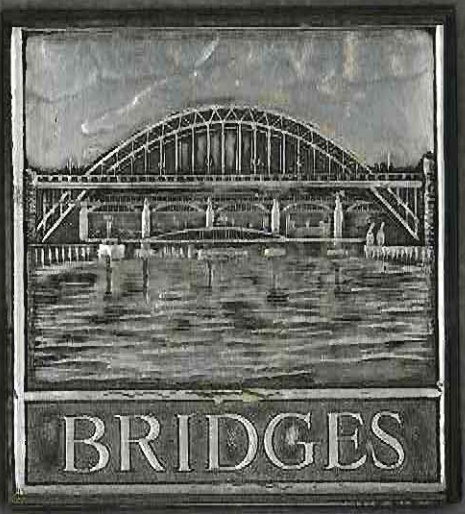

BRIDGES

BRIDGES: A FEW EXAMPLES OF THE WORK OF A PIONEER FIRM IN THE MANUFACTURE OF STEEL AND STEELWORK

Illustrated by photographs & line drawings

DORMAN LONG AND COMPANY LIMITED
HEAD OFFICE AND WORKS, MIDDLESBROUGH
LONDON OFFICE, 55 BROADWAY, S.W.1., ENGLAND

THE SYDNEY HARBOUR BRIDGE

In 1922 an Act of Parliament was passed by the Government of New South Wales authorizing the construction of a single-span bridge across Sydney Harbour at a sufficient height to permit the passage of the largest ocean liners. Mr J. J. C. Bradfield, M.E., M.Inst.C.E., who was appointed by the New South Wales Government as Chief Engineer for the Bridge, drew up the general design and specification, which provided for four railway tracks as well as a 57 ft. roadway and two footways.

The contract for the supply and erection of this bridge was put up for World competition, and was secured in February 1924 by Dorman Long & Co., Ltd., who submitted seven alternative tenders, both for arch and cantilever bridges. The successful tender was for an arch bridge giving a clear headroom of 170 feet at high water, and with a span of 1,650 feet, the largest in the World. The detailed design and erection scheme were prepared

for the Company by their Consulting Engineers, Mr Ralph Freeman, M.Inst.C.E., M.Am.Soc.C.E., of Sir Douglas Fox and Partners, and Mr G. C. Imbault, and the abutment tower design is the work of Sir John Burnet and Partners. Particular attention was paid to the æsthetic features of the bridge, since it was realised that a structure of such magnitude placed across the entrance of one of the World's finest harbours must be inherently attractive in its outline and dimensions, and that all decorative and architectural features should be in keeping with the natural beauty of the surroundings.
The total length of the arch and approach spans is 3,770 feet, and the height to the top of the arch from water level is 450 feet. Owing to the unusually heavy traffic accommodation required, the deck has a total width of 160 feet, and the construction of the main span is therefore exceptionally heavy, containing about 37,000 tons of steel.
Special workshops were erected close to the bridge site, where all material required for the construction is fabricated from the Company's own steel. A method of erection is being employed similar to that which was successfully used by the Company in the erection of the New Tyne Bridge, and construction is proceeding from both shores simultaneously.
The general supervision of the entire undertaking is under the personal direction of Mr L. Ennis, a director of the Company, and it is estimated that the bridge will be open for traffic towards the end of 1931.

INTRODUCTORY

A very important stage was recently reached in the history of bridge building with the inauguration in 1926 of the International Bridge and Structural Engineering Congress. This Congress gave to Bridge Building its first official recognition as a separate branch of the science of Engineering, requiring specialized knowledge, and at the same time established an international " exchange " where bridge builders of all nations could assemble periodically and reap the benefits of the experiments and experience of their fellows.

It is not proposed to give here a history of Bridges through the ages, since such an account would merely serve to show that, while it has only very recently become a Science, Bridge Building has always been an Art.

In different countries we are able to find examples of architectural inspiration at all times during the past ; with each century there have been radical changes marking the evolution of civilization. Where can we find the counterpart in bridge design? It does not exist. Until the economic exploitation of iron and steel in the latter half of the last century, there had been no appreciable advance in scientific bridge-building since the days of Rome. Steel has enabled engineers to make good this delay, and to-day design and practice are advancing at a speed that cannot be estimated. Bridges with spans of a magnitude that would have been regarded as fantastic fifty years ago are practical structures in these days of steel. It is not remarkable therefore that, as one of the pioneers of the Iron and Steel industry, Dorman Long & Company should stand to-day in the front rank of the world's bridge builders, and it is as a record of their achievements in this branch of engineering that this volume is produced.

Founded in 1876 by Mr A. J. Dorman, now Sir Arthur Dorman, Bart., the Company owns at the present time the largest coal, iron and steel undertaking under one management in Great Britain, and is able to carry out its own work entirely from raw material to finished product, thus enabling that standard of excellence to be maintained which will always be associated with the name of Dorman Long.

This volume does not attempt to deal exhaustively with the Company's bridge-building activities, but examples have been chosen to show the versatility and resource of the bridge engineer in overcoming difficulties and bringing a contract to a successful conclusion in spite of adverse working conditions.

Since 1909 Messrs. Dorman Long & Company have manufactured and fabricated approximately 2,500 bridge spans of all types for export to India and Burma alone, and it is the experience gained in these last 20 years that has enabled the Company to undertake such large work as the Sydney Harbour Bridge now under construction.

LONDON, JUNE, 1930

OUTPUT CAPACITY OF STEEL:
1,750,000 TONS PER ANNUM,
BRITISH THROUGHOUT.

THE NEW TYNE BRIDGE

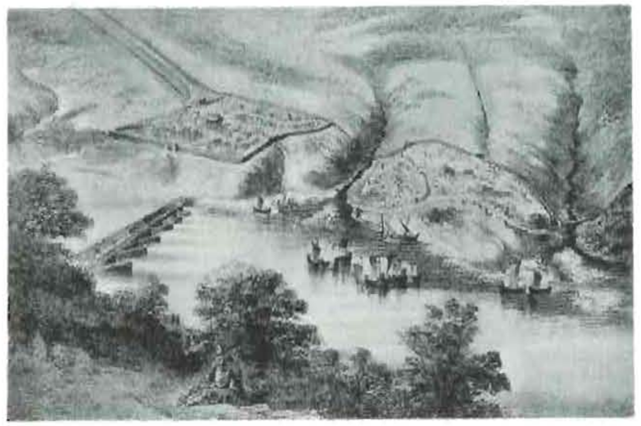
About the year A.D. 120 the first of all the Tyne Bridges was built by Publius Aelius Hadrianus, Roman Emperor from A.D. 117 to A.D. 138, in connection with his great wall across England that ended at Segedunum, now Wallsend, about three or four miles East of Newcastle. It was called the Pons Aelii, and as there has been a bridge on this site ever since, a brief account of its successors may not be out of place.

The Roman bridge, which had a level roadway of timbers 18 ft. wide resting on stone pillars, served as a highway to the North for over a thousand years and was also the connecting link between Bede's monastery at Jarrow and that at Tynemouth whose ruins still stand at the river mouth. There is thus no doubt that the building of the bridge preceded the building of Newcastle city.

In 1248, however, a disastrous fire destroyed the greater part of the town, including the bridge which, after considerable delay, was replaced by a more permanent stone structure, the cost of which was borne jointly by the Corporation of Newcastle and the Bishop of Durham. Although a very fine bridge this structure did not include the steep ascents on either bank, considered at that time to be both difficult and dangerous. It was a typically picturesque mediæval structure, carrying houses, shops, a chapel and a prison, and allowing a narrow roadway of 15 feet in width to provide the only means of crossing the lower Tyne for the next five centuries.

This bridge was built higher so as to be less liable to damage by floods, and ranked among the finest in England until 1771 when, in common with all but one of the then existing Tyne bridges, it was swept away by an overwhelming flood. The exception was the bridge at Corbridge, built in 1674.

The next bridge was started in July, 1773 and



THE PONS AELII

was finished and opened for traffic in April, 1781. It was 300 feet long from North to South, and had nine semi-circular arches. The piers were buttressed, and there was an angular recess at every pier. In 1810 the bridge was widened from 21 ft. 6 ins. to 33 ft. 6 ins., but in 1866 arrangements were made for its demolition on the grounds of obstruction to river traffic, and it was succeeded 10 years later by the existing swing bridge.

For a long time, rail communication from the South stopped at Gateshead, but in 1849 the North Eastern Railway were building a high level bridge to the designs of Robert Stephenson, a son of the famous locomotive pioneer. Opened by Queen Victoria in 1850, this bridge, though primarily a railway bridge, has a roadway underneath it which can be used by vehicles on payment of a toll. It is however, too narrow for present-day traffic.

