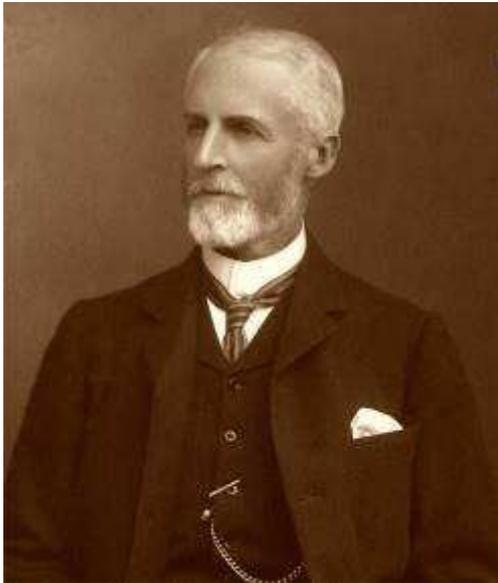


# William Dyce Cay (1838-1925), Civil Engineer

## *James Clerk Maxwell's mathematical cousin*



William Dyce Cay

© ICE Archives



Cay's Glenlair road bridge – 45ft span © K..McCrae

by Prof/Dr **ROLAND PAXTON** MBE FICE FRSE, *Honorary Professor, Heriot-Watt University;*  
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William Dyce Cay, second son of Robert Dundas Cay, W.S., lawyer and brother of Frances Cay mother of James Clerk Maxwell (1831-79), was born on 28 March 1838 at 18 Rutland Street, Edinburgh. He was educated at the Rev. William Bliss's school, Peebles from 1844-53 and Edinburgh University where, in 1856, he obtained its highest mathematical prize, the Straiton Gold Medal and 1<sup>st</sup> prize in the 2<sup>nd</sup> Division of the Natural Philosophy class.

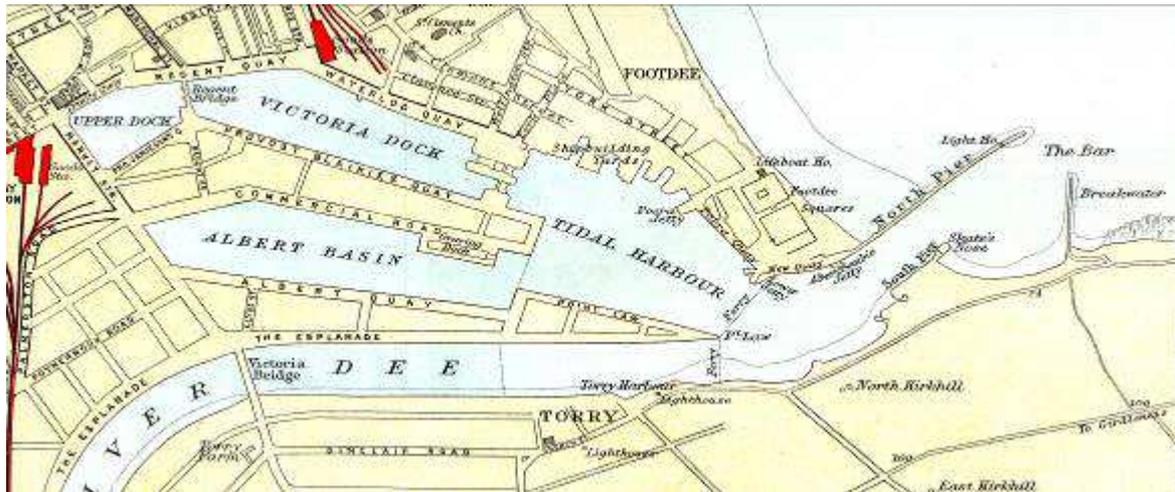
In obtaining these awards Cay acknowledged that the 'tuition and example' gained from his cousin on long walks from the Maxwell estate at Glenlair, Kirkcudbrightshire, in 1855 had 'had good effect'. In 1856 Maxwell went with Cay to Belfast and introduced him to his friend James Thomson (elder brother of William, later Lord Kelvin), Engineer to Belfast Waterworks, from 1857 Professor of Engineering at Queens College, Belfast.

Cay served as a pupil under Thomson from 1856-58, completing his four-year apprenticeship in November 1860 as an assistant resident engineer with leading Edinburgh consulting engineers B. and E. Blyth. He worked on the Creetown, Caste Douglas and Loch Ken Viaduct (iron) contracts on the 60-mile Portpatrick Railway and afterwards in the firm's Edinburgh office. Interestingly, a resident engineer contemporary on this project was Maxwell's fellow *Edinburgh Academical*, Allan D. Stewart (1831-94 - a Cambridge University 9<sup>th</sup> wrangler in 1853, the year before Maxwell became a 2<sup>nd</sup> wrangler). Stewart later contributed significantly to the design of the Tay and Forth Bridges, including the Forth suspension bridge (abandoned in the wake of the Tay Bridge failure), in the feasibility report on which it is noted that he applied 'Professor Clerk Maxwell's diagrams of forces with much skill'.

