-scale work cutting diagonally across Scotland to link the Atlantic to the North Sea, on which Jessop (q.v.) also became involved.

Telford also carried out extensive road works in England. One of his triumphs is the London to Holyhead road, required to enhance communications with Ireland. Part of this scheme involved a bridge over the Menai Straits. Telford's suspension bridge, completed in 1826 was built on a truly staggering scale, with the deck of 580 ft span suspended by sixteen wrought iron chains from towers 50ft above the roadway.

Many other fine bridges could be mentioned. The cast iron Bonar Bridge across Dornoch Firth and Craigellachie Bridge over the Spey were so gracefully designed as to seem almost fragile. Splendid stone bridges include Mythe Bridge at Tewkesbury with its single span of 170ft, Over Bridge at Gloucester, while Dean Bridge at Edinburgh is one of Telford's last and noblest structures. Added to such works was the construction of St Katherine's Dock, London, in 1828.

Telford played an important role in the foundation of the Institution of Civil Engineers in 1818 and was its first President in 1820. Highly esteemed in his lifetime, he was honoured in death by burial at Westminster Abbey, where there is also a statue of him.

Bibliography:

Alastair Penfold, editor *Thomas Telford: Engineer*, London 1980

Samuel Smiles, *Lives of the Engineers*, vol.2, London 1862

L.T.C. Rolt, *Thomas Telford*, London 1958

JOHN RENNIE, F.R.S. (1761-1821)

John Rennie's claim to distinction as a civil engineer rests on the considerable number large-scale engineering works he executed, encompassing canals, docks, harbours and bridges, many of them characterised by great beauty of design. His masterpiece as Waterloo Bridge (1811-17), once of the finest large masonry bridges ever built.

Of Scottish descent, Rennie was educated at Dunbar High School and Edinburgh University. An interest in mechanical engineering brought him eventually to London to design and supervise the millwork for the Albion Mill at Blackfriars on behalf of James Watt. After this, he started business as a mechanical engineer on his own account at Blackfriars, but was soon actively engaged in civil engineering works. Early works with which Rennie was associated include two canals – the Lancaster (1792 -1803), which linked industries in the north-west with the Midlands network, and the Kennet and Avon Canal (1794 – 1810), which created a vital navigable link between the metropolis and Bristol. Most canal work was challenging, and these two were no exception, if one considers the great flight of twenty-nine locks to reach the summit at Devizes on the Kennet and Avon and the impressive aqueduct 600ft in length over the River Lune on the Lancaster.

Like other engineers in this period, Rennie was frequently called in, either alone or in collaboration with others, to design or advise on schemes for the construction and improvement of many docks and harbours. These include London Docks, East India Docks (London), Hull Docks, Holyhead Harbour, and Sheerness Dockyard. Another massive work was Plymouth Breakwater, consisting of a wall a mile in length constructed across the Sound. Built at a cost of one and a half milling pounds sterling, it is one of Rennie's great achievements.

Rennie's ingenious schemes for the drainage of the fens were brilliantly conceived and enabled large areas of land to be reclaimed. But perhaps it is as a bridge builder that he showed his total engineering mastery. His bridges are all distinguished by the solidity of their design and their architectural elegance. His three bridges over the Thames Waterloo Bridge, Southwark Bridge and London Bridge) were splendid examples of his work, regrettably all now replaced. His London Bridge, however, was dismantled and re-erected in the U.S.A. in 1973.

Rennie's sons, George Rennie, F.R.S. (1791-1866) and Sir John Rennie, F.R.S. (1794-1874), also became well-known civil engineers.

Immensely hard-working, Rennie was consulted on virtually every major public work in progress, as well as many minor ones, bringing to the task the concentration of meticulous mind. A Fellow of the Royal Society and widely esteemed in his lifetime, he was honoured in death by burial in St Paul's Cathedral.

Bibliography:

Samuel Smiles, *Lives of the Engineers*, col. 2, London, 1862

ROBERT STEPHENSON, F.R.S. (1803 – 1859)

Robert Stephenson was an exact contemporary of Isambard Kingdom Brunel (q.v.) and with him one of the principal engineers of Great Britain's pioneering railway system. And like Brunel, he received a better and more theoretical training than had been usual with their fathers' generation.

In 1823 Robert achieved his first influential role when he became a managing partner, of R. Stephenson and Co., the Newcastle firm founded by his father, George Stephenson, to build locomotives. It was from here that Robert designed and built *Rocket*, the locomotive which won the Rainhill Trials in 1829, and is to be regarded as the prototype design from which all Victorian locomotive practice was derived.

Robert Stephenson's greatest contribution to railways was in civil engineering. The London and Birmingham Railway brought him his first large independent contract, for which he received the notably large salary of £2,000 per year. Long difficult tunnels (such as Kilsby), a troublesome embankment (Wolverton) and enormous cuttings (like Tring) where characteristic of this new era in civil engineering. On another contract, the Chester to Holyhead line, Robert Stephenson faced critical bridge building problems: failure of the Dee Bridge in 1847 all but ruined him, the completion of the Britannia Bridge in 1850 was a triumph. More than any other structure, the Britannia Bridge marks a transition in bridge building, for it was large, it spanned high above the water, it carried heavy loads, it was metal, and its design was verified bother analytically (by Eaton Hodgkinson (q.v.)) and experimentally with scale models. Other important bridges by Stephenson were the Royal Border Bridge at Berwick-on-Tweed, the High Level Bridge at Newcastle-upon-Tyne and the Victoria Bridge at Montreal, by no means his only overseas contract.