The King Edward Bridge, built 50 years later, was designed to relieve the pressure of rail traffic on the high level bridge.

A new name has now been added to the list by the construction across the Tyne of the largest arch bridge in Great Britain. It solves the problem that had long confronted the municipalities of Newcastle and Gateshead of the passage through their borders of the ever-increasing stream of traffic along the Great North Road. In the past, this traffic has had to descend to river level, pass over the swing bridge (which has to be closed for the passage of every vessel with resulting road congestion) and then climb the ascent on the other side. Built in the direct line of the Great North Road, the new bridge connects the main streets of Newcastle and Gateshead, crossing the river in a single span of 531 ft. Being a municipal undertaking, it is of course toll-free. There are approach spans on both sides of the river, carrying the roadway over streets and houses, making the total length of the bridge up to 1254 ft.

There is also clear headroom of 88 ft. 3 ins. for shipping, the minimum clearance required by the Bridge Act of Parliament being 84 ft. 6 ins., while the top of the arch is 200 ft. above the river.

The Great North Road is connected to the bridge by the usual earth-filled abutments at either end with concrete retaining walls, and has a width on the bridge between kerbs of 38 ft., with a footwalk 9 ft. wide on each side. This allows for four lines of traffic, inclusive of the two sets of tramlines. The bridge was designed to carry not only the standard Ministry of Transport loading, but also a lorry with a load of 100 tons on four wheels, on account of the heavy traffic met with in this important industrial area. The gradients are easy, being 1 in 66.4 on the Newcastle approach, and 1 in 91.5 on the Gateshead approach, the length over the arch being graded to a very flat parabolic curve.

In addition to road traffic, the bridge carries, in an enclosed duct under the footwalks, two 2-foot diameter water mains and two gas mains of the same size.

THE FOUNDATIONS

For the foundations of the main arch it was necessary to sink heavy caissons to solid rock, which was found on the Newcastle side at −60 O.D. and on the Gateshead side at −40 O.D.

THE MEDIAEVAL BRIDGE

Each caisson is of rectangular section 84 ft. 6 ins. long by 28 ft. wide weighing 90 tons, and these were sunk under compressed air in the usual manner, two steel air shafts and locks giving access to each working chamber. On an average twenty excavators were employed in each caisson at a time, working twelve-hour shifts, and the volume excavated per caisson per shift was approximately 109 cubic yards. The headroom provided in the working chamber was 7 ft. and the maximum pressure under which the excavators were called upon to work was 30 lb. per square inch above atmospheric pressure. Up to bearing level each caisson, surmounted by its concrete pier, contains approximately 7000 cubic yards or 10,400 tons of concrete. When the caissons were finally founded on the sandstone rock, the working chambers were filled with concrete, the crevices being filled by cement grout placed under pressure, and the steel shafts removed, their places also being taken by more concrete.

The rate of sinking of these caissons was very fast, being an average of about 15 ins. per day. The bearings of the arch rest on heavy granite skewbacks built into the concrete, and consist of built-up pedestals with forged steel saddles to carry the 12 in. diameter pins of the arch.

The approach span foundations consist of cast-iron cylinders, 22 ft. 6 ins. in diameter, sunk to a firm bearing and filled with concrete. On completion of these foundations, steel columns were built up for the support of the approach spans. They are of varying heights, up to 75 feet, consisting of 10 ins. by 6 ins. by 42 lb. joists and plates 1 in. thick, built into octagonal form, 5 ft. in diameter, and filled with concrete: each column has a portal bracing at the top consisting of members with single webs and four angles.

ENGRAVING DATED 1849 SHOWING THE TWO BRIDGES IN EXISTENCE AT THAT TIME.

THE ARCH SUPPORTED BY CABLES FROM PANEL POINT 21, WITH THE MASTS AND SECOND POSITION CABLES IN COURSE OF ERECTION.

The approach spans were erected in field shops at the inshore end on either bank, and were gradually rolled forward from the masonry abutment over steel rollers fitted on the tops of the columns. On the site of the granite tower at the river end, a temporary column and raking member were erected, designed to take the horizontal and downward thrusts from the approaches, imposed by the anchorage to them of the arch.

A light falsework nosepiece 20 feet long was constructed on the leading end of the spans to guide them over the rollers, and hand winches, used throughout to move the steelwork forward, were found to be admirably suited to this sensitive and gigantic operation. As much as 2000 tons of steel was on the move at the same time on the Newcastle side at a speed of approximately 6 ins. per minute, with 10 men working to each of the 4 winches. When the spans were in position, the falsework nose

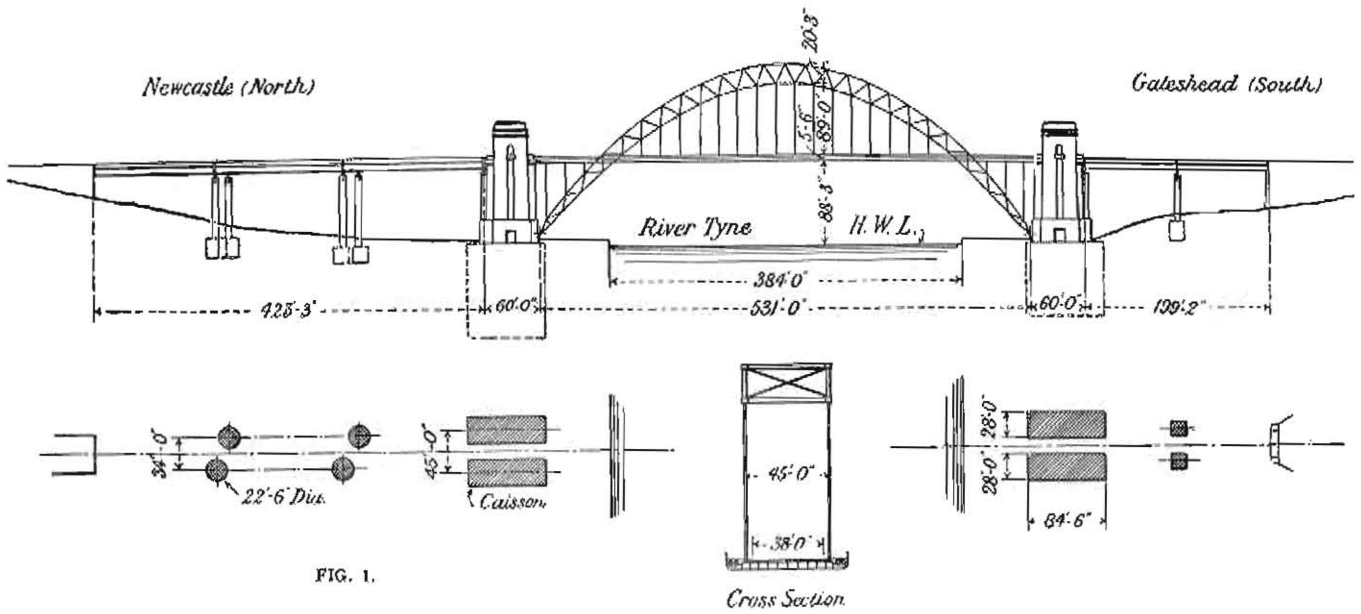


FIG. 1.

was removed and jacks were put on top of the columns to take the weight of the steel while the rollers were being replaced by the permanent bearings. The continuous girders of the approach spans are of the twin plate web type, at 34 ft. centres and inter-connected with heavy diaphragms. Each girder is a single web member with four angles and flange plates, the depth over angles being 11 ft. 6 ins. and the width of the flange plates 2 ft.

On the Gateshead side the approach is divided into two equal spans of 99 ft. 7 ins. each, but on the Newcastle side the columns are skewed to the centre line of the bridge and divide the approach into spans as follows: on the East side, 136 ft. 11$\frac{1}{4}$ ins., 141 ft. 1$\frac{1}{16}$ ins., and 145 ft. 2$\frac{3}{8}$ ins, while on the West side the spans are 153 ft. 6$\frac{7}{16}$ ins., 136, 11$\frac{1}{4}$ ins., and 132 ft. 9$\frac{1}{2}$ ins.

