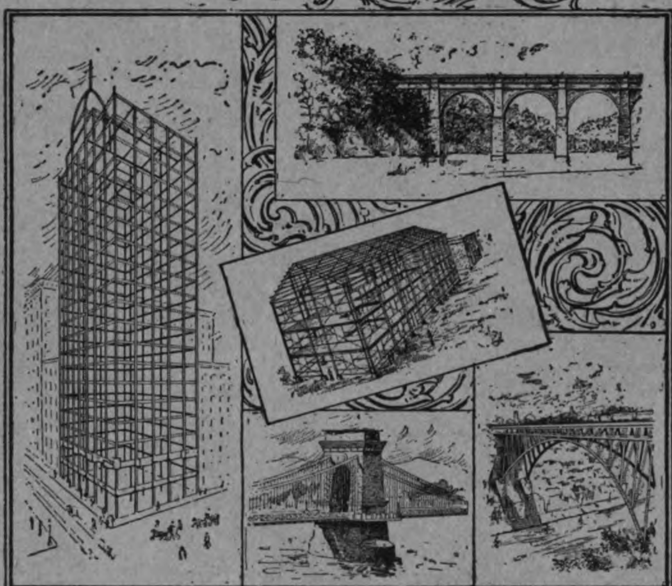
Vol. I. No. 1. April, 1899. Price 30 Cents.

BRIDGES

AND FRAMED STRUCTURES

AN ILLUSTRATED MONTHLY MAGAZINE



FOR
ENGINEERS
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LEADING FEATURES OF THIS NUMBER

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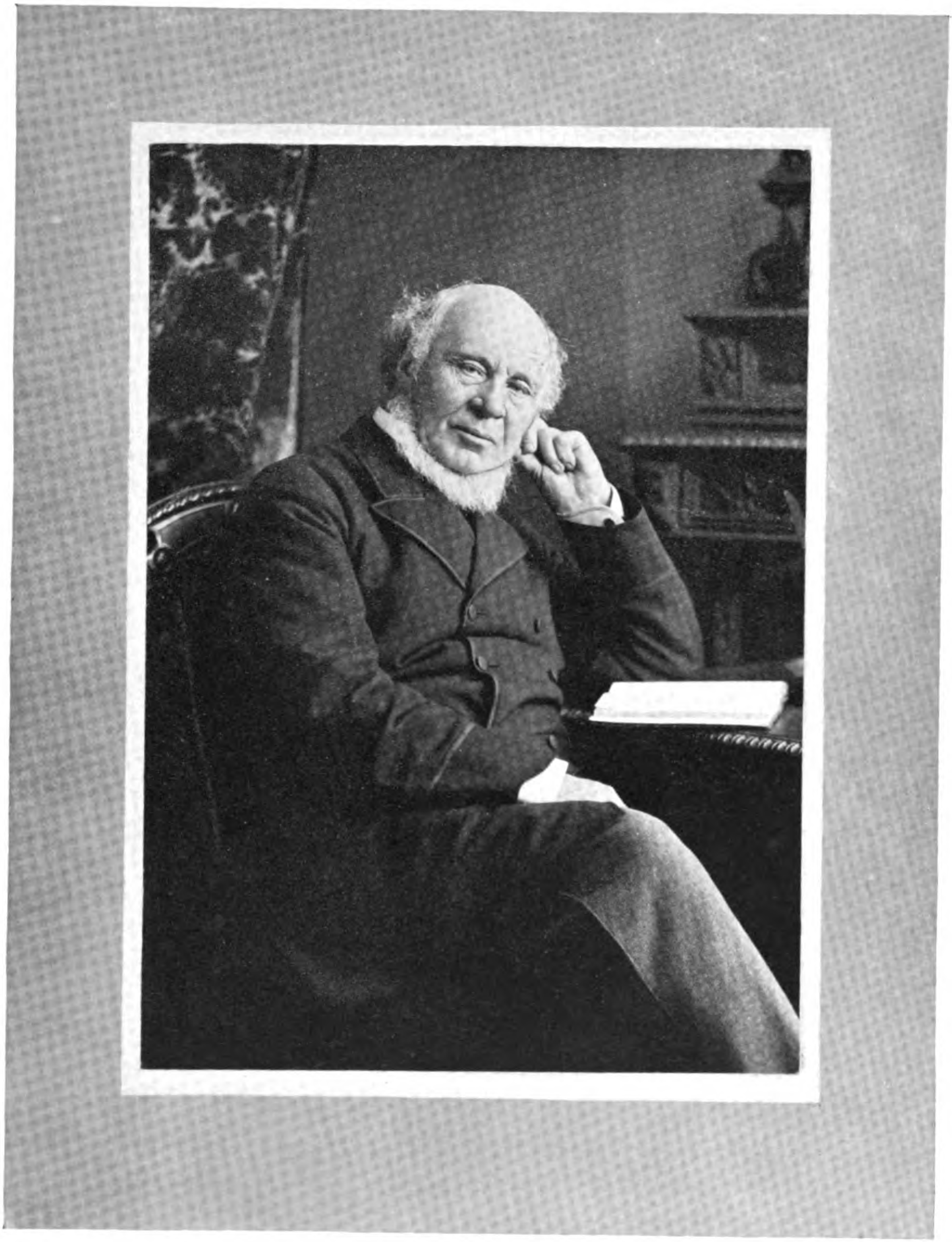