Robert Stephenson fulfilled numerous public and professional duties. He presided over the Institution of Mechanical Engineers from 1849 to 1853 and the Civils from 1856 to 1858. He served as M.P. for Whitby for 12 years and from 1847 to his death. He was elected F.R.S. in 1849 ad in 1857 he received an honorary degree from Oxford University in the company of not only Isambard Brunel but also Dr Livingstone.

Bibliography:

M. Robbins, *George and Robert Stephenson,* HSMO, 1981

L.T.C. Rolt, *George and Robert Stephenson*: *The Railway Revolution,* Longmans, 1960

ISAMBARD KINGDOM BRUNEL, F.R.S. (1806 – 1859)

The name of Isambard Kingdom Brunel is one of the most famous in engineering history, whether as an engineer of Clifton Suspension Bridge or as a great railway engineer of as the designer of three of the early 'great ships'.

After a good education in France and England, Brunel began his formal training as an engineer in 1822 by working for his father, Sir Marc Isambard Brunel, the distinguished French engineer, who was at the time in charge of building the first tunnel under the River Thames. Two encouraging events occurred for Brunel at the end of the decade, when he won the competition for the design of a bridge over the River Avon at Bristol and was appointed Engineer to the Bristol docks. Bedevilled by lack of funds, work the now famous Clifton Suspension Bridge dragged on through the 1830's only to be stopped in 1842: happily it was completed soon after Brunel's death.

His frustration over the slow progress on the bridge was lessened when in 1833 he was appointed Engineer to the newly Formed Great Western Railway (G.W.R). The line, which ran from London to Bristol, was notable for its masonry bridges (particularly those at Hanwell and Maidenhead), the tunnel at Box and the terminus building with its timer roof at Temple Meads, Bristol. The line later extended into Devon and Cornwall, where he designed an impressive array of timer viaducts, and into South Wales. The tour de force of the line was the Royal Albert Bridge, which crosses the River Tamar at Plymouth, with its twin 455 ft span tubular wrought-iron trusses.

Not content with his continuing with his continuing dock and railway work, Brunel looked for further challenges by turning to the design of large steamships. The year 1837 saw the launch of the *Great Western,* the largest steamship in the world. It was followed in 1843 by the *Great Britain* (with an iron hull and four times the size of any previous iron ship) and then, in 1858, by the even larger *Great Eastern* (twice the length of the *Great Britain*). The problems faced by Brunel in building these three revolutionary ships, particularly the *Great Eastern*, aggravated his poor health and he died at the early age of fifty-three.

Apart from his honorary degree from the University of Oxford, Brunel was also a Knight of the Legion of Honour. He served on the Council of the Institution of Civil Engineers from 1845 and was a Vice-President from 1850 until his death.

The middle of the nineteenth century was a time of optimism and expansion and engineers were quick to respond to the challenges. Sometimes they overstretched themselves pushing the frontiers of engineering knowledge forward too rapidly. Brunel had many outstanding successes and some magnificent failures, but it is his triumphs we rightly recall and applaud.

Bibliography:

Sir Alfred Pugsley, editor, *The Works of Isambard Kingdom Brunel: and Engineering Appreciation*, Institution of Civil Engineers and University of Bristol, 1976

L.T.C. Rolt, *Isambard Kingdom Brunel, a Biography*, Longmans, 1957

Theorists Contemporary with this Group

THOMAS TREDGOLD (1788-1829)

Thomas Tredgold was the most influential technical author of his generation. The numerous editions of his books, the range of his interest, the scholarliness of his approach, all conspired to make his name a household word among engineers in the nineteenth century.

Born at Brandon, near Durham, Tredgold was apprenticed at fourteen to a local carpenter. After a period of Scotland as a journeyman carpenter he joined an architect's practice in London in about 1813. Its seems likely that he acted as their engineer with special responsibility for structural design in timber and cast iron, and in later years, heating schemes. In 1823 he began his own practice as a civil engineer and author.

Tredgold's first publication was a two-page note for the *Philosophical Magazine* on the comparative stiffness of beams, during the next fifteen years he published more than fifty papers on topics as diverse as the strength of materials, geology, hydro-dynamics, calculcus, steam boats and carriages, and the heating of buildings.

With his early training it was natural that his first book, published in 1820, should be E*lementary Principles of Carpentry.* There has been many previous books on carpentry and joinery, mainly from an architectural point of view, whereas Tredgold's was the first to be devoted entirely to carpentry and the first to treat the material using engineering principles. During the next nine years he wrote books on *Cast Iron*, *Warming and Ventilating, Railroads and Carriages* and, finally, the *Steam Engine*. All went into several editions and some were translated into French, German and Spanish. *Carpentry* was the most popular with over twenty editions, the last appearing as recently as 1946.

His most memorable words were not, however, in his articles or books. In 1827 the Institution of Civil Engineers (of which he was an Honorary Member) asked him for a description of civil engineer for their new charter. Tredgold's reply began with the now famous words:

> 'Civil engineering is the art of directing the great sources of power in Nature for the use and convenience of man'

When he wrote these words, Tredgold was at the peak of his career, but within thirteen months he was dead, his health broken by over-work and the demands of his desire for knowledge. He died in relative poverty, leaving his family to depend on the charity of his fellow civil engineers.

Tredgolds influence was long felt and his books put into the hands of engineers practical manuals of the highest quality and reliability.