Above the level of the ground the abutments take the form of impressive pylons of grey Cornish granite, 100 ft. wide fronting the river and 75 ft. deep along the axis of the bridge. These towers rest on the two concrete foundation piers and on a heavily reinforced concrete floor which bridges the two caissons, and at the same time serves as a warehouse floor. The abutments from ground level upwards are hollow shells intended to be used as warehouses, and for this purpose steelwork for floors has been provided at suitable levels as well as facilities for the addition of goods lifts if required. For the convenience of foot passengers between the quaysides and the bridge deck, stairways have been constructed inside both Newcastle and Gateshead abutments and on the Newcastle side two passenger lifts have also been installed. In order to set off the main arch and enhance the appearance of the whole bridge, the granite masonry of the abutments is continued to 35 ft. above deck level in the form of pylons on either side of the roadway, and these pylons have been adapted to form convenient entrance chambers for the lifts and staircases, besides giving space for motor rooms over the lift shafts. The bridge roadway is supported through the hollow abutments on steel girders of 60 ft. span, carried by steel columns resting on the concrete foundation piers below, and built into the walls of the abutments.

THE ARCH

The arch is of the two-hinged type and consists of two trusses 45 ft. apart, each made up of two crescent-shaped ribs connected by a single system of web members. It rises 180 ft. from the springing point and has a maximum depth between ribs at the centre of the arch of 20 ft. 3 ins.

The rib members are of box section with constant inside dimensions of 40 ins. by 30$\frac{1}{4}$ ins., the gussets for web members passing through slots cut in the flange plates, while the web members themselves are of the H- or single web type with four bulb angles.

There is a duplicate lateral system between the two trusses consisting of K-bracing throughout, except where the portals occur. All these members are four angles with single flat lacing at 60° between the two pairs of angles, except in the case of the bottom two panels of bracing in which a plate is substituted for the lacing. Connecting the two systems of laterals there is, in the plane of each web member, a cross frame consisting in every case of two diagonals, each a single 8 ins. by 8 ins. angle.

The roadway cuts horizontally through the main arch 93 ft. 9 ins. above high water level and is carried on cross girders hung from the arch trusses by 36 hangers in the central portion of the span and supported by 12 steel spandrel columns from the backs of the trusses at the two ends where the arch passes below the level of the roadway. These cross girders are single members consisting of four angles and flange plates, and have a plated contilever portion for the support of the footway. The depth over angles is 48 ins. in the main girder and 26 ins. in the cantilevered portions. The hangers are made up of two channels and two plates giving overall dimensions of 13 ins. by 10 ins.

Between cross girders are stringers, interconnected by cross joists, to which system steel buckled plates are riveted. These stringers are single web plate girders with four angles, the overall depth being 36 ins.

The 50-ft. girders spanning the abutments are single web members with angles and flange plates, the overall depth being 86 ins.

THE MAIN ARCH ERECTION

There was included in the contract a special clause to the effect that no material whatever was to be hoisted from the river, which had at all times to be kept clear for traffic. This necessitated the use of a novel method of erection which it is believed had never been employed before in Great Britain, and which was watched with the greatest interest by technical experts from all over the Country. The important details of the main arch erection can easily be grasped by the aid of the accompanying diagrams and the following explanatory note.

The first, or lowest members of the arch on either side were supported on a temporary steel cradle while they were being put in place, and in this way the two halves of the arch were built up from the abutments to a height at which they could be conveniently anchored by wire ropes at about road level. After serving its purpose on the Gateshead side, this cradle was dismantled and re-erected on the Newcastle side, where it was used for a similar operation.

Before removal of the cradle, each half arch

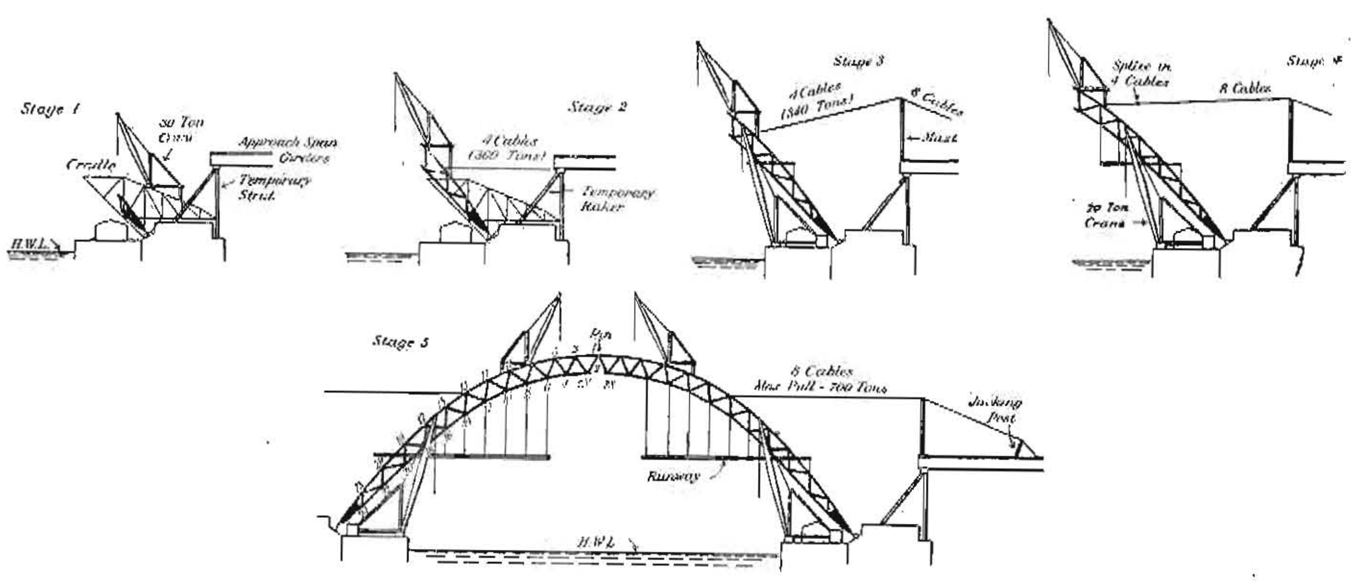
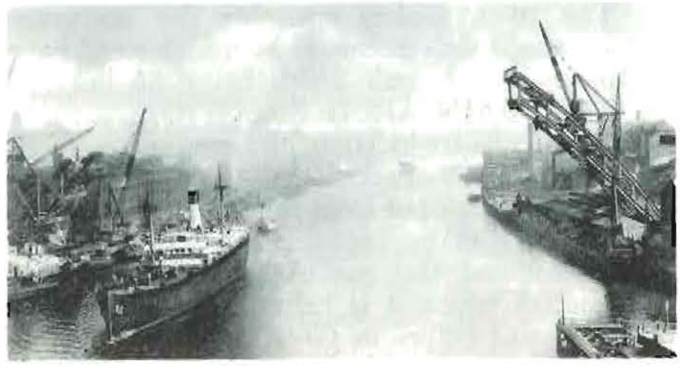


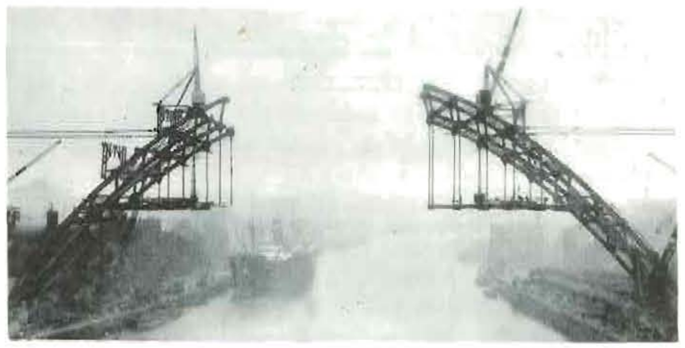
FIG. 2. DIAGRAMS TO SHOW METHOD OF ARCH ERECTION.



OCTOBER 20th, 1927

DECEMBER 16th, 1927

JANUARY 12th, 1928



JANUARY 26th, 1928

was tied back from panel point 21 by means of 8 steel ropes each 8 ins. in circumference, to the ends of the approach spans. The cables were attached to the trusses by means of a U-bolt working on a steel pin. Threaded on the legs of the U-bolt were cast steel sockets in which the ends of the cables had been spread and then run in with white metal. The nuts on each leg of the U-bolt provided the means of adjustment necessarily to ensure each set of cables being the same length and therefore taking an equal share of the load, and measurement of stresses on the cables was carried out by periodical vibration tests.

The next stage was the erection, on the ends of the approaches, of temporary steel masts 70 ft. high, built on pins and free to rotate, from the tops of which 16 wire back-stay ropes were carried down for each half arch to an anchorage in the approach span web members at a point 150 ft. back from the base of the mast. From the river side of each mast, 8 ropes were taken to panel point 17, and when these were in place the first position cables were removed. When the arch erection had proceeded to a sufficient height, more cables were put from the masthead to panel point 13, and those to panel point 17 were removed. The cables, 16 on each side, remained in this position until the final closing, at which time each set was supporting a load of about 2,000 tons. These cables were all of one type and specification, each being 2¾ inches in diameter and composed of 217 wires in 8 layers with a breaking load of 350 tons and a working load of 90 tons.