SIR JOHN FOWLER

Bridges and Framed Structures.

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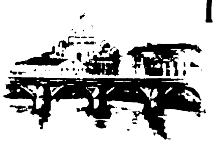
SIR JOHN FOWLER



THE period over which Sir John Fowler's career extended practically coincides with that of the profession of modern engineering. In saying this we do not forget the illustrious men who preceded him, such as Telford, Trevithick, Watt, Smeaton, and Rennie. But these all flourished before the manufacture of iron, and the tools for working it had so far progressed that it was readily available for every-day use. Many of them executed splendid works in brick and stone, works which will uphold their reputations for centuries, and others of them were capital mechanics. But it was not then practicable to use iron, and particularly wrought iron, for large structural purposes. It is worth while to recall a few instances in exemplification of this fact which is often forgotten. The first flour mill which had iron wheels and shafting was erected by Rennie in 1788. The first iron bridge was designed by French-Italian engineers in 1755, and was attempted to be constructed at Lyons, but the founders proved unable to cast it. In 1777 a cast iron bridge of 100-foot span was erected at Coalbrookdale, and this was followed in 1796 by one over the Wear. This latter had been constructed to the directions of the celebrated Tom Paine for a different site. A third bridge was erected by Telford over the Severn about the same date, and he constructed four other cast iron bridges before the century terminated. Rennie's first iron bridge was opened in 1803 at Boston. It is thus shown that the employment of iron on a large scale during the Eighteenth Century was practically unknown. In the early part of the Nineteenth Century, cast iron was largely used for bridges, for canal aqueducts, for locks, and for dozens of other purposes, only to be supplanted in its turn by wrought iron. When this metal could be obtained cheaply and abundantly, engineering entered upon a new phase of its existence, and the world commenced to progress at a speed hitherto undreamed of.

It was under conditions such as these that the subject of this memoir entered his professional career. He was born in 1817 at Wadsley Hall, Sheffield, the residence of his father, Mr. John Fowler, and when his general education was completed the boy, at the age of seventeen, became the pupil of Mr. J. T. Leather, the well-known hydraulic engineer. Here he had ample facilities for obtaining a thorough training in several branches of his calling, and in all cases his experience was gained in works of very considerable magnitude. Yorkshire enjoys the advantage of possessing a great number of diverse industries, and it was very early in the field as a manufacturing district. The county was thus able to find employment for many engineers, and among them Mr. Leather took a leading position.