Bibliography:

L.G. Booth, R.J.M. Sutherland, and N.S. Billington, 'Thomas Tredgold: some aspect of his work' *Transactions of the Newcomen Society*, vol. 51, 1979, pp. 57-94.

EATON HODGKINSON, F.R.S. (1789-1861)

Easton Hodgkinson's main contribution to civil engineering was to the understanding of the nature and behaviour of iron as a structural material. In a period where the building of railways challenged engineers to produce structures on an unparalleled scale, using materials barely understood, Hodgkinson's work was of fundamental importance.

Despite simple origins in Cheshire as the son of a farmer, Hodgkinson was able to develop his bent for mathematics, and after he and his mother moved to Manchester when he was twenty-two, to write during the following few years a number of very important paper based on both theoretical experimental research. The influence of Dr John Dalton and other gifted men in the Manchester Literary and Philosophical Society, whose meetings he attended, was a formative one on Hodgkinson in this period. In 1822 he corrected existing theories on the position of the 'neutral line' in the section of rupture of a beam, and this understanding enabled him to go on to experimental work on the strength and best form of iron beams. His paper on the strength of cast iron pillars earned him the Royal Medal of the Royal Society in 1841 and election to the Fellowship.

In the next few years he edited Tredgold's (q.v.) classic book, *The Strength of Cast Iron and Other Metals,* and added a volume of his own. Many of his experiments were made at the works of William Fairbairn, a man whose reputation in work on strength of materials was well established, and with whom Unwin (q.v.) was later to work as an assistant. Hodgkinson's work played a critical role when, about 1845, he was invited by Robert Stephenson(q.v.) to verify mathematically Fairbairn's experiments on the wrought iron tubular beams proposed for the Conway and Britannia bridges. In a series of tests and calculations that have now become famous, Hodgkinson and Fairbairn established for the first time a theoretical and practical understanding of the strength of thin plates as used in a box girders. For this work, Hodgkinson received, in conjunction with Fairbairn and Edwin Clark, a Silver Medal at the Paris Exhibition in 1855. In 1846 Hodgkinson published his *Experimental Researches on the Strength and Other Properties of Cast Iron,* a critically important contribution to knowledge of the strength of materials. From 1847 to 1849 Hodgkinson was a Royal Commissioner appointed to enquire into the application of iron to railway structures. In 1847 he was appointed Professor of the Mechanical Principles of Engineering at University College, London, a post he held until his death. He was elected an Honorary Member of the Institution of Civil Engineers in 1851.

Hodgkinson's work, particularly the part carried out in collaboration with Fairbairn, was significant in establishing a scientific approach to structural problems, in which theory, experimentation and calculation come together in the design process.

Bibliography:

Obituary, *Minutes of the Proceedings of the Institution of Civil Engineers*, vol. Xxi, 1891, pp. 542-45

Practising engineers of the mid-century

and second half of the nineteenth century

SIR PROBY CAUTLEY, K.C.B., F.R.S. (1802-1871)

Proby Thomas Cautley belongs to the first generation of British engineers involved in the building of public works in India in the nineteenth century. He was responsible for the design of a pioneer work, the Ganges Canal, a large perennial canal system built primarily for irrigation, which was to have a profound influence on subsequent development of irrigation in India and elsewhere.

Educated at Charterhouse and Addiscombe Military Seminary, Cautley arrived in India in 1819 as an officer in the Bengal Artillery. His service coincided with the period in which a start was being made on the construction of public works by the government, much of the engineering undertaken by military officers. Nothing in his training had prepared Cautley to become a hydraulic engineer, and the skill he showed in carrying out the tasks, assigned to him can only be ascribed to a brilliant ingenuity and courage. Cautley's first years were spent on the restoration of an old canal system derived from the River Jumna. The success of this and the protection it gave against famine encouraged the government it invite Cautley to explore the possibility of leading a very large canal from the Ganges. This was triumphantly achieved in a canal with a main channel more than 500 miles long at the time of its opening in 1854. It was a innovative work, for there were no models anywhere in the world to guide the engineer in the design of such a large channel. At its head it is 200ft wide and 12ft deep, and it had on it the longest aqueduct in the world at the time. Considering the primitive state of knowledge about flow in open channels, it was an amazing successful work, and, with the extensions since made, it is now more than, 1,000 miles long, with over 6,000 miles of distributaries, and plays a critical role in the economy of Uttar Pradesh. It inaugurated a period of large canal construction in Northern India and the area that is now Pakistan, which has continued to the present day. The influence of the Ganges Canal and the lesions learnt from it were felt beyond India in Iraq and Egypt, through experience taken there by men who had served in the Public Works Department in India.

Cautley was also a member of the newly formed Council for India which was constituted in 1858 to rule India after the Mutiny in place of the East India Company. He served on the Council for ten years. He was elected a Fellow of the Royal Society in 1846 and knighted for his services to India in 1854.

Bibliography:

Joyce Brown, 'Sir Proby Cautley (1802 – 1871)- a pioneer of Indian Irrigation', *History of Technology*, vol. 3, 1978, pp. 35-89.

P.T. Cautley, *Report on the Ganges Canal Works: from their commencement until the opening of the Canal in 1854*, London, 1860, 3 vols and folio atlas.

THOMAS HAWKSLEY, F.R.S. (1807-1893)

Thomas Hawksley was a celebrated water engineer, much esteemed and highly regarded in his day. In a period when water and sanitary engineering was in its infancy, he was responsible for building waterworks in most of the major cities in England – over 150 works in all – and also for carrying out sewage and gas works for a large number of towns.