The foregoing paragraph deals with the support of the arch during erection, whilst the diagrams themselves show clearly the "cranework" required to raise the huge members, some of which exceed 20 tons in weight. The sections of steelwork were supplied to the cranes with the minimum of handling. A 20-ton derrick crane with a special jib 115 ft. long picked them out of the railway wagons on the quayside and deposited them on to a bogie pulled by a winch along a narrow-gauge track or runway laid on top of the bridge cross-girders in the line of one of the footpaths. Carried on the back of the ribs of each half-arch was a 30-ton electric standard

Scotch derrick, mounted on a steel gantry to give a level platform. This derrick reached out over the bogie on the runway, picked up each piece of steelwork, slung at the correct angle, and lowered it to fit easily and accurately into place with the minimum of time and effort. When the 30-ton crane had worked out to the limit of its reach, it erected a 5-ton derrick at the extreme point of the steelwork. This 5-ton derrick then dismantled the 30-ton crane and re-erected it alongside itself, and the crane, before proceeding with the erection of the steelwork dismantled the 5-ton derrick and laid it down ready to repeat the whole process a little later. This scheme of operations continued until the final stages, when the two 30-ton cranes were able to co-operate in the erection of the central members.

At this stage it only remained to bring the two halves together, and this extremely delicate operation was performed in the following manner.

The arch ribs had been built and were held suspended so that the centre of the span was at a level 6 ins. above its final true position, and when erection was complete except for the centre panel of the bottom boom, a 5-in. pin was inserted into the gap between the two halves in the plane of the top booms, and by means of an ingenious jacking arrangement the halves, pivoting on their own main bearings, were lowered until they met, and the arch temporarily became of the three-hinged type. The process of lowering the halves was performed very simply and effectively. (See Fig. 4). A telescopic steel saddle, actuated by four 200-ton hydraulic jacks was placed, close to the anchorage, under each group of backstay cables supporting an arch rib. By jacking the saddles up or down and thus deflecting the cables out of a true line from construction mast to anchorage, an appreciable movement could be produced at the centre of the span, and in this way, assisted by constant telephonic communication between the top of the arch and each set of jacks, the closing was accurately carried out.

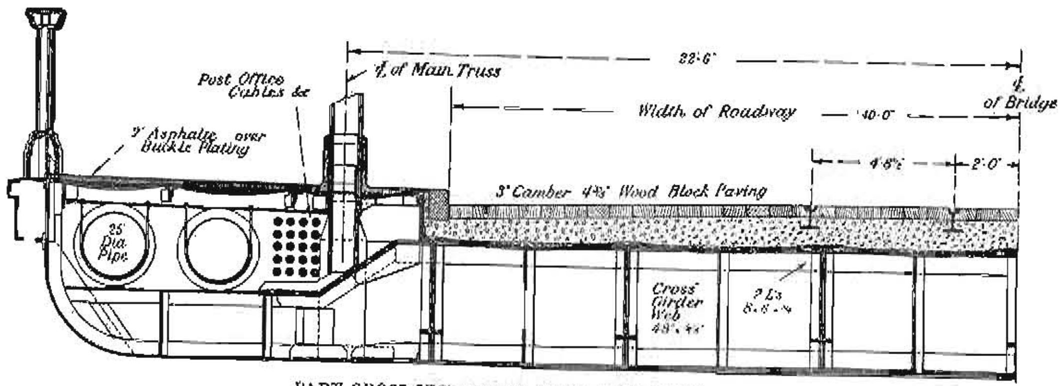
This operation, which was marked by the firing of maroons and breaking of flags on the bridge itself, took place on February 25th, 1928, six months after the date on which the construction of the arch was started.

FEBRUARY 2nd, 1928

FEBRUARY 15th, 1928

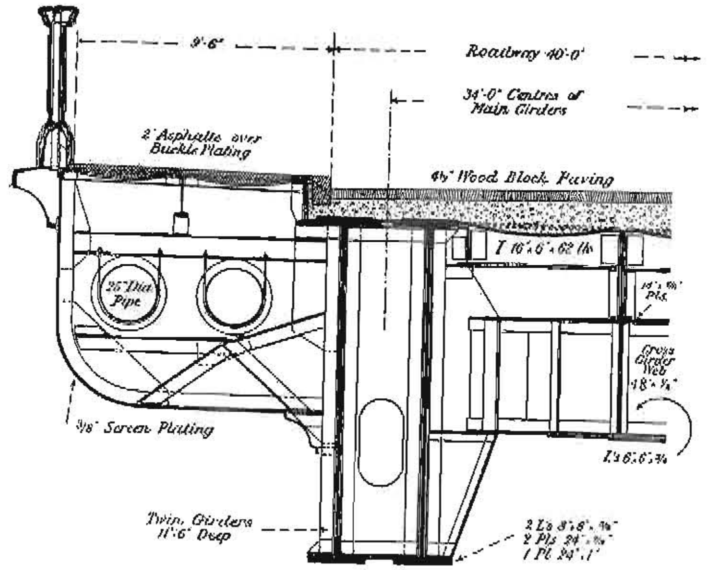
FEBRUARY 22nd, 1928

FEBRUARY 27th, 1928

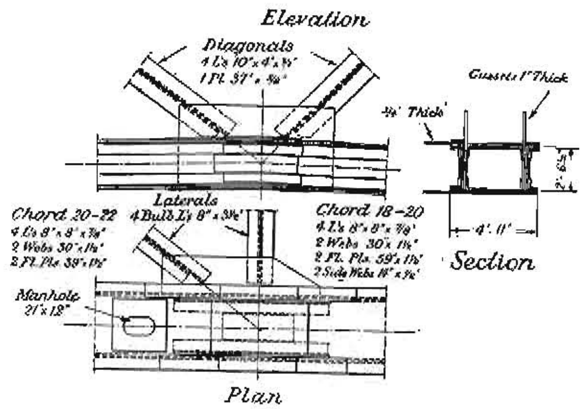


PART CROSS-SECTION OF MAIN ARCH DECK.

FIG. 3.