When Mr. Fowler left Mr. Leather, the railway mania had commenced, and he went straight into the railway world, finding in the office of Mr. J. U. Rastrick a very wide field. He became his chief assistant in the preparation and contracts for several railways; among these was the line from London to Brighton. To this latter Mr. Fowler gave great attention, and there is scarcely a bridge or viaduct which was not personally worked out by him. After two years spent in London, he returned to Mr. Leather, and became responsible resident engineer of the Stockton and Hartlepool Railway. After it was completed he remained two years as engineer, general manager, and locomotive superintendent of that and the Clarence Railway.

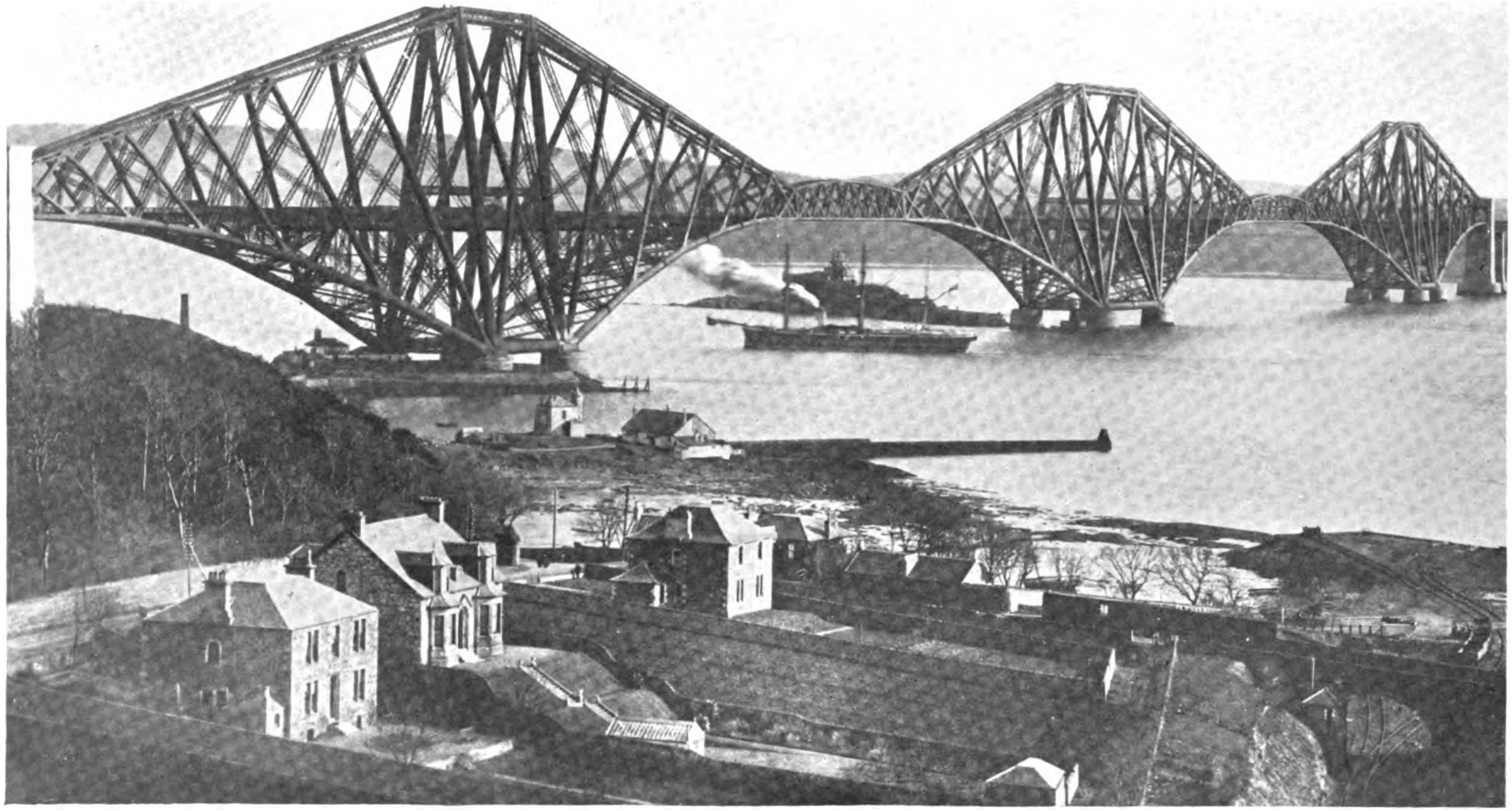
On the termination of this engagement, Mr. Fowler visited, at the invitation of Sir John Macneil, several railways in the neighborhood of Glasgow, and gave evidence before Parliamentary committees regarding them. He commenced an independent career at the age of twenty-six, and, as we have already seen, he started with a broad and solid foundation of experience, suitable for the towering reputation which was to be built upon it. Several important railways were then being promoted from Sheffield, such as the Sheffield and Lincolnshire, the Great Grimsby, the New Holland, the East Lincolnshire, and others, and of these Mr. Fowler became the chief engineer, conducting them through Parliament and carrying them out.

