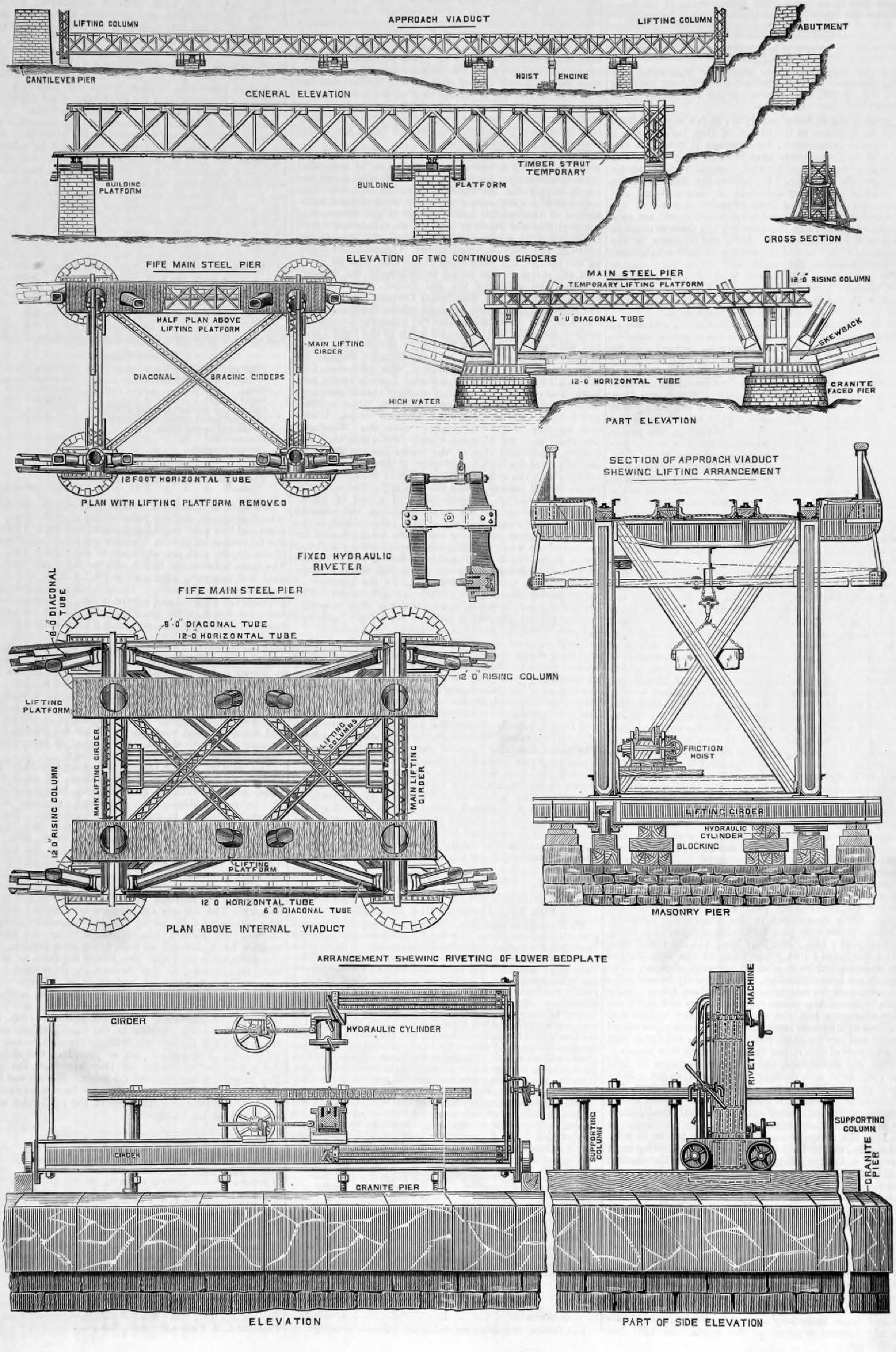
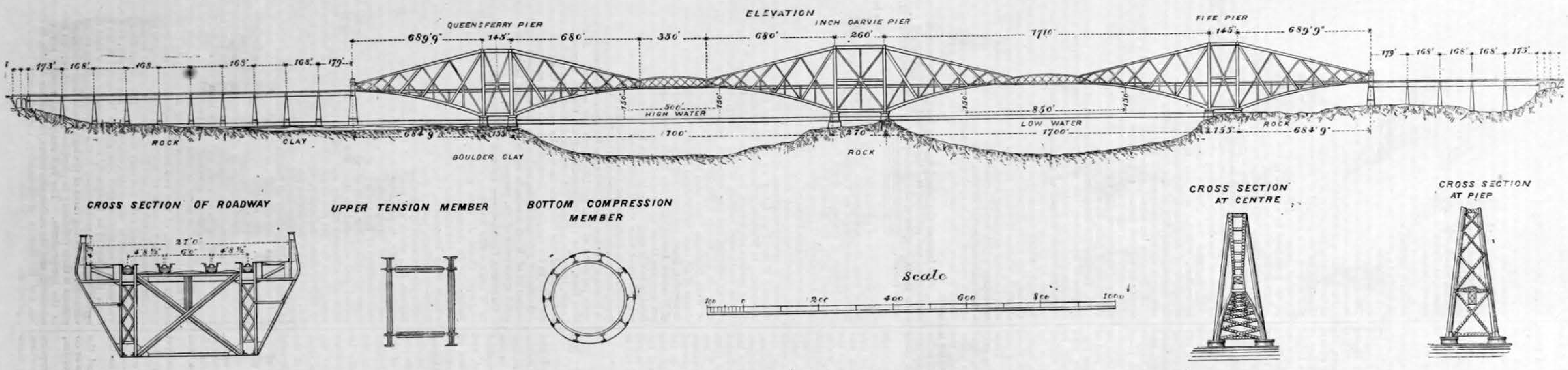
ERECTING THE GREAT FORTH BRIDGE.