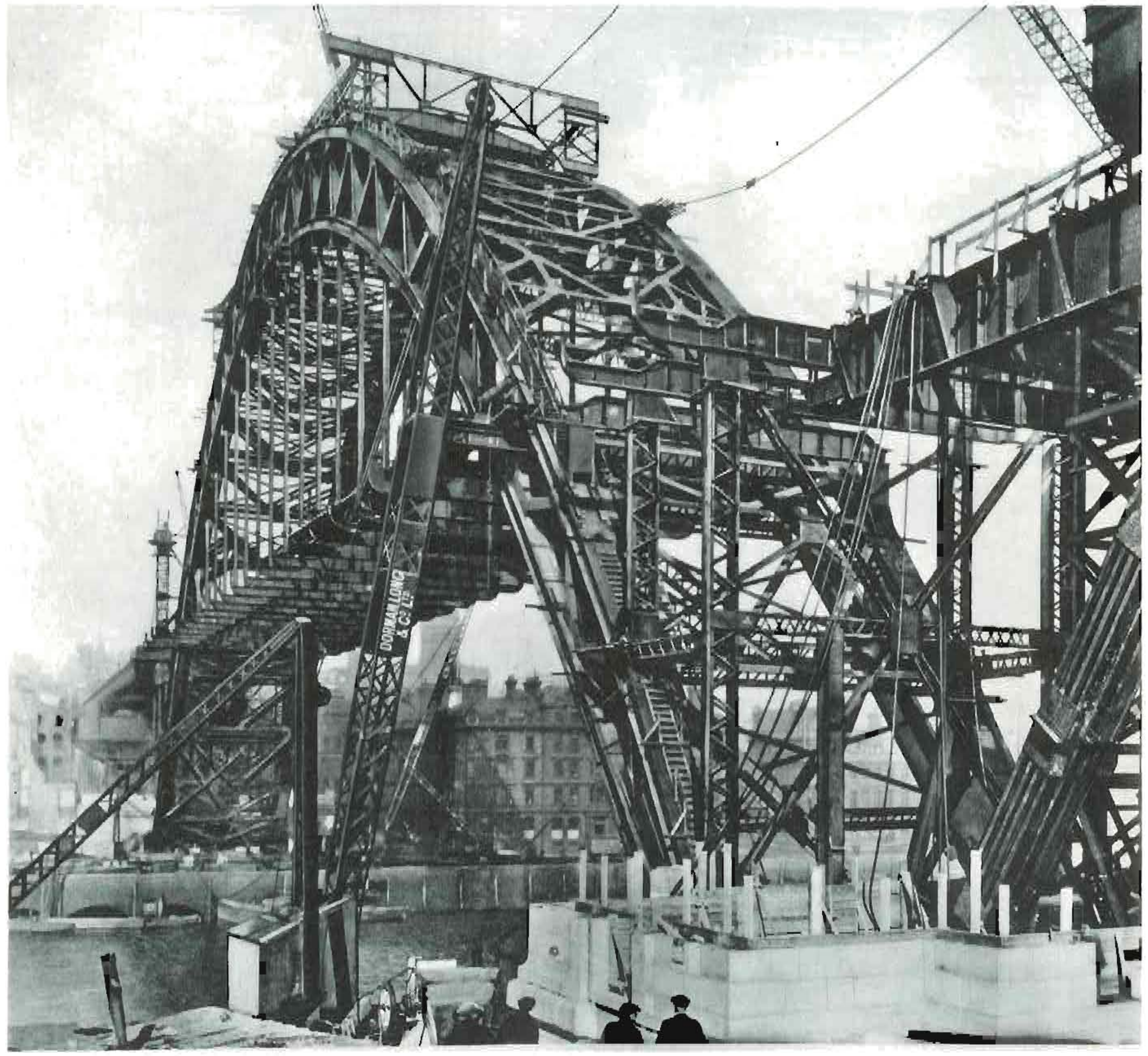


PART CROSS-SECTION OF APPROACH SPAN DECK.



DETAIL OF TYPICAL JOINT IN BOTTOM CHORD OF MAIN ARCH.

After the completion of the arch, the work, if not of such a spectacular nature, continued to be of great interest to engineers all over the country. Fig. 5 shows the arrangement by which the central member of the bottom chord was put into place. Holes were drilled in the member for connections at each end in the usual manner but only one connection was completed, the gussets for the other end being left "blind." This end of the member was supported top and bottom by temporary cleats so that it was free to slide between the gussets without deviating vertically from its final position. Twin jacks were then inserted in the positions shewn and the member was gradually brought into a state of stress, the amount of which was measured by means of extensometers on the member itself. When the stress had risen to a previously calculated intensity, holes were drilled in the gussets corresponding to those already in the member, and the connection was riveted up, the jacks and temporary cleats being subsequently removed. Special permission was obtained from the authorities to raise the three centre roadway cross girders from a barge in the river, which was done early one morning, so as not to interfere with the river traffic, and the laying of the roadway proceeded. The surface consists of wood block paving on concrete, which in turn rests on the buckled steel plates previously mentioned. The tramrails are of British Standard Section No. 8, 60 ft. long, tied to gauge at intervals of 7 ft. 6 ins., and the footways are finished with tar macadam, flanked by balustrades of closely pitched vertical bars arranged in groups of three panels. On October 10th, 1928, the bridge was formally



GENERAL VIEW OF BRIDGE IN MARCH, 1928

opened by H.M. the King, whose Ascot landau was the first carriage to cross.

The contract for the construction of this bridge included a considerable amount of subsidiary work such as the demolition of nearly 6 million cubic ft. of existing buildings and the re-making and widening of several streets. The quantities in the bridge itself include over 40,000 cubic yards of excavation and 12,000 cubic yards of filling; 41,000 cubic yards of concrete and 90,000 cubic ft. or 6,000 tons of granite ashlar facing.

There are altogether 8,000 tons of British Steel in this structure, all of which was manufactured and fabricated by Messrs. Dorman Long and Company in their Works at Middlesbrough. The total weight of steel used in the arch is 4,000 tons, of which 2,400 tons is in the trusses etc., while the remaining 1,600 tons is in the deck. A further 4,000 tons of steel is used