Mr. Fowler had now attained a position which necessitated his permanent residence in the metropolis, and work of all kinds flowed in to him. It is quite beyond the limits of our space to notice, much less to describe, one half of the matters about which he was consulted, or the works he carried out. Among them we may mention the following: The Oxford, Worcester, and Wolverhampton Railways; the Severn Valley Railway; the London, Tilbury and Southend Railway (in conjunction with Mr. Bidder); the Liverpool Central Station; the Northern and Western Railway of Ireland; the railways of New South Wales and India; the Sheffield and Glasgow waterworks; the Metropolitan Inner Circle Railway; the St. John's Wood Railway; the Hammersmith Railway; the Highgate and Midland Railway; the Victoria Bridge and Pimlico Railway; the Glasgow Union and City Railway, and St. Enoch's Station; the Millwall Docks; the Channel Ferry, and many others.

Mr. Fowler's reputation with the general public of this generation rests to a great degree on his construction of the Metropolitan Railways. These were so far out of the common that every Londoner, and a great many people out of London, took the greatest interest in them.

The construction of the so-called Underground Railway was the means of solving a great many problems which at the time presented much difficulty. Questions which are now fully understood, and which would be undertaken by contractors as a mere matter of course, then were of very grave importance, and had not only to be exhaustively discussed, but to be attacked with the greatest caution.

Mr. Fowler was elected President of the Institution of Civil Engineers for the year 1866, and took the chair for the first time in that capacity on



FORTH BRIDGE—GENERAL VIEW.

January 9th. His presidential address was devoted to the subject of the education of an engineer, and was so important and valuable that it has been reprinted and distributed extensively, notably by the Government of India to the engineers in its employment.

In 1870 he was a member of a commission to examine the railways of Norway, with reference to the proper gauge to adopt for the railways of India, and he made decided recommendations regarding it. During the winter of 1888-9 he had the opportunity of verifying by actual inspection on the spot the opinion he had formed as to the railway policy of India, and it is well known that he has expressed himself as having had his former conclusions strongly confirmed by his Indian visit. He was naturally much consulted, both professionally and otherwise, in India by the authorities on the subject of railways, docks, and waterworks, and was received everywhere with great distinction. His general impressions of India and its resources were of the most favorable character.