MESSRS. BAKER AND FOWLER, MM.I.C.E., ENGINEERS; MESSRS. TANCRED, ARROL AND CO., CONTRACTORS.

(*For description see page 285.*)



THE BRIDGE OVER THE FORTH.



THE FORTH BRIDGE.*

PROPOSED METHOD OF ERECTING THE MAIN STEEL PIERS AND APPROACH VIADUCTS.

By Andrew S. Biggart, C.E.

Works of exceptional magnitude, and more especially those in which the difficulties in the way of their accomplishment are in any degree proportionate to their size, must of necessity be of interest to this Association, constituted, as it is, to assist, and in its own way act as a beacon to all in search of true knowledge. While the difficulties met with in preparing for and founding the piers of the Forth Bridge have been neither few nor unimportant, it is patent to even the uninitiated that causes for anxiety will neither disappear nor diminish till the erection of the steel superstructure has been completed. Presently our remarks will be confined to the main steel piers and approach viaducts. The term steel piers refers to those parts of the superstructure immediately over and between any of the three groups of four caissons. Described generally, each may be said to consist of two sloping and two vertical planes, the sloping including one connecting horizontal column and two 12ft. rising columns, joined at the upper extremities by the top member, while from the lower end of each to the top of the opposite one there extends a diagonal 8ft. tube. These two planes run parallel with the centre line of the bridge, and are 120ft. apart at the base and 33ft. at the top. The vertical planes complete the structure at the ends of the two sloping planes. They consist of the 12ft. rising columns already mentioned, with the lattice bracing joining these together. These members, with the internal viaduct and the bracing girders attached to the skewbacks, form the principal parts of the steel piers, the extreme height of which is fully 340ft. above the bottom of the lower bed-plates.

The approach viaducts are, generally speaking, of ordinary design, with the exception of some special features to meet the unusual requirements demanded of them. The girders span a distance of 160ft., and rest on granite-faced piers, rising to a height of 130ft. above high water; the heights of these piers themselves gradually diminishing as they near the abutments, owing to the rising nature of the banks of the river. The magnitude of the main steel piers, both in respect of their great height and immense weight, demands that exceptional means be employed in their erection. Many proposals for effecting this have been suggested, and may be said to range from that of Mr. Arrol's first, which was to run up the columns independently, using them as the only staging, to that proposed by Mr. Baker, viz., to carry up simultaneously with the columns a rising platform, extending round the whole four columns, by utilising them as supports, and upon this platform to carry up the top member, having the end junctions all previously rivetted up, so that on arrival at the top, the final closing lengths of the 12ft. rising columns had only to be joined to the junctions already fitted to complete this part of the work. After careful consideration, the weight requiring to be lifted was found to be too great, when compared with the advantages to be gained, to allow of its full adoption. In the case of the Fife and Queensferry piers the weight was close on 1200 tons, and several hundred tons more in that of Inch Garvie. A modification of this plan is that finally adopted by Mr. Arrol, with Sir John Fowler and Mr. Baker's full approval. The carrying up of the top member is done away with, but otherwise it is very similar. The engravings on page 284 illustrate the pier and this platform. The main lifting girders of the platform pass through the 12ft. rising columns, and running in line with the vertical planes, extend from the one sloping plane to the other. Lying across these are placed other four girders, one being on either side of each set of 12ft. rising columns, thus completing a rectangular platform resting indirectly on the main rising columns. The weight of this platform, including the necessary cranes and other plant required during the erection of the higher parts of the pier, will be about 400 tons.