Hawksley originated in Nottingham and began his career in 1822 by taking articles with an architect, subsequently forming with him, and another, the partnership of Stavely, Hawksley and Jalland, engineers and architects. He became ultimately the sole partner and continued the business until 1852, when moved to London, establishing himself a year later at No. 30 Great George Street, Westminster, which remained his address until his death.

His contributions as an engineer were in three main areas: water supply, gas supply and main drainage. He constructed new waterworks for Nottingham, Liverpool, Sheffield, Leicester and many other cities, either by using gathering grounds or pumping systems. Such works were highly innovative in this period. His designs were based on meticulously obtained hydrological data and carefully prepared mathematical calculations, and his reputation for soundness as an engineer was very high. He attached great importance to purity and strove to supply a system of constant service, ingeniously overcoming the problems of keeping supply pipes always charged under pressure.

Hawksley also built a large number of gas works and sewage works for many towns. He reported, with George Bidder and Joseph Basalgette (q.v.), to the Metropolitan Board of Works on the Main Drainage of London, and was involved in later Royal Commissions on Water Supply, and other Parliamentary Enquiries, where he was greatly valued as a lucid witness. An excellent mathematician, he established many useful formulae for professional purposes.

Elected F.R.S in 1878, Hawksley was also President of the Institution of Civil Engineers from 1871 to 1973 and President of the Institution Mechanical Engineers from 1976 to 1977. Many honours were bestowed upon him by foreign governments for his services to them. When in 1914 the City and Guilds College expanded its premises into the Goldsmiths Extension (the L-shaped building on the corner of Prince Consort Road and Exhibition Road, now part of the Royal School of Mines) Hawksley's son Charles donated over £5,000 towards the cost of equipping the new Hydraulics laboratory. This laboratory became known as the Hawksley Hydraulics Laboratory in memory of this distinguished civil engineer.

Bibliogrpahy:

Obiturary, *Minutes of the Proceedings of the Institution of Civil Engineers*, vol. cxvii, 1894, pp 364-76.

G.M. Binnie, *Early Victorian Water Engineers*, London, 1891.

SIR JOSEPH BAZALGETTE, C.B. (1819-1891)

Sir Joseph Bazalgette (the g is pronounced soft as in jet) was of French ext??, his grandfather having been born in the Ardéche and coming to England via the West Indies in 1784. His father became and English naval officer and ironically was wounded in action against the French. Joseph was born in Enfield in 1819.

Joseph Bazalgette's education was private and details are few, although the profession of civil engineering was always the intention. For a few years as a very young man he worked in Ireland on railways and land drainage. He was still only twenty-three year old when he set up as a consultant in Great George Street, London. In 1849 he became Assistant Surveyor to the Metropolitan Commission of Sewers, the body founded in 1848 to take charge of London's chronic public health problem and especially the daunting task of sewage disposal in Europe's biggest city.

In 1856 the Metropolitan Board of Works came into being. Its function was to organise London's public works, the Main Drainage in particular, but also streets and roads, Thames bridges and tunnels, ferries and flood prevention. Joseph Bazalgette was appointed as the Board's engineer. His most urgent problems was the Main Drainage and it proved to be his finest achievement. North and south of the Thames a multiplicity of minor sewers were arranged to empty into a main interception sewer falling at 2 ft per mile from west to east. In the vicinity of Dagenham Reach each interceptor sewer terminated in an outfall where great collecting tanks held the sewage until steam-powered pumps could discharge it into the river on the ebb tide. This huge and unprecedented drainage scheme required the construction of 1,300 miles of sewers, 82 miles of intercepting sewers and the use of 320 million bricks. Throughout Bazalgette specified Portland Cement, the first time that this new material had been used so extensively.

Alongside the Main Drainage, Bazalgette undertook the construction of the three Thames Embankments – Victoria, Albert and Chelsea – designed to constrict the river and reclaim land. In the case of the larger Victoria Embankment, the northern outfall sewer was incorporated into it along with the Metropolitan District Railway. In an effort to improve traffic flows in London, Bazalgette supervised the freeing of its tolls on twelve Thames bridges, designed replacement structures for three others (Putney, Hammersmith and Battersea) and supervised plans for some 3,000 new streets. In over thirty years of engineering work, Bazalgette's impact on London's development was enormous.

Bazalgette was knighted by Queen Victoria at Windsor in 1874 and elected President of the Institution of Civil Engineers in 1884. In 1889 he retired to his house in Wimbledon where he died in 1891. Sir Joseph Bazalgette is not one of the most famous of nineteenth century civil engineers, but he was one of the most important.

Bibliography:

Denis Smith, 'Sir Joseph William Bazalgette (1819-1891): engineer to the Metropolitan Board of Works', *Transactions of the Newcomen Society*, vol. 58 (1986-87), pp 89-110.

Obituary, *Minutes of the Proceedings of the Institution of Civil Engineers*, vol. Cv. 1891, pp.302-08

SIR ALEXANDER BINNIE (1839-1917)

The name of Binne is so well-known in consulting engineering that it seems appropriate to celebrate the distinguished founder of the firm, Sir Alexander Richardson Binnie. Although he specialised mainly in water engineering, Binnie is notable as the engineer of the Blackwall and Greenwich tunnels under the Thames.