One of the most interesting chapters in Mr. Fowler's career is that connected with Egypt. He went there in the first instance in search of health; and the connection thus accidentally formed lasted as long as Ismail Pasha remained in power. Before Mr. Fowler returned home he had several interviews with the Khedive, explaining to him his views concerning the Suez Canal, the irrigation schemes, and many other matters in which Ismail Pasha was interested. The outcome of this was that he accepted the position of consulting engineer to the Khedive and the Egyptian Government, a post which he held for eight years—that is, until the abdication of that ruler. The office involved yearly journeys to Egypt, the first being in the latter part of 1871, and required Mr. Fowler to personally investigate all the great undertakings then in hand. The most important matter presented to him for solution was the projected Soudan Railway. It is needless to say that, although commenced, and 150 miles constructed, it was never carried out, or recent Egyptian history would have been greatly changed, while thousands of British soldiers and millions of money would have been saved.

One of the first matters claiming his attention on undertaking the duties of consulting engineer was the organization of the existing railways, and to this he devoted much time on his first official visit. As a preliminary he employed Mr. D. K. Clark to obtain for him full details of the rolling stock and plant. With this information before him, he was able to advise great changes in the direction of simplicity and economy, most of which were carried out.

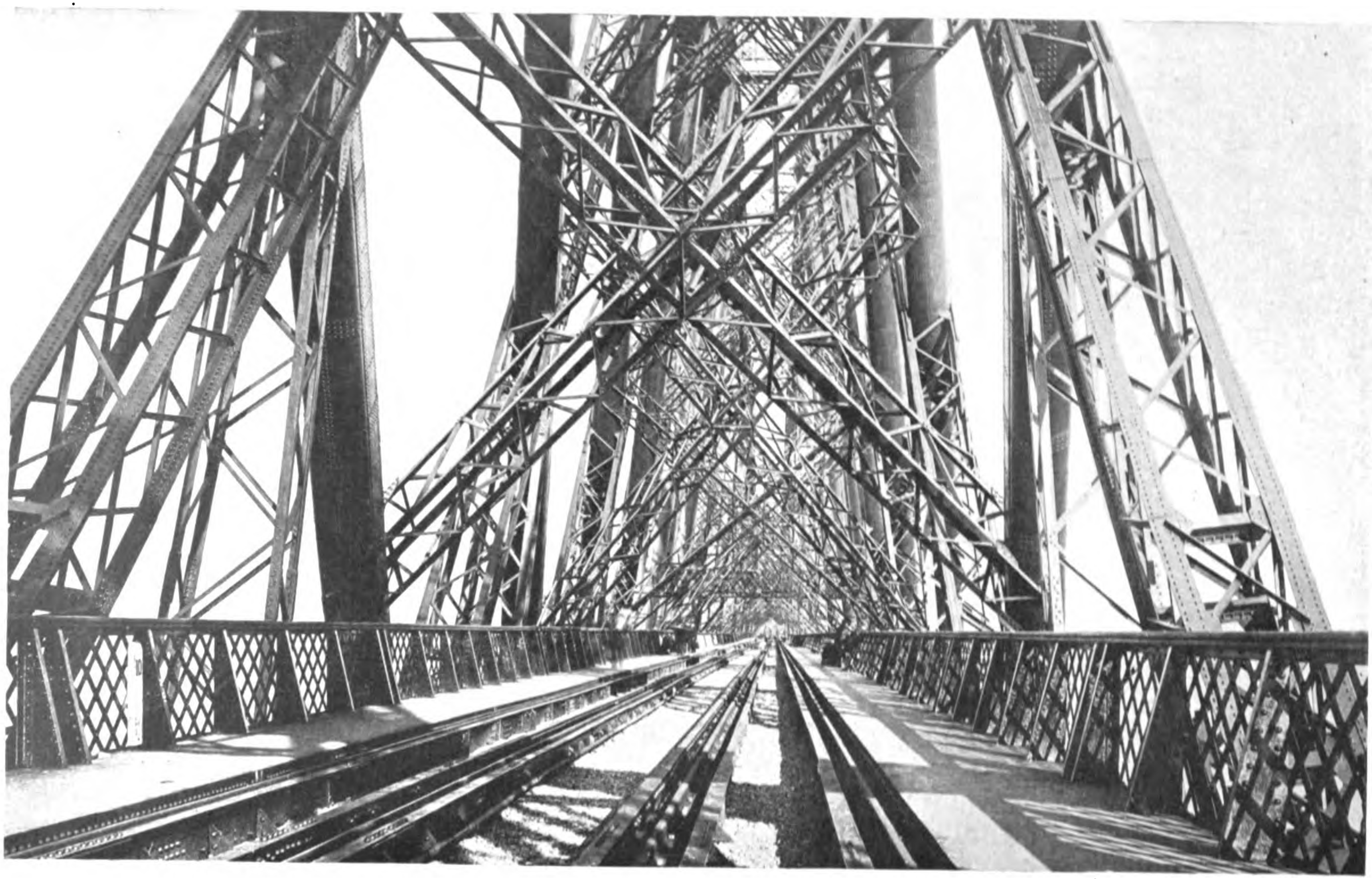
Another important matter presented to him was that of irrigation. Upon this depends to a great extent the fertility of Lower Egypt, for although the annual inundations can be depended upon to give the land one thorough watering, there are many crops that need to be watered several times, and at different seasons of the year from that at which the flood comes. Under the existing conditions, Mr. Fowler was instructed (1) to prepare alternative plans for placing all the cultivated and cultivable lands of Lower Egypt in a position to be irrigated at any time of the year without pumping; (2) to devise an improved means of introducing flood water several times during high Nile upon any required lands on the left bank of the Nile, and of discharging it at pleasure without interference with other lands; (3) to prepare a scheme for a ship canal between Alexandria and Cairo.