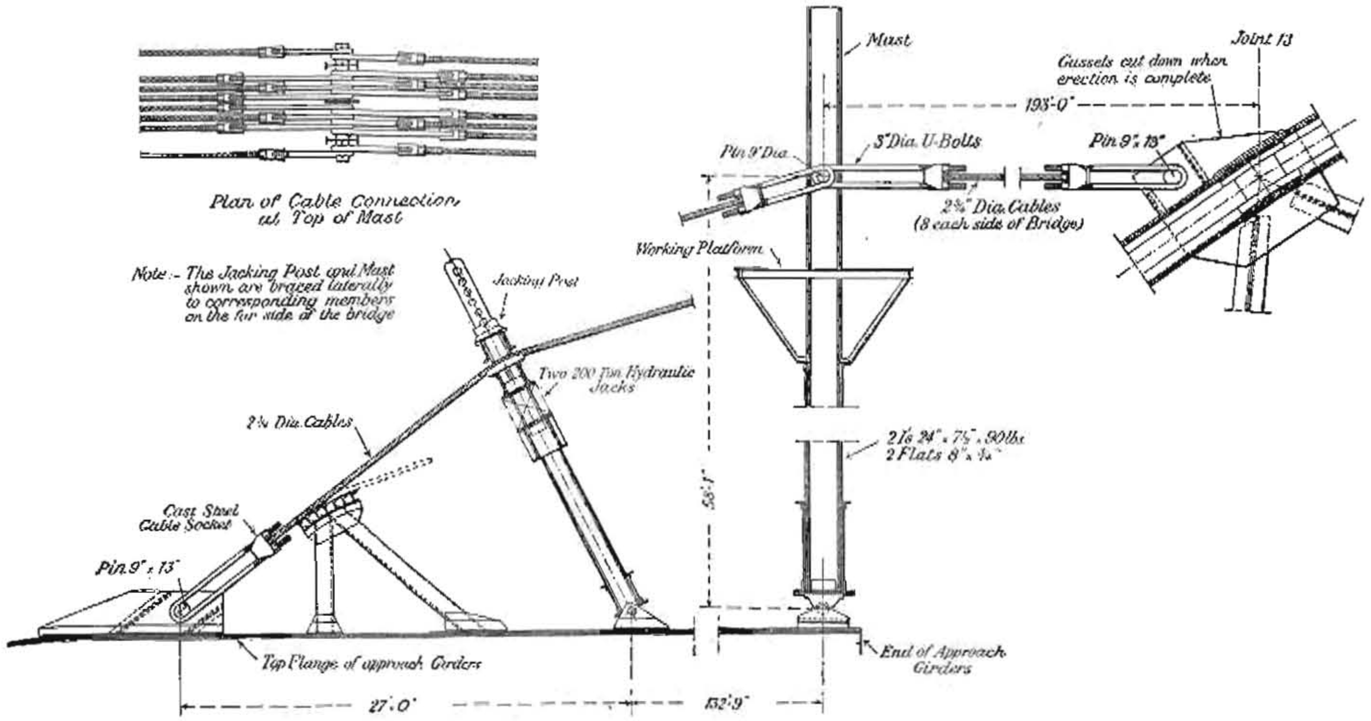


FIG. 4

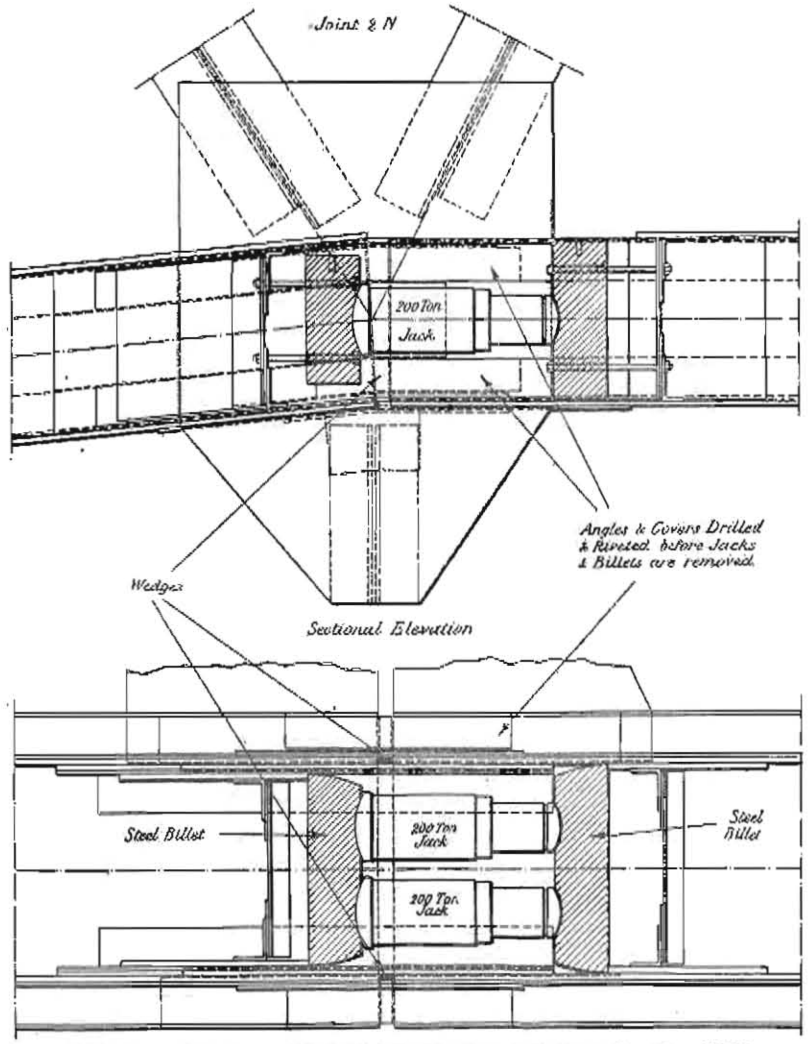


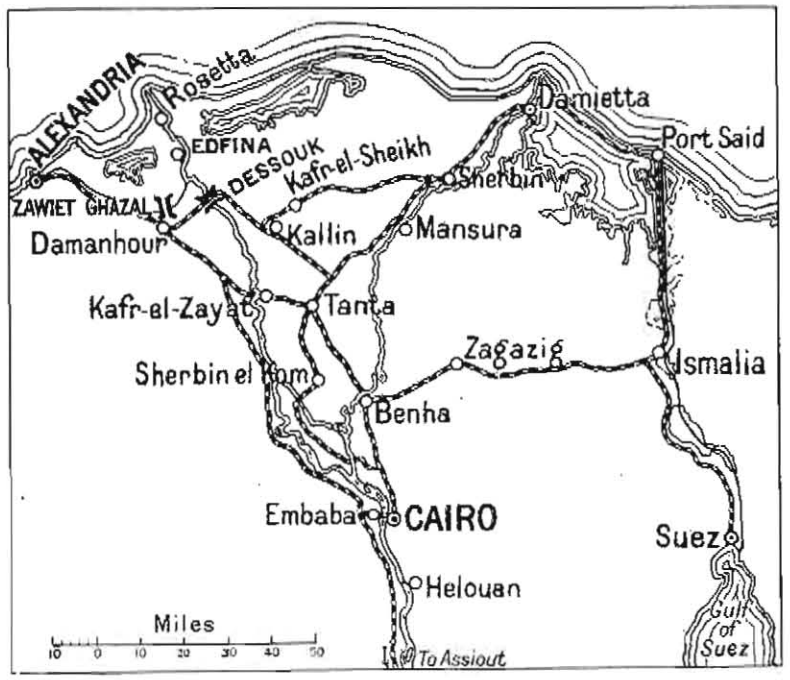
FIG. 5. METHOD OF JACKING STRESS INTO CENTRAL BOTTOM CHORD MEMBER OF MAIN ARCH

THE GATESHEAD SIDE, SHOWING THE CABLES IN THEIR FINAL POSITION. JANUARY 13th, 1928

THE OPENING CEREMONY, OCTOBER 10th, 1928. THEIR MAJESTIES THE KING AND QUEEN DRIVING ACROSS THE BRIDGE

in the abutment towers and approaches. Messrs. Dorman Long & Company were responsible for the entire undertaking, which was carried out under the direct supervision of Mr Charles Mitchell, head of the Bridge Department, Mr James Ruck being the Contractors' Agent on the site.

The contract for this work was placed in December, 1924, at a price of nearly £600,000 and work on the site commenced in August, 1925. The total cost of the undertaking was nearly double this sum, the difference being accounted for by the purchase of land, property and wayleaves, and the cost of street improvements. The Ministry of Transport, however, bore 60 per cent. of this total cost. The Consulting Engineers for the bridge were Messrs. Mott, Hay & Anderson of London, with whom were associated Messrs. Coode, Wilson, Mitchell & Vaughan-Lee. The architectural features embodied in the abutment towers, etc., were carried out by Mr R. Burns Dick of Newcastle.



EGYPTIAN BRIDGES

The Egyptian State Railways, now operating over 2,000 route miles, commenced their existence under Khedive Abbas I by the opening in 1856 of a line from Alexandria to Cairo. This line, which was laid out by Robert Stephenson, crosses the Nile in two places, Kafr-el-Zayat and Benha. In 1858 it was pushed on to Suez, making a most important connection for travellers to India, as the Suez Canal was not opened until ten years later.

By 1898 the Nile had been crossed in two more places, at Cairo, to connect that city with the line from Assiout and at Nag Hamadi to carry the line from Assiout to Luxor. In 1924 the first of these bridges was replaced by the modern Embaba Bridge which has a total length of nearly 1,600 ft., comprising six fixed and one swing span. The work before the Egyptian State Railways in opening up this country is never-ending, as the population of Egypt is over 13 million and its area is nearly 400,000 square miles, only 12,500 of which are cultivated.

The latest work of development is the bridge from Dessouk to Rahmanieh over the Rosetta branch of the Nile, here described. A typical piece of work performed by the Company in Lower Egypt is the chain of bridges between Sherbin and Kallin, while the third description deals with a small swing road bridge, yet another branch of the activities of Dorman Long & Co., Ltd.

THE DESSOUK BRIDGE ACROSS THE NILE

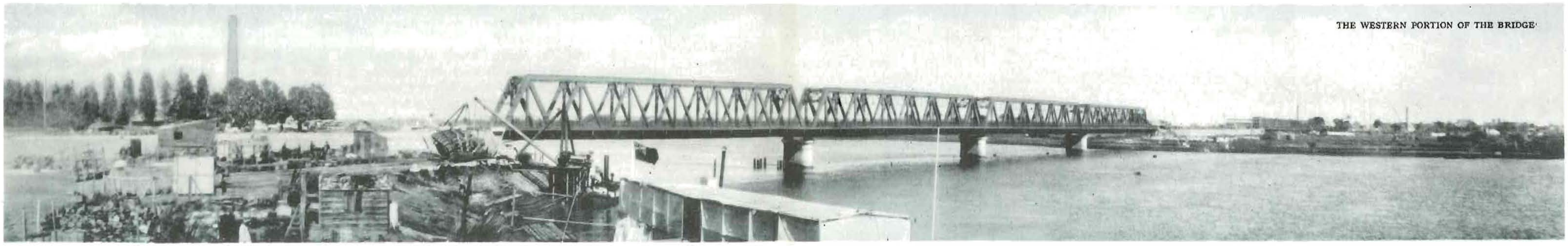
The bridge which we are about to describe has two distinct points of interest apart from its actual construction. The first lies in its history, the second in the novelty of the process of erection as well as the rapidity with which this was carried out.

The point at which the bridge crosses the River Nile is Dessouk, about forty miles south-east of Alexandria. The line it carries connects the northern part of the Delta with Damanhour, a station on the railway between Alexandria and Cairo. A considerable amount of traffic passes over this line, in fact much more than was ever anticipated, and the original bridge, built in 1895, eventually proved too light for the heavier rolling stock which accompanied the increase of traffic. Accordingly for some time, the tedious expedient was adopted of stopping the trains at the end of the bridge, and then taking them over by a light engine at the rate of one carriage at a time. Finally in 1925, it was decided to demolish the old bridge and build a new one.

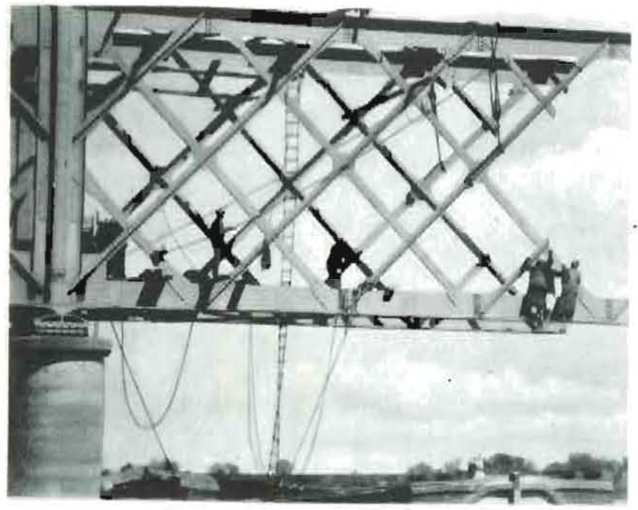
The existing piers had, however, a margin of stability, so they were tested before interference with the old bridge superstructure, to see if they could carry the weight of the new and heavier bridge without signs of settlement. A strong wooden platform extending right round each pier, was suspended from it by five heavy chains passing over the cap. On this platform was piled a large quantity of old steel rails, while others were also placed on the cap wherever there was space. The combined weight was equal to the extra load the pier would be called upon to bear when the new bridge was in position. There was no evidence of settlement in any of the old piers, and they have therefore been retained, though they have been re-capped to accommodate the new and wider bridge.