Binnie began his training by being articled in 1858 to Terence Woulfe Flannagan and, after the death of the latter, to Frederic la Trobe Bateman, an eminent water engineer. On leaving Bateman in 1862, Binnie worked on railways in mid-Wales, before taking up a post in India in 1868 under the Public Works Department. Here, among other projects, he carried out works in 1873 for the supply of water to Nagpur. For his account of this undertaking he was awarded Telford Premium by the Institution of Civil Engineers. His pioneering work in searching for coal established the Chandha coal-field in the Central Provinces. Binnie's experience in India was to be important to him in establishing the relationship between rainfall and water-supply and the necessity for good rainfall records.

In 1875 Binnie became Chief Engineer for Waterworks for the City of Bradford and was active in the repair and construction of several reservoirs and large schemes for water supply. His success in this office led to his appointment as Chief Engineer to the London County Council from 1890 to 1902, in a period when many important works were needed in the capital. Under him the sewage disposal works at Barking and Crossness were completed, the Barking Road Bridge over the Lea, and the Blackwall and Greenwich Tunnels. He was constantly involved in water supply matters and along with Sir Benjamin Baker (q.v.), Binnie was consulted on the Main Drainage of London and the engineering work it entailed. He was often called to give evidence in Parliamentary Committees and Royal Commissions in connection with this and other metropolitan works, such as the new Highgate archway, and the scheme for widening of the Strand with Holborn – all works executed under his general direction.

Binnie's private practice dated from 1901, and two or three years later he formed a partnership with his elder son, W.J.E Binnie; later in 1909, on the death of Dr G.F. Deacon, they were joined by Martin Deacon, his nephew. Binnie's reputation by now brought international work, particularly in drainage and water supply. A series of lectures on the latter, given in 1877 to the School of Military Engineering at Chatham, was published as a book and went into two editions. In 1913 he published an important work, *Rainfall, Reservoirs and Water Supply,* based on lectures he had delivered at the request of the Chadwick Trustees.

The competition of the Blackwall Tunnell earned Binnie a knighthood in 1897. A few years later, in 1905, he had the distinction of being President of the Institution of Civil Engineers. The firm which bears his name has grown to be one of the largest international consulting firms and one which enjoys a very high reputation.

Bibliography:

Obituary, *Minutes of the Proceedings of the Institution of Civil Engineers*, vol. cciii, 1917-17, pp. 413-15.

Obituary, *Times*, 19 May 1917.

SIR BENJAMIN BAKER, K.C.B., K.C.M.G., F.R.S (1840-1907)

In the second half of the nineteenth century Britain produced a number of civil engineers of international stature, of whom Sir Benjamin Baker was one of the most eminent.

Benjamin Baker was born at Frome in 1840. As a young man he served a four-year apprenticeship at the famous Neath Abbey Ironworks, and then in 1862 he joined the staff of Sir John Fowler as a junior assistant. It was to be a long association, leading ultimately to partnership. At first Baker was involved with railways and especially the construction of major portions of London's Underground. It was his experience of these difficult works that led to the publication in 1881 of his famous paper, 'The Actual Lateral Pressure of Earthwork'.

In the 1870s Baker made his first contact with Egypt, a country with whose engineering he was closely associated for the rest of his life. An early scheme for a ship-cum-irrigation canal between Alexandria and Cairo never materialised; an eccentric little contract in 1878 involved the design of a 'tubular barge' to float Cleopatra's Needle to England; and above all, there was engineering on the Nile. Baker not only built the first Aswan Dam (1898-1902), but he also supervised designs for its first heightening (achieved in 1912). In the process, he dealt resolutely ad skilfully with the concerns then current that gravity dam design in general and the Aswan's design in particular were seriously deficient.

Baker's other great work the Forth Railway Bridge near Edinburgh. Working so closely after the notorious Tay Bridge failure, Fowler and Baker took no chances and built a 1-mile-long steel structure of massive proportions and revolutionary design in that it was made of steel. The largest bridge in the world, it was opened in 1890.

Throughout his life Baker believed absolutely that engineering was a practical art which demanded above all common sense, experience and an instinctive command of men, methods and materials. He had a healthy disregard for calculation for its own sake and once sharply observed that there is nothing more fallacious than facts, except figures'. Yet he was a good theorist as his books and papers on strength of materials, theory of structures and soil mechanics illustrate.

Benjamin Baker was accorded many honours, including a knighthood. He was elected F.R.S. in 1890 and President of the Institution of Civil Engineering in 1895. Honorary membership of numerous North American engineering societies came his way because he had been so frequently consulted there. He died at Pangbourne in May 1907 and is commemorated by a memorial window in Westminster Abbey.

Bibliography:

Rolt Hammond, *The Forth Bridge and its Builders*, London 1964

Obituary, *Minutes of the Proceedings of the Institution of Civil Engineers*, vol. clxx, 1907, pp. 377-83

Academic Engineers of this Period

WILLIAM JOHN MACQUORN RANKINE   F.R.S. (1820-1872)

William Rankine was the foremost engineering academic in Scotland in the nineteenth century and in a relatively short career exerted great influence on engineering education, not just in Britain but throughout the English-speaking world. He was born in Edinburgh, went to school in Glasgow and entered Edinburgh University in 1836. His early career involved him in railway building in Ireland and Scotland, and in 1852 he worked on a scheme to supply Glasgow with water from Loch Katrine. However, before work began, Rankine had, in 1855, joined Glasgow University as Professor of Civil Engineering and Mechanics.