From June 1862 to August 1863 Cay was resident engineer on the Turin and Savona Railway in Italy under its chief engineer James Abernethy, then for two years in London as an assistant to Alexander Meadows Rendel, returning to waterworks in Scotland from 1865-67 as chief assistant to James Leslie, Edinburgh Waterworks Engineer. In a testimonial to Leslie, Maxwell, who had returned to Glenlair after resigning his Natural Philosophy chair at King's College, London, wrote of Cay:

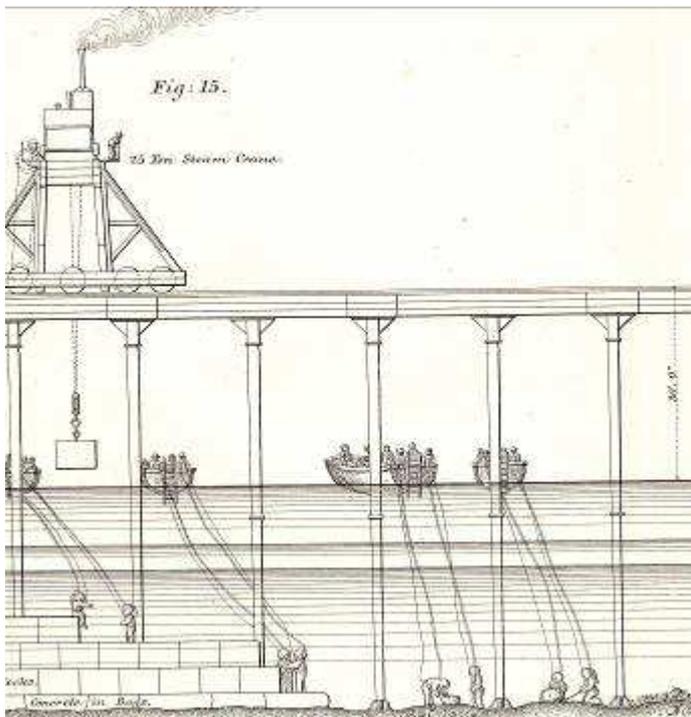
*'His mathematical knowledge is sound and he has made a special study of iron and stone bridges, some of the results of which he has been in the habit of communicating to me ... A skew bridge had to be erected, but some of the stones ... were not properly shaped. Mr. Cay however designed the correct form ... and the bridge was erected according to his plans. Mr. Cay has made a design of a bridge for me across the River Urr which I intend to have executed next Spring'* (1866 – still in service, see photograph)  
 Cay also designed an iron bridge over the Whitadder Watter in the Scottish Borders.

Cay then embarked on his most important civil engineering work as Resident Harbour Engineer at Aberdeen from 1867-80. His direction of a major improvement of the harbour (see map) included, diversion south of what became an extensive and valuable harbour area including Albert Basin and channelizing about a mile of the River Dee; design and construction of the present South Breakwater (1873 - 1050 ft. long – at right on map); extension seaward of the Smeaton/Telford North Pier by about 1000 ft (1877) forming one of the widest artificial harbour entrances in the UK; new quays; dredging about 3,000,000 tons of silt; and as resident engineer on the 5-arch granite Victoria Bridge.