The bridge consists of ten spans of a total length of 2,010 ft., and the river at the point of crossing is divided by an island into two channels. The western channel is bridged by four spans of 200 ft. 8 ins., each, and the eastern channel by four spans of 200 ft. 8 ins., a hand-operated swing span of 194 ft. 6 ins. and a short span of 177 ft. 6 ins. between the swing span and the shore on the Dessouk side. The gauge of the railway is the standard of 1.5 metres between centres of rails, and the bridge carries a single track only, but outside the main girder on each side is a cantilever roadway of a total width of about 11 ft. for pedestrian and vehicular traffic. The bridge is designed to comply with the requirements of the Egyptian State Railways, and to carry the heaviest rolling stock which is likely to be used in the future.

The trusses are of the Warren type, 30 ft. 3 ins. deep and 17 ft. 1½ ins. between centres. The top chords are 2 ft. 6 ins. deep, of double web, plated over the top. The bottom chords, also of double web, are the same depth but



THE WESTERN PORTION OF THE BRIDGE



DISMANTLING SPAN No. 7 OF OLD BRIDGE

RIVETING SPAN No. 1

open. The railway stringers are single web, 2 ft. 6 ins. deep, with a top plate 18 ins. wide. and the portal members are double web, 2 ft. 6 ins. deep, with angle lacing on the underside. The diagonal members are of H-section with plate webs, the verticals being of double angles each side, with flat lacing between, and angle-cross bracing is provided in both top and bottom chords. This bracing as well as the portal and sway bracing, is shown in the accompanying diagrams.

The roadway is carried on cantilever brackets, across which run four stringers of channel section. The surface, of reinforced concrete, is built directly on to these and has a net width of 8 ft. 7⅛ ins., with a sidewalk of 2 ft. 3⅜ ins. from the edge to the centre of the handrail. The space between the handrail stanchions is filled in with ¼ in. steel wire mesh.

Rapidity was an essential feature of the erection, while it was also necessary to avoid any method likely to be interfered with by the inevitable Nile flood, so a scheme of building out the girders from each side of the piers was

PHOTOGRAPH TAKEN AS THE BRIDGE APPROACHED COMPLETION, SHOWING OVERHUNG SPAN REACHING ALMOST TO THE NEXT PIER, THE TEMPORARY TOP CHORD TIES CAN PLAINLY BE SEEN

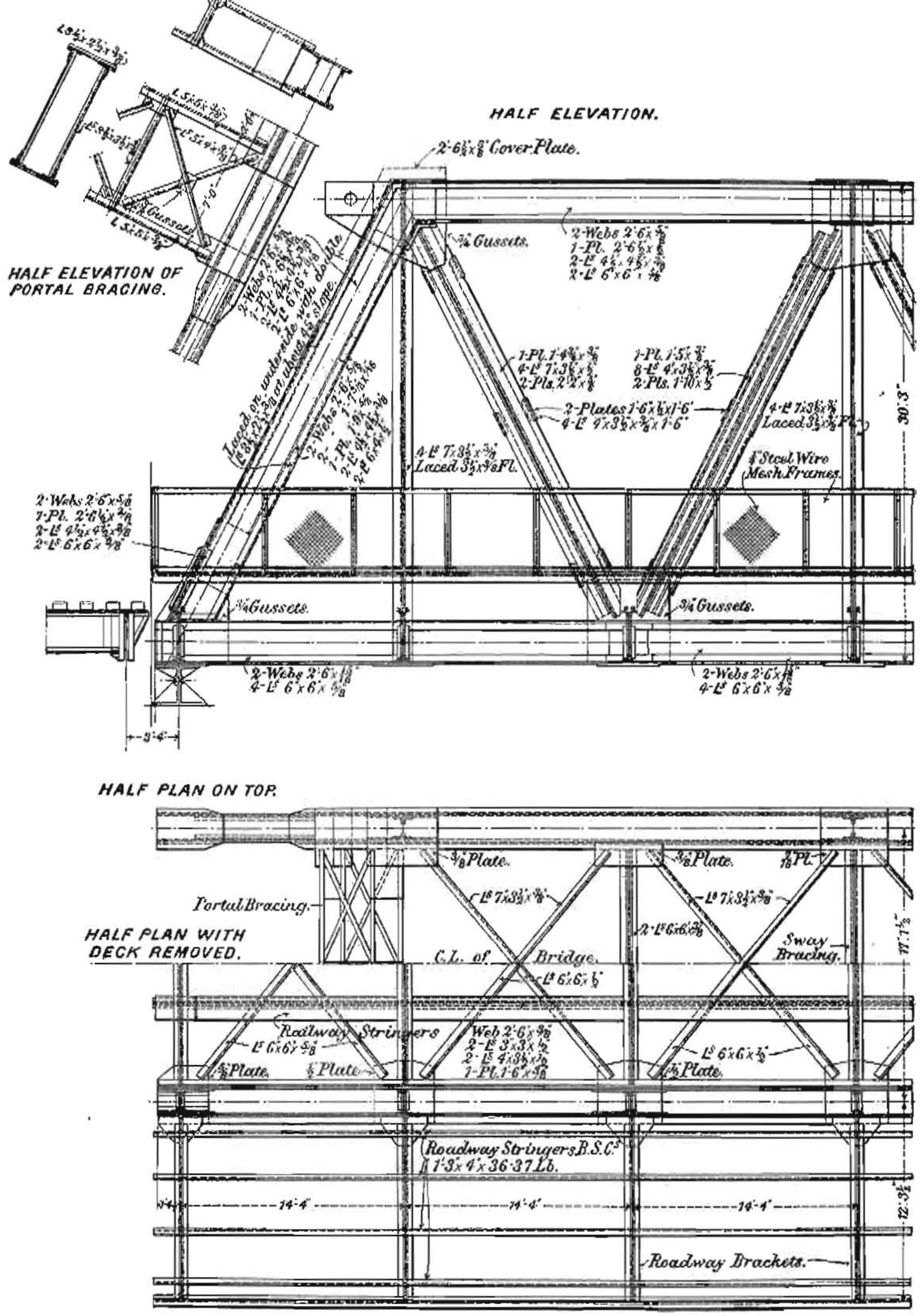


FIG. 1

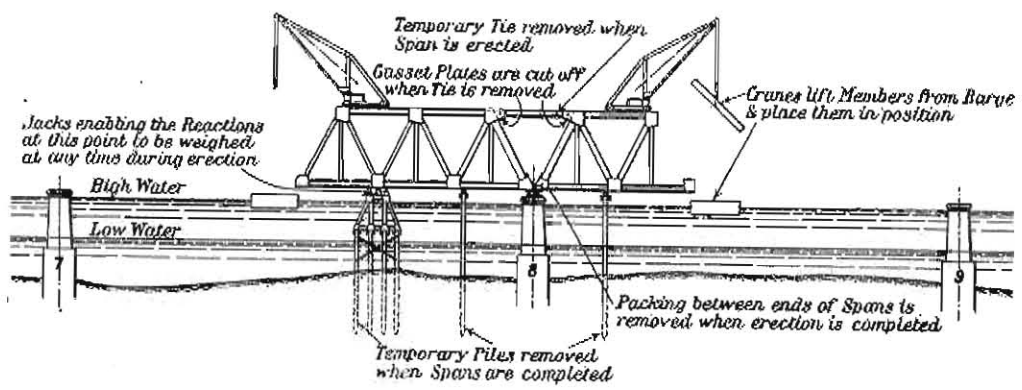


FIG. 2

adopted. This enabled work to be carried on at four points simultaneously, that is, two in each channel. The method is shown in Fig. 2 which illustrates one pair of points. After the removal of the old bridge superstructure, the re-capping of the piers was commenced. A wooden staging was built near the top of the pier, and from this the new, reinforced concrete cap was laid, the finished caps being both thicker and wider than the old ones.