We come now to the Forth Bridge, the best known of all the works with which Sir John Fowler was associated, and one which has engaged the attention both of the general public and of engineering experts in all parts of the world. The design was not his alone, but was the joint outcome of four minds, all bent on discovering the best and cheapest means for carrying a railway over the Firth of Forth. When the Tay bridge was destroyed preparations were being made, and were actually commenced, for bridging the Forth. Sir Thomas Bouch had designed a suspension bridge for the purpose, and an Act of Parliament had been obtained authorizing its construction. The failure of the Tay bridge at once threw doubts upon the safety of this most ambitious project, and the works were stopped. Subsequent investigation showed that the proposed bridge could not have been a satisfactory one.

A bridge across the Forth offered so much advantage to the railway companies forming the east coast route to Scotland that, after two years, the idea was revived. On February 18, 1881, the four great railway companies concerned, the Great Northern, the North Eastern, the Midland, and the North British, wrote to their consulting engineers—Mr. T. Harrison, Mr. W. H. Barlow, and Mr. John Fowler, associated with Mr. B. Baker—propounding two questions for their joint opinions. They were asked to consider the feasibility of building a bridge for railway purposes across the Forth, and, assuming the feasibility to be proved, what description of bridge would be most desirable to adopt. The matter involved so large an expenditure and contained so many novel issues that it needed to be approached with the greatest possible care. It was fairly well known how many types of bridge there were to select from for such a site—(1) Mr. Bouch's original design, (2) a stiffened suspension bridge, (3) a second form of stiffened suspension bridge, (4) a cantilever bridge. Calculations of weight and cost were made for each type of bridge, and were discussed by Messrs. Harrison, Barlow, Fowler, and Baker, with the general result that the cantilever type was chosen. A report was made to the railway companies on May 4, 1881, embodying the result of the deliberations, and pointing out that the cantilever principle offered a cheaper and better solution of the problem than any other. The report did not enter into the details of construction; indeed, it could not be said to give even the broad features, other than those which are involved in the use of the cantilever. These still remained to be elaborated in council, and it was only by united discussion that the original plan developed into the final design. Although the type of the bridge is very ancient, there were many features in it which were open to consideration, and to differences of opinion, and at each meeting of the engineers new ideas were propounded and novel methods of overcoming difficulties were mooted. After most elaborate investigations and calculations the structure gradually, by a process of evolution or development, assumed its present form.