The first part of the superstructure is that termed the lower bed-plate. Several of these are now completed and in position. They are made up of a series of longitudinal and transverse plates securely rivetted together, and run about 37ft. long by 17ft. 8in. wide, with a thickness of from 3in. to 4in., as seen in the engravings of lower part of page 284. The whole plate is bolted on a number of short iron columns *in situ*, and is rivetted up by a special hydraulic machine. Two girders are employed, one above and the other below the bed-plate, and extending beyond it are there joined together. On each of these girders slides a hydraulic cylinder, one having a little more effective area than the other, while both are regulated by the same cock. The result is that when water is admitted the total pressure on one cylinder is greater than that on the other, thereby holding the rivet head firmly in place while the point is being pressed up. The work thus produced is of the very highest quality. Since the whole machine moves lengthwise and the cylinders slide crosswise, the full surface of the plate is commanded by it. The rivetting is also done expeditiously, the machine being capable in ordinary work of closing during a single shift 600 1⅛in. countersunk rivets. When finished the bed-plate is finally lowered into position. The upper bed-plate, or base on which the various connections at the foot of the rising column rest—and which collectively constitute what is termed the skew-back—is proposed to be rivetted in a like manner to the lower bed-plate. While being rivetted it will be secured to heavy steel girders, instead of columns, as in the case of the lower bed-plate, to keep it in true form. After lowering the upper bed-plate into position, the diaphragms and various other parts will then be built on it, and rivetted up by common hydraulic machines, as well as by the special hydraulic machines designed by Mr. Arrol for the purpose. As many of the spaces in which rivetting has to be done are very confined and difficult of access, high pressures will be used with machines correspondingly small; thus while the ordinary pressure will still be 1000 lb. per square inch, it will be increased in some cases to as high as three tons per square inch by a simple pressure multiplier wrought by the ordinary 1000 lb. pressure. This low pressure is admitted to the large end of the compressing ram, the smaller end of which produces the increased pressure—proportional to the difference in areas—required to close up the rivet properly. The rivetting machine is very small, each cylinder weighing about half a hundredweight. The smallest proposed cylinder is only 4in. diameter, is of the simplest form, and contains a hollow plunger provided with a single cup leather at the inner end. A spring is secured to the plunger and back end of the cylinder for the purpose of drawing back the plunger when the exhaust water is allowed to escape. When in place and at work the machine will be hung to the one end of a small wire passing over of a pulley, while at the other will be fixed a balance weight to relieve the operator of the weight of the machine. Two cylinders, one outside and one inside, will be required at the closing up of the rivets; both will be connected to the compressor and wrought by it. The horizontal tubes, skewbacks, and lower parts of all the columns will be built by ordinary cranes till they attain a height of about 30ft. above the bed-plates. At this point of the 12ft. rising columns will then be commenced the longitudinal channels—through which are drilled the holes for the steel pins to pass through them and the cross girders—to these channels the cross girders will now be attached within the column, on the higher of which will be laid the two main lifting girders of the platform. Extending between and beyond these, but at right angles, will be the other girders required to complete the rectangular platform already referred to. The principal work above this will be executed from this platform, as it is being raised towards the top of the pier. In that work will be included the 12ft. rising or supporting columns, the 8ft. diagonal columns, and the bracing in the sloping planes. The vertical planes will be built similarly as the platform is raised upwards. When all is ready to be raised for the first time the positions of the various members in the pier will be somewhat as follows: The four rising 12ft. columns will have the whole of their channels, and eight of the ten plates in section, in each column at a convenient working height above the platform. The other two plates require to be kept off at this point to allow the main lifting girders to pass through the columns, and can only be placed in final position from underneath the main lifting girders. The columns will only be bolted together at this point, but as few more bolts will be required than those necessary to make good work when rivetting up, very little labour will be lost. The 8ft. diagonal tubes in the sloping planes will also be carried up above the level of the platform. They pass between the girders and lie in the sloping planes, and will be wholly rivetted up above the level of the platform. The bracing in the vertical planes being 12ft. wide, allows the main lifting girders to pass through it, and will be built to a large extent from a platform on the top of these girders, only the top and bottom bracing requiring to be placed and rivetted in position underneath the main lifting girders. While the whole of the tubes will be built in single pieces, in the case of the bracing girders, it is intended to take up and fix in position sections of a size convenient for handling with despatch under the somewhat novel circumstances around.