Professor Rankine was one of the first to recognise the necessity, if engineering education was to develop successful, of a full selection of text-books, and proceeded to contribute some important ones himself. The first to appear was his *Manual of Applied Mechanics* in 1858, closely followed by *Manual of Civil Engineering* in 1861. Both became classics and proved so indispensible that they went through many editions well into the twentieth century. Other standard texts prepared by Rankine included *The Steam-Engine and other Prime Movers*, his book *Machinery and Millwork* and the definitive *Shipbuilding, Theoretical and Practical.* At the time, these books were regarded as very mathematical, although one would hardly feel that to-day.

Rankine was also a prolific author of papers and articles, expressing his very wide research interest. Something like 150 titles appear in the Royal Society's *Catalogue*. Early papers deal with railway vehicles and include some of the first discussions of metal fatigue. Otherwise, Rankine's principal subjects for enquiry were these: thermodynamics, into which he introduced the fundamental heat-engine cycle named after him; the strength of materials, where he established rigorous definitions of stress and strain; and the theory of structures, in which he developed methods of frame and arch analysis. Especially important were Rankine's papers 'On the Stability of Loose Earth', a fundamental contribution to soil mechanics, and 'Report on the Design and Construction of Masonry Dams', published in his last year, which brought the crucial middle-third rule into gravity dam design.

William Rankine helped to found the Institution of Engineers in Scotland and was its first president. For the scientific work which he carried out and published in his early career, he was elected F.R.S. in 1853. Surprisingly late, 1872, he became a Member of the Institution of Mechanical Engineers, and in the same year he died unexpectedly in Glasgow on Christmas Eve.

Bibliography:

David F. Channell, 'The harmony of theory and practice: the engineering science of W.J. M. Rankine', *Technology and Culture*, 1982, vol. 23, no. 1, pp 39-52.

Sir Richard Southwell, 'W.J.M. Rankine, a commemorative lecture' *Proceedings of the Institution of Civil Engineers*, col. 5, 1956, Pt. 1, pp. 177-93

WILLIAM CAWTHORNE UNWIN, F.R.S. (1838-1933)

William Cawthorne Unwin has a particular claim on our attention as the first Professor of Engineering in the Central Institution, the College Institution, the College founded in 1884 which was to become the City & Guilds College. He was thus our first Head of Department, as both Civil & Mechanical Engineering were combined in the Department of Engineering and did not separate until 1913. He established the teaching of engineering on such a firm basis that is has continued for over a hundred years in the College, with a deservedly high national and international reputation. Unwin was also a distinguished engineer in his worn right, who made important research contributions in a number of fields and was widely consulted on a range of major contemporary engineering problems.

Unwin's early career was spent with William Fairbairn of Manchester, an eminent engineer with whom Eaton Hodgkinson (q.v.) had earlier worked. Unwin was his assistant for six years, carrying out tests on iron and certain aspects of locomotive technology, and later becoming Manager of the Fairbairn Works. An interest in teaching brought him eventually the post of Professor of Hydraulics and Mechanical Engineering at the Royal Indian Engineering College at Cooper's Hill, Egham. After twelve years in this post, he was appointed Professor of Engineering at the Central Institution

Like Rankine (q.v.) and Reynolds (q.v.), Unwin had to create a suitable course. The one he established was unusual in its period in trying to bridge the gap between theoretical knowledge and its practical applications. His own research on machine design and the strength of materials was possible through the well-equipped laboratories he created. His text-books on these subjects, *Elements of Machine Design* (1877) and *The Testing of Materials* (1888), went through several editions, the former translated into French and German. An acknowledgement of his success as a teacher was his appointment as a Professor of the University of London in 1900.

Among important engineering works in progress at the time, Unwin advised on the Forth Bridge, the Manchester Ship Canal, the Aswan Dam, the Periyar power scheme in Madras, the Central London Railway, the Mersey Tunnel, the London electricity supply and the development of the Niagara Falls of power. His many papers cover a wide range of engineering subjects, including the stability of dams, the testing of the diesel internal combustion engine and the flow in gas mains.

Unwin's distinction as an engineer brought him many honours and prizes, including election to THE Royal Society in 1886. He was President of the Institution of Civil Engineers from 1911 to 1912, President of the Institution o Mechanical Engineers from 1915 to 1917 and President of the Engineering Section of the British Association from 1892 to 1893. The Kelvin Medal, presented by the three leading engineering institutions for outstanding eminence in engineering, was awarded for the first time in 1921, and Unwin was the recipient.

Bibliography:

E.G. Walker, The *Life and Work of William Cawthorne Unwin*, 1938

Joyce Brown, editor, *A hundred years of Civil Engineering at South Kensington*, Civil Engineering Department, Imperial College, 1985, pp.20-32

OSBORNE REYNOLDS, F.R.S. (1842-1912)

Osborne Reynolds, the son of the Rev. Osborne Reynolds, schoolmaster as well as cleric was born in Belfast on 23 August 1942. His early training was as an engineer. He was apprenticed as a mechanic in Stony Stratford in 1861 and then, when he was twenty-one years old, he went up to Cambridge where he graduated with a B.A. in Mathematics in 1867. After Cambridge, Reynolds worked for two years in London with the civil engineers, Lawson and Mansergh. In 1868, at no more than twenty-six years of age, he appointed to the new Chair of Engineering at Owens College in Manchester. For the rest of his working lift it was his one and only position.

Reynolds, as one of the early professors of engineering in England, had to establish teaching programmes in the absence of any recognised procedures. His approach took the view that all young engineers should be given a broad and fundamental training regardless of later specialisation, an attitude which could more easily prevail a century ago. Gradually he also became convinced that the other essential feature of an engineer's training must be laboratory work. The achievement of the necessary facilities at Owens took time, money and effort.