The design being settled and the execution decided upon by the associated railway companies, the carrying out of the work was intrusted to Mr. Fowler, in conjunction with his partner, Mr. Benjamin Baker.

The Parliamentary fight was exceedingly stubborn, for great interests were at stake. Hitherto the London and Northwestern and the Caledonian companies had enjoyed a great advantage in carrying the Scotch traffic to



FORTH BRIDGE—LOOKING ACROSS THE BRIDGE.

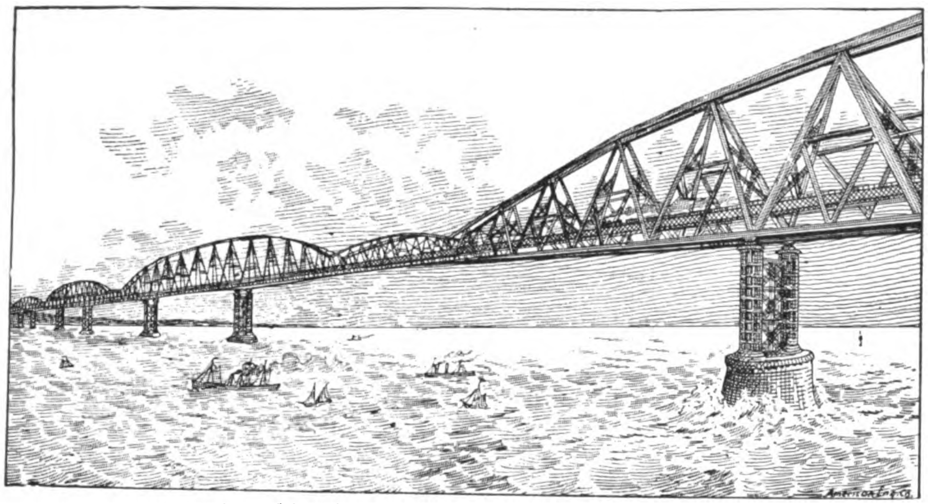
Perth and the Highlands, in consequence of the east coast traffic having to traverse the circuit from Edinburgh via Larbert and Sterling to Perth. But when the bridge was opened this advantage disappeared. A very strong hybrid semi-public committee was appointed, with Lord Stanley, of Preston, and later Governor of Canada, as the chairman. Engineering evidence was brought forward to condemn the structure, and every possible description of hostile evidence for shipping interests was adduced against it, and made the most of by eminent counsel, who both in speeches and cross-examination strove to the utmost to prejudice the undertaking. But at the close of the case the committee were unanimous in favor of the bill, only stipulating that the Board of Trade should maintain a general inspection of the works during construction. It was finally arranged, at the suggestion of Mr. Fowler, that the inspectors should report to Parliament every three months as to the progress of the bridge, and the quality of the materials and workmanship. These reports, made by General Hutchinson and Major Marindin, made their appearance regularly. Sir John Fowler and Mr. Baker kept a personal and continuous control over the entire operation of building the bridge, and have superintended the series of processes, from the rolling of the plates to the driving of the rivets.

The bridge consists of two approach viaducts and the cantilever bridge proper. The viaducts only differ in extent; the height above the water and the lengths of the spans being the same. It will be seen that a similar viaduct or permanent way is carried through the cantilevers and central towers at one uniform level. Commencing at the south end there are four granite masonry arches, which terminate in the abutment for the south approach viaduct. Here the girder spans commence—ten in number—the end of the last being supported in the south cantilever end pier. On the north shore there are three similar masonry arches, terminating in an abutment, and five girder spans to the north cantilever end pier.