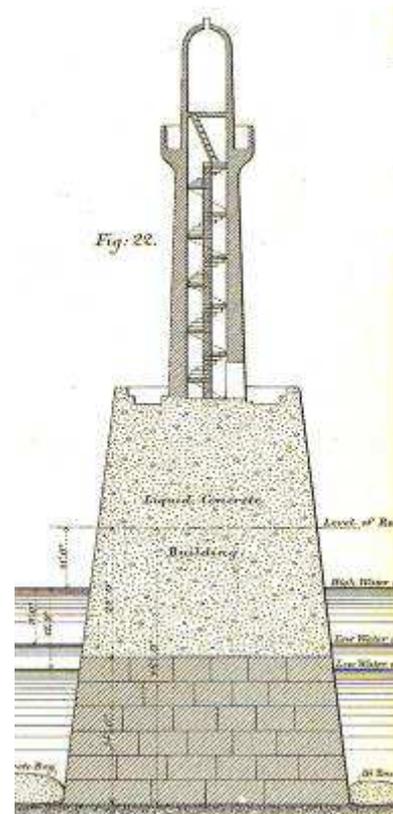


Aberdeen Harbour after improvement

Groome's Gazetteer 1882



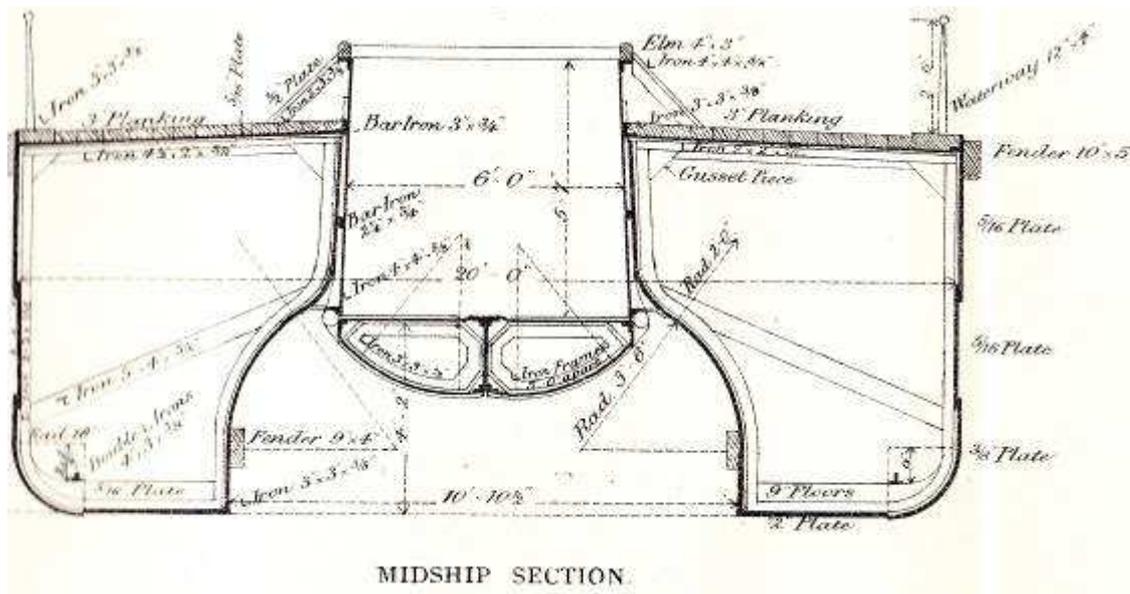
South Breakwater being built under Cay's direction MPICE 39



Breakwater end 1873 and lighthouse

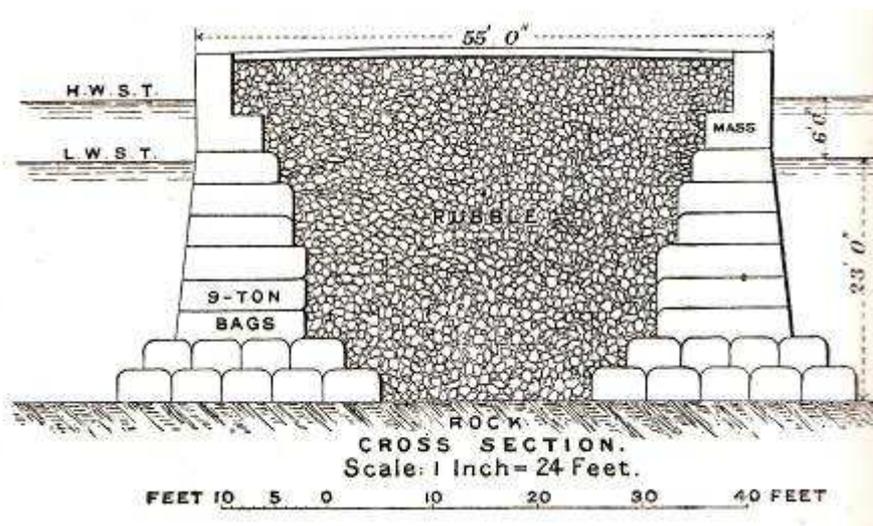
In constructing the harbour entrance, still in service, Cay adopted concrete, in preference to the less reliable traditional practice of rubble base and masonry walls, using about 15,000 tons of Portland Cement in liquid concrete and large blocks. Full width single pours ranged up to a then remarkable 1,300 tons. He engaged to a considerable extent in mechanical engineering, designing the plant and staging and implementing from 1872 a new mode of depositing liquid concrete from a hopper barge to 20 ft below Low Water in jute bags holding up to 100 tons.

Cay also invented and designed steam-operated barges for carrying dredged material to sea, and a concrete-box mixing machine. His experimental work included quantification of the significantly increased early strength of cement briquettes made using salt water. Although he did not invent the concrete-in-bags technique he was the first to use it on a large scale to fit a breakwater sole neatly to its undressed firm foundation, thus minimizing costly excavation. Cay's achievement at Aberdeen was identified and illustrated in Vernon-Harcourt's *Harbours and Docks* classic text book and, that he deserved 'great credit' for his work at Aberdeen, was also publicly acknowledged by other eminent engineers including James Abernethy and Sir John Hawkshaw.