In research Reynold's achieve were prodigious and many of his papers were – and remain –classics. Striking too is the wide variety of his research interests, far too numerous to detail. Broadly speaking, one can say that his work covered aspects of physics and physical chemistry, the mechanic of friction, inertia, fatigue and dilatancy, thermodynamics, pumps and turbines, and hydraulics. And undoubtedly it is his work in hydraulics which is best known and has been generally of greatest importance. In his research on river and estuary behaviour, he determined the means to correlate the length and time-scales of hydraulic models in which the horizontal and vertical scales are different. Although others before him had identified the existence of laminar and turbulent flow, it was Reynolds who introduced viscosity into the parameter which defines the transmission from one state of flow to the other, the so-called Reynolds Number.

Reynolds was elected F.R.S. in 1877 and became a member of the Institution of Civil Engineers in 1883. In 1887 he was President of a Section of the British Association and he served as both Secretary and President of the Manchester Literary and Philosophical Society in the 1870s and 1880s. Poor health forced an early retirement in 1905 and Reynolds died at Watchet in Somerset on 21 February 1912.

Bibliography:

D.M. McDowell, *Osborne Reynolds and Engineering Science Today*, Manchester University Press, 1970.

O. Reynolds, *Papers on Mechanical and Physical Subjects*, Cambridge, 1900, 2 vols.

Engineers working in this century

SIR ALEXANDER GIBB, G.B.E., C.B., F.R.S. (1872-1958)

Sir Alexander Gibb was a distinguished engineer who made an important contribution in naval civil engineering, especially during World War I, and as the first Director-General of Civil Engineering of the newly formed Ministry of Transport in 1919. He was also the founder of the firm of Sir Alexander Gibb and Partners and in his working life was involved in a very large number of works, in particular ports, docks and hydro-electric schemes in Britain and overseas.

After education at Rugby and University College, London, Gibb served his pupillage with the firm of Sir John Wolf Barry and Henry Marc Brunel (a son of Isambard Kingdom Brunel (q.v.)), followed by a period on the firm's staff until 1900. This was succeeded by a period in his father's firm, Easton Gibb & Son, which was later to become Easton Gibb & Son Ltd., under Alexander's chairmanship. During this period he was involved in dock and navel work, becoming, after the outbreak of war, Chief Engineer, Ports Construction, to the British Armies in France and Belgium, and subsequently Deputy Director of Docks for the British Expeditionary Force in France, and in 1918 Civil-Engineer-in-Chief, Admiralty. For his war-time service he was created K.B.E. and later G.B.B., granted a C.B. for his work in France, and given the rank of Brigadier-General (retired) in the Royal Marines, and Colonel (retired) in the Royal Engineers.

Gibb's work at the Ministry of Transport brought under his review schemes which are still topical today – for a Channel Tunnel and a Severn Barrage. He advised on Swansea Docks, and was involved in government committee work in relation to the railways.

In 1922 he set up his own firm of consulting engineers, and was among the first to realise the importance of hydro-electric development in Britain. An early scheme with which he was involved was the Galloway scheme in Scotland (1926-29). He also advised many overseas governments, particularly on hydro-electric schemes and dock and harbour engineering. He was, for example, the consultant on the development of Canadian National Ports (1932), and the construction of the extensive Captain Cook Graving Dock in Sydney (1941-45). Projects at home included the Kincardine Road Bridge (1936) and the renovation of the Menai Straits Bridge – a job which gave Gibb particular satisfaction because of his admiration for Telford (q.v.)

Many honours both native and foreign were heaped upon him and he held office as President in a number of institutions, including the Institute of Welding, the Institution of Chemical Engineers, the Institute of Transport, and the Institution of Civil Engineers, over which he presided from 1936 to 1937, as well as being active on many committees. He was elected a Fellow of the Royal Society in 1936, and subsequently received the honorary degree of Doctor of Laws from Edinburgh University. He is noteworthy too as the author of a book on Telford in 1935, and was thus among the first writers to take engineering history seriously.

Bibliography:

Godfrey Harrison, *Alexander Gibb – the Story of an Engineer*, London, 1950.

G.P. Harrison and A.J.S. Pippard, 'Alexander Gibb, 1872-1958', *Biographical Memoirs of Fellows of the Royal Society*, vol 5, 1959, pp. 75-86.

SIR RALPH FREEMAN (1880-1950)

It seems particularly appropriate to commemorate the life and work of Ralph Freeman, since he was a student and special Lecturer on the College, Fellow of the City & Guilds Institute and among the first nine Fellows of Imperial College when that distinction was created in 1932.

Freeman was a prize winning pupil at the Haberdashers 'Aske's School, Hoxton, and in 1897 won a Siemens Scholarship to the Central Technical College (later to become the City & Guilds College), where Unwin (q.v.) was still Professor of Engineering. He was the top student in every one of his nine terms, winning the coveted Siemens Medal and other awards. He then accepted an offer as an 'improver' from the well-known firm of Sir Douglas Fox & Partners, joining in January 1901. He became a partner in 1912, taking full charge of all the firm's war work from 1914, and senior partner in 1921. The year 1938 saw the change to Freeman, Fox & Partners, the name by which the firm, founded back in 1857, has become distinguished in modern times. In the early 1920s Freeman lectured for several years to fourth-year students of the City & Guilds College on 'Steel Structures'.