(*To be continued.*)

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THE QUETTA RAILWAY.

Very considerable interest is felt in the progress of the railway to Quetta, the completion of which is rightly considered the first step necessary for the sufficient execution of the new schemes of defence on the western frontier of India, and we are in a position to describe the exact state of the railway now in course of construction from the extreme limits of Scinde into the Pishin Valley. The title of this line has varied, during the six years that have elapsed since it was first projected, with the ultimate intentions of its official promoters. Its earliest designation was the most ambitious, for it was then termed the Candahar State Railway, but in its present form, which will very shortly be practically completed, it is called the Scinde-Pishin State Railway. We have preferred, however, to consider this railway as the line to Quetta, which, although there is some talk of superseding it as our principal military station, is still the most important strategical position on the Indian frontier. To prevent misconception, it may be stated that Quetta is not on the main line to the Pishin Valley, which must inevitably be continued before very many years pass by to Candahar, but it will be connected with it by a loop line from Bostan. In order to make the subject perfectly clear, we will begin with a sketch of the earlier history of the line, which will reveal the evil consequences of the four years' delay in completing it that followed the determination of the late Cabinet to suspend operations in this direction.

The first order of the Government of India for the construction of a railway in the direction of Sibi from Rukh, a station on the Indus Valley Railway near Sukhur, was given on the 11th of September, 1879. That order stated that "the gauge of the railway was to be the standard one of 5ft. 6in., and that it was to be laid as far as practicable on the surface without ballast." Nine days later Government came to a further decision. They decided that "from the terminus of the broad-gauge line a cart road should be made up the Bolan Pass, and on probably to Quetta and Pishin," and, further, that on this road "a 2ft. tram, to be worked by steam power, should be laid." Fifty lakhs were granted for the railway, and 26 lakhs for the road and tramway materials, and the Viceroy, Lord Lytton, requested that 200 miles of metre-gauge permanent way might be sent out from England. This was done at a cost of about £150,000. One month later the Viceroy asked for 200 miles more of the same material, with girders, engines, and rolling stock, as well as broad-gauge materials. The total cost of this further order was £420,000. An official telegram, dated October 21st, 1879, described these works as being in active progress. It will simplify matters if we point out that at this period it was assumed that the railway to Quetta would be laid down through the Bolan Pass, and consequently the preliminary measure was to construct the line as far as Sibi with all possible expedition. Two months later Sir Richard Temple, who had been pushing forward the line in the plain with characteristic energy, reported in favour of a route to Pishin and Candahar, north and north-west of Sibi, and passing through Hurnai and Gwal. This route was then adopted for a railway in preference to the proposed tramway through the Bolan. In June, 1880, the line was in use for 140 miles, from the Indus to the Murree Hills, north of Sibi. Beyond this the Nari river section was in active progress, while 100 miles of service road to the Quetta plateau were nearly complete, and a further section of 50 miles to the Amran range was under survey. Such was the exact position of this important line in 1880, when the change of Government occurred at home.

Lord Hartington's first act in connection with this question on coming into office was to authorise the completion of the surveys to the Amran range and as far as Candahar, but to order that "nothing further should be done on either of these two sections towards the construction of a railway without previous reference" to the Home authorities, adding that "in the event of her Majesty's Government deciding not to maintain permanently a military force at Candahar the completion of the surveys of these sections of the lines will enable me to arrive at some conclusion as to the most appropriate terminus for the railway." Four months later—October, 1880—the Viceroy—Lord Ripon—telegraphed :—

"We have decided to make Candahar railway only as far as Gulistan Karez, and will therefore not change gauge from broad. Order at once 50 miles of permanent way, ordinary broad-gauge type, complete with sleepers, and twenty light engines. Despatch follows with full indent."

Let it be said parenthetically, for the sake of clearness, that Gulistan Karez is at the extremity of the Pishin Valley, near the passes over the Amran range, and that it is quite impossible for us to have railway communication with this place before 1887. Yet the Viceroy proposed to press on the railway to it in October, 1880. Lord Hartington's reply in the name of the Cabinet to Lord Ripon's request for 50 miles of material was sent in a telegram on October 21st, 1880:—"Further information required before indents can be sanctioned." Three days later he asked for information by telegraph as to "extent completed of Candahar railway, also estimated time of finishing it to Quetta and Gulistan." To this inquiry the Viceroy replied as follows :—

"Line practically complete, with temporary bridges, to foot of Bolan and Nari Gorge. Distance in all about 165 miles; perma-