Hopper Barge for depositing 50-ton concrete bags TRSSA 12

Cay's innovations earned him a bronze medal at the Royal Mining Engineering & Industrial Exhibition at Newcastle-upon-Tyne in 1887 and a Brisbane Medal from the Royal Scottish Society of Arts in 1888. By then his concrete-in-bags technique, although of limited later application as plant and use of compressed air and sheet steel developed, had been used at Buckie, Lerwick, Fraserburgh, Arbroath and Newhaven (Sussex) harbours, and New Plymouth Breakwater (Ngamotu), New Zealand, Sunderland Breakwater, Bilbao and in a modified form at La Guaira.



Lerwick Pier 1882 – 9-ton concrete bags MPICE 171

By the mid-1870s Cay had become a leading exponent of the application of concrete in harbour development. He was elected to the Institution of Civil Engineers (MICE, 1872); FRSSA (1867) and FRSE (1882). From 1880–1907 he practised in Edinburgh as a consulting engineer, firstly at 8 South Charlotte Street, from 1882-98 at 107A Princes Street and then from 1 Albyn Place. Work on which he was engaged included harbours at Buckie and Lerwick, reconstruction of the sunken dock entrance at Arbroath and the Royal Bridge over the Dee at Ballater. In 1908 he went to London and took an office at 39 Victoria Street until c.1918. He also engaged on water and gas works at various harbours.

Cay's progressive practice formed the subject of his influential papers published by the Institution of Civil Engineers and Royal Scottish Society of Arts. His career was also remarkable for many valuable experience-based contributions made to *ICE Proceedings* from 1873-1922. Subjects included stability of channels and walls, sand travel, training of rivers, bars at mouths of tidal estuaries, reduction of wave action, coast erosion, use and testing of concrete, groynes, harbour layout and dredging. Many related to specific projects at home, also in Holland, France, Panama, Japan, South Africa, Ceylon, Burma and India including a £760,000 proposal for an outer harbour at Madras (*Engineering* 78 (1904)). He engaged on parliamentary work, extensive surveys, reports, arbitration and evidence, and also, writing of articles on pumps and retaining walls for *Chambers' Encyclopaedia*.

In his 'Recollections' of Maxwell, Cay notes he was '*very fond of society and conversation ... He took much pleasure in my studying and was unwearied in explaining difficulties and wrote out for me a treatise on hydrostatics, hydrodynamics, statics, dynamics and solid geometry ... Although clear on paper he was not so in viva-voce explanations (e.g.) in trying to explain by illustration the principle of virtual velocities ... before I had got to the bottom of one example he had rushed off into another!*'. '*I went to be best man at his marriage at Aberdeen*' (June 1858). '*When professor at King's College, London, I remember his explaining to me the reasons which made him give up that post viz. that the students did not care for instruction except in engineering or practical mathematical subjects*'.

Cay never married and lived during the latter part of his life at the Junior Carlton Club in London or at hotels in various places. He was a member of this and numerous other clubs including the Oriental Club, London; the University Club, Edinburgh; the Royal Northern Club, Aberdeen; the Hon'ble Company of Edinburgh Golfers, Musselburgh; the Aberdeen Golf Club; and of the Casino, Savona. He died on the 2 December 1925 in a nursing home at Folkestone after a short illness.

**Main sources:** ICE Archives; MS. Abstract from Cay's 'Family Book'(1865), CV 1908, Testimonial by Maxwell for W.D. Cay, 26 Sept. 1865, 'Recollections of James Clerk Maxwell (1854-64) by W.D. Cay, 30 April 1881', for copies of which, and encouragement, the author thanks David Forfar; Campbell L. & Garnett W. *The life of James Clerk Maxwell*, 1882, 276; *The Times* 4 Dec. 1925, 1; *Engineering* 11 Dec. 1925, 749; *PRSE XLVI* (1925-26); *TRSSA XII* (1891); *MPICE 37-212* (1873-1922); *Edinburgh P.O. Directories*; Vernon-Harcourt L.V. *Harbours and Docks*, 1885; Paxton R. & Shipway J. *Civil Engineering Heritage Scotland H. & I.*, 2007, 87-93.



Cay's Breakwater still protects Aberdeen Harbour after 140 years

Postcard 1910

Edinburgh: School of the Built Environment, Heriot-Watt University, EH14 4AS, Scotland. 9 December 2013

2<sup>nd</sup> edition [School of EGIS] 29 June 2015 (copies available from [R.A.Paxton@hw.ac.uk](mailto:R.A.Paxton@hw.ac.uk)).

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