Although early work included the design of railways and irrigation works in Africa, hydro-electric works in Wales and explosives works for the admiralty, Freeman's talents were superbly revealed in the design of bridges. In 1903, under G.A. Hobson, he prepared the design of the famous 500 ft span Victoria Falls arch bride over the Zambezi. Later, in the 1930's he designed five important highway bridges for the Belt Trust in the Rhodesias, including two highly innovative single spans over 1,000ft. But his masterpiece is undoubtedly the Sydney Harbour Bridge, built between 1924 and 1932. The clear span length 1,650 ft, deck arrangement (57 ft road width, four railway tracks) etc., were specified by the purchaser. Tenderers had to prepare, price and guarantee their own designs. Freeman's designs won the contract for Dorman, Long & Co. For one of his papers on the bridge he was awarded a Telford Gold Medal by the Institution of Civil Engineers, and for the other, jointly with Lawrence Ennis, a Telford Premium. He also received the first Baker Gold Medal for his contribution to the development of engineering practice in the long-span bridge field. At the time of his death, soon after completing the structural design of the Dome of Discovery for the Festival of Britain in 1951, Freeman was working on designs for the projected Auckland Harbour Bridge, New Zealand, and, jointly with the late Sir David Anderson, for the Forth Bridge and the River Severn Bridge, both have main spans of about 3,300 ft.

Freeman's work id described as combining 'boldness of conception with simplicity of design'. He served on the Council of the Institution of Civil Engineering from 1938 to 1942. Chairman of the Ministry of Supply's Structural Engineering Committee during the vital period of World War II, he was also President of the Institute of Welding from 1942 to 1944, and a member of the Royal Fine Art Commission from 1939 to 1948. His eminence as an engineer was recognised by the knighthood conferred on him in 1947.

Bibliography:

Dictionary of National Biography, 1941-50

Obituary, Journal of the Institution of Civil Engineers, Vol. 34, May 1950, p. 276

SIR WILLIAM GLANVILLE, C.B., C.B.E., F.R.S. (1900-1976)

Sir William Henry Glanville was an outstanding engineer and scientist who his main contribution to engineering through research, notably into the properties of reinforced concrete.

After graduation from what is now Queen Mary College, University London, Glanville joined the staff of the Building Research Station in 1922, where he was to become eventually head of the engineering division. His early years there culminated in the publication in 1930 of a three-part paper entitled 'Studies in reinforced concrete', and this, together with further work published in 1939, formed the basis for codes of practice for the design of reinforced concrete structures. He was awarded the degree of D.Sc in 1930.

Glanville was, in fact, to spend all his working life in the scientific civil service under the Department of Scientific and Industrial Research. In 1936 he transferred to the Road Research Libratory and in 1939 became its head, a post he held until his retirement in 1965. His first years there coincided with the outbreak of war and he turned over the research activity of the Laboratory to work on, for example, the rapid construction of airfields and to studies of soils sampled from operations areas. Important work on explosion phenomena and the effect of the blast on earth –movements and concrete was carried out through model testing, on dramatic outcome being the pin-pointing of the position and charges necessary for the destruction of the Möhne and Eder dams.

After the war Glanville's team became more interested in traffic and safety research, and this led to many innovations in relation to road safety, speed and flow of traffic, as well as new ideas about road networks and designs of towns. There was also extensive research on road materials, enabling the engineering properties of road aggregates to be classified. All of this work brought the Road Research Laboratory an international reputation, largely achieved through Glanville's vision and drive.

Glanville served on a large number of national and international committees. Many honours came his way – election to the Royal Society in 1958, the award of the Ewing Gold Medal of the Institution of Civil Engineers and the Gold Medal of the Institution of Structural Engineers in 1962. He was President of the Institution of Civil Engineers from 1950 to 1951. He also received civil honours, being appointed C.B.E in 1944, C.B.E in 1944, C.B in 1953 and knighted in 1960.

Bibliography:

J.F. Baker, 'Sir William Glanville, 1900-1976' *Biographical Memoirs of Fellows of the Royal Society*, vol. xxiii, 1977, pp. 91-113

BIBLIOGRAPHY

The bibliography given for each engineer has been limited to one or two works of a biographical nature. Other works of more interest include the following:

Asa Briggs, *Iron Bridge to Crystal Palace. Impact and Images of the Industrial Revolution,* London, 1979.

George Charlesworth, *A History of the Transport and Road Research Laboratory: 1933-1983,* Avebury, 1987.

John Copeland, *Roads and their Traffic, 1750-1850,* Newton Abbot, 1968.

Eric de Maré, *Bridges of Britain,* London, 1954.

W.M. Frazer, *A History of English Public Health, 1834-1939,* London, 1950.

Charles Hadfield, *British Canals. An Illustrated History,* Newton Abbot, 1950.

Bryan Morgan, *Railways: Civil Engineering,* London, 1964.

J.P.M. Pannell, *An Illustrated History of Civil Engineering,* London, 1964

L.T.C. Rolt, *Navigable Waterways,* Longman, 1969.

L.T.C. Rolt, *Victorian Engineering,* Allen Lane, The Penguin Press, 1970.

Ted Ruddock, *Arch Bridges and their Builders, 1735-1835,* Cambridge, 1979.

A.W. Skempton and Esther Clark Wright, 'Early members of the Smeatonian Society of Civil Engineers', *Transactions of the Newcomen Society,* vol. xliv, 1971-72, pp. 23-47.

Norman Smith, *Man and Water. A History of Hydro-Technology,* London, 1976.

INDEX