The bridge proper consists of three double cantilevers and two central connecting girders. Each double cantilever consists of a central tower supported on four circular masonry piers—a cantilever projecting from each side of it. The two outside piers—the Fife and Queensferry—have, in addition to the four supports of their central towers, a further support, inasmuch as their outer cantilevers rest in the cantilever end piers. No such additional support was available in the case of the Inchgarvie pier, and the length of the base has here been nearly doubled. The length of the cantilever bridge is 5,330 feet, consisting of the central tower on Inchgarvie, 260 feet; the Fife and Queensferry central towers, 145 feet each; the two central connecting girders, 350 feet each, and six cantilevers of 680 feet each. The cantilever end piers are 5,349 feet six inches apart, center to center. The south approach viaduct is 1,978 feet long from center of cantilever end pier to end of arches, consisting of ten spans of 168 feet each, four arches of sixty-six feet each, center to center, and thirty-four feet made up by abutments. The north approach viaduct is 968 feet three and one-half inches long to end of arches, consisting of five spans of 168 feet each, three arches of thirty-seven feet, thirty-one feet, and forty-six feet, center to center, respectively, and fourteen feet three and one-half inches, made up by abutments. The total length of the structure is, therefore, 8,295 feet nine and one-half inches. The two main spans are 1,710 feet from center to center of vertical columns, made up of two cantilevers of 680 feet each and one central girder of 350 feet.

The waterway to be crossed is about 5,700 feet, extending from the south circular piers on the Fife to viaduct pier No. 3 at Queensferry. The rail level has been fixed at 157 feet above high water, which leaves for a total length of 500 feet in the center of each channel a clear headway of 151 feet, no train load on the bridge; the ordinary load of two trains not reducing this headway by more than three and one-half inches.

The Fife and Queensferry piers are alike and identical in every respect, and only reversed with regard to their outer cantilevers. All six cantilevers are not only of the same length, but are of same height and width also—330 feet high at the central towers, by 120 feet wide at the bottom, and thirty-three feet wide at the top; and thirty-four feet high at the endposts, with a width of thirty-two feet at the bottom and twenty-two feet at the top. The only difference in the cantilever lies in the arrangement of the



PROPOSED BRIDGE OVER THE ENGLISH CHANNEL.

endposts, and further, in the fact that the two outside or fixed cantilevers of Fife and Queensferry are somewhat heavier in construction than the others.

Some of the piers were founded by means of cofferdams, while others were carried to rock by circular pneumatic caissons. This portion of the work was in itself a great feat of engineering, and could only be described in a volume.

The amount of steel work in the cantilever bridge is about fifty thousand nine hundred and fifty-eight tons, and three thousand two hundred tons in the viaduct spans. Of the above amount 4,200 tons was for rivets. Special workshops were built, and much of the work accomplished by the use of machines especially designed for the purpose.

Had Sir John ended his labors as an engineer with the Forth bridge it would have sufficed to place his name at the top of a list of the world's greatest engineers.

The scheme for a bridge over the English Channel, which was developed by the continental engineers, Messrs. Schneider and Hersent, has had the support of Messrs. Fowler and Baker as consulting engineers. This most ambitious project contemplates the building of a great cantilever structure between the English coast at Folkestone, where it would connect with the South Eastern Railway, and a point on the French coast near Port d'Ambletense, where it would connect with the Chemin de Fer du Nord. From Folkestone the line would bear to the southeast to La Varne, a rocky reef, making a deflection to the left to Le Colbert, a second rocky reef, from which, by a second deflection to the left, it would extend directly to the French coast. Whether or not the structure is ever built, the idea will be a lasting credit to the engineers whose names are connected with it.

Sir John became consulting engineer to the Great Western Railway upon the death of Brunel, and in connection with Sir Benjamin Baker he was consulting engineer of late years on the Hudson River tunnel at New York City.

He was knighted in 1885 for his services in Egypt, and in 1890 his labors received still further recognition by the conferring of a baronetcy. Upon his death, on November 21, 1898, there remains but little which could have been done by him or for him, to add to a lasting renown.—*Adapted from "Engineering."*