When the particular cap selected for the starting point was completed, two groups of piles were driven on each side of the pier, and the

SPANS Nos. 7 & 8. ERECTION TIES REMOVED, BUT GUSSET PLATES NOT YET CUT AWAY

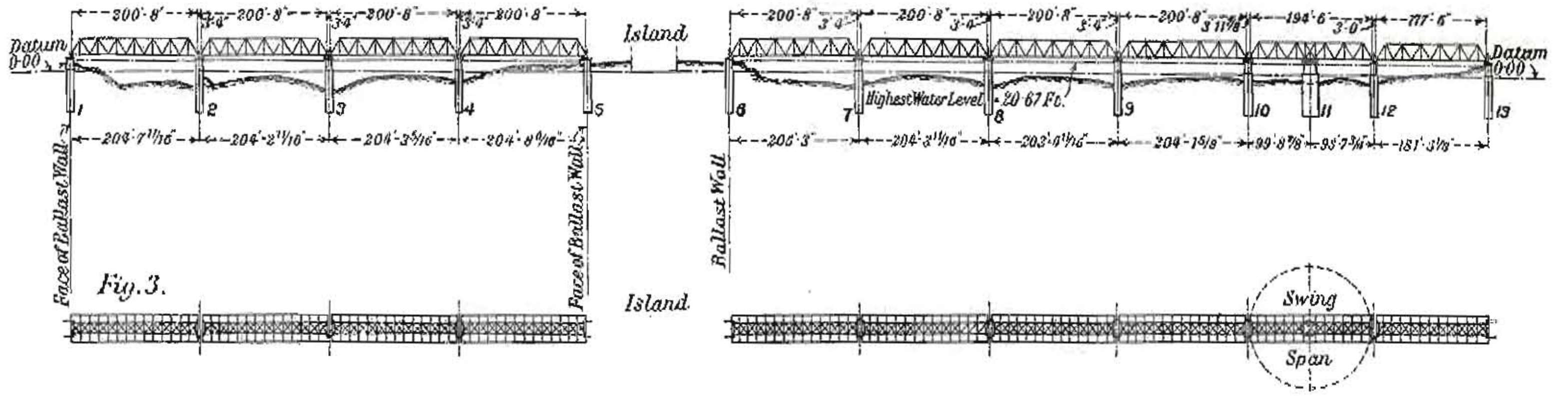


FIG. 3

first lower members laid across them and the pier. On these as a base the first panels of the Warren girders which form the bridge were built. When the top member of each adjacent span was in position, they were connected to one another by a temporary tie, the point of junction of which is seen in the top left hand corner of Fig. 1. A third trestle was constructed of piles, and used to check the reactions at that point as the work progressed by carrying the load on jacks. As soon as there was sufficient of the top member of each span to carry it, a travelling derrick crane was mounted, which lifted the material direct from barges floated underneath it. Erection thus proceeded outwards from the pier, the precise order in which the members were put in place being determined by careful calculation, so that the balance should be preserved, and the load on the temporary pile trestles kept within definite maximum and minimum limits, which were checked by the jack weighings. The weighing trestles were only put in at the starting points, and were not, of course, required for those spans built out subsequently from a completed span.

In order to lessen the stress in the temporary top chord ties during erection, the cantilever brackets carrying the side roadways were not put in place until the span was self-supporting; this is clearly shown in the illustration on page 24, where they are in place on the finished spans but not on the one under erection. Against these, however, may be set the weight of the working platform suspended underneath the bridge and the load imposed by the travelling crane, particularly when this was at the extreme outer end.

The ends of the spans are carried on roller chocks of ordinary pattern which were, of course, not constructed to carry the thrust caused by the weight of the overhanging span. During construction this thrust was met by packing the space between the ends of the spans with a solid filling, so that the bottom members were actually opposed to one another. On the completion of a span—that is, when the whole of its weight was taken by the piers,—this packing was taken away and the temporary ties, being no longer necessary, were removed and the projecting part of the gusset plate shown in Fig. 1, was cut away.

Every member had been marked at the works with a number denoting the exact period of the erection at which it was to be fitted. This prevented any accident arising from one span proceeding more quickly than the other, and so overbalancing its shorter neighbour. This rigid numbering system may have accounted for the fact that erection was slow to begin with, but once the gangs had got used to it however, the rate improved to a point beyond all expectations. The swing span could not, of course, be erected in exactly this manner, but a modification of it was adopted. It was erected in its open position—that is, parallel to the course of the river—by a floating crane situated at the centre, the members being added first to one side and then to the other to preserve the balance. When completed, it was

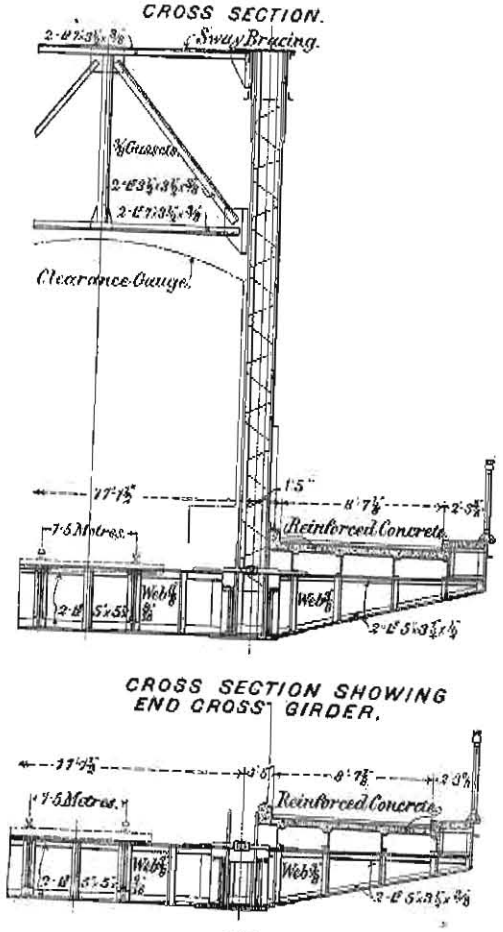


FIG. 4

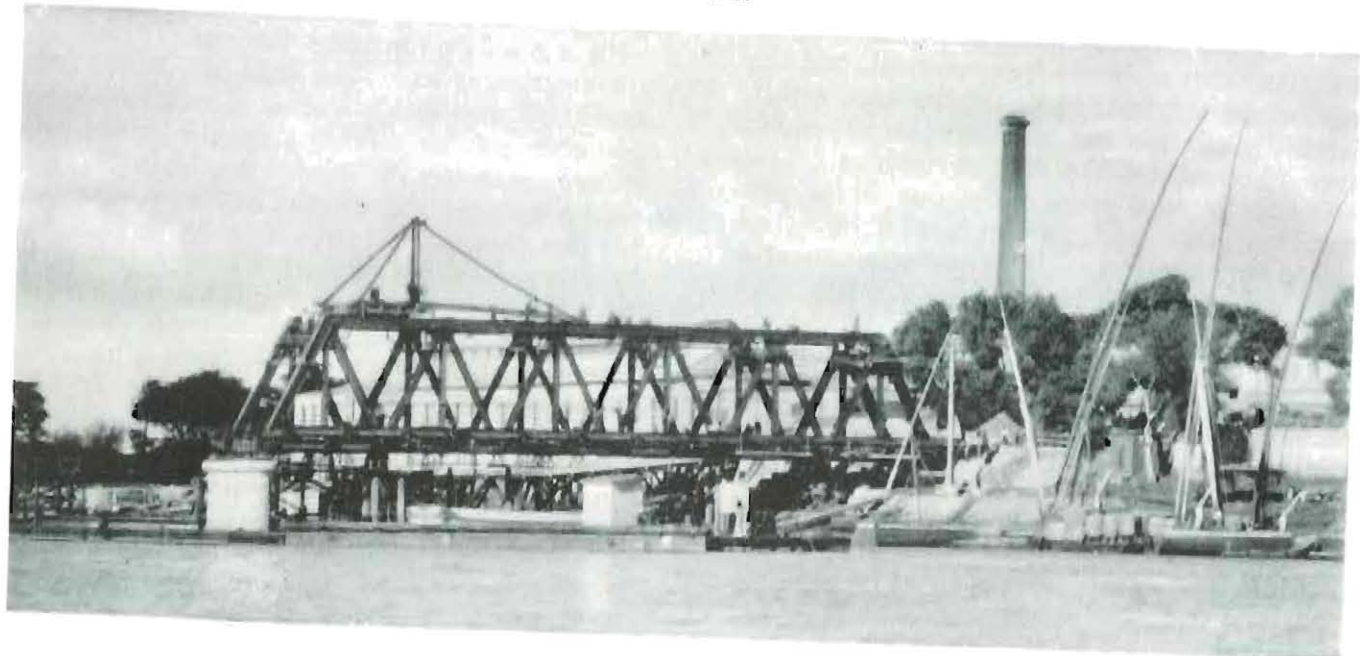
swung round to its closed position by its own operating gear, which is of the hand winch type. The roller track is of the usual pattern, consisting of a cast-steel path 17 ft. 3 ins. in diameter and 36 steel rollers held in position by radial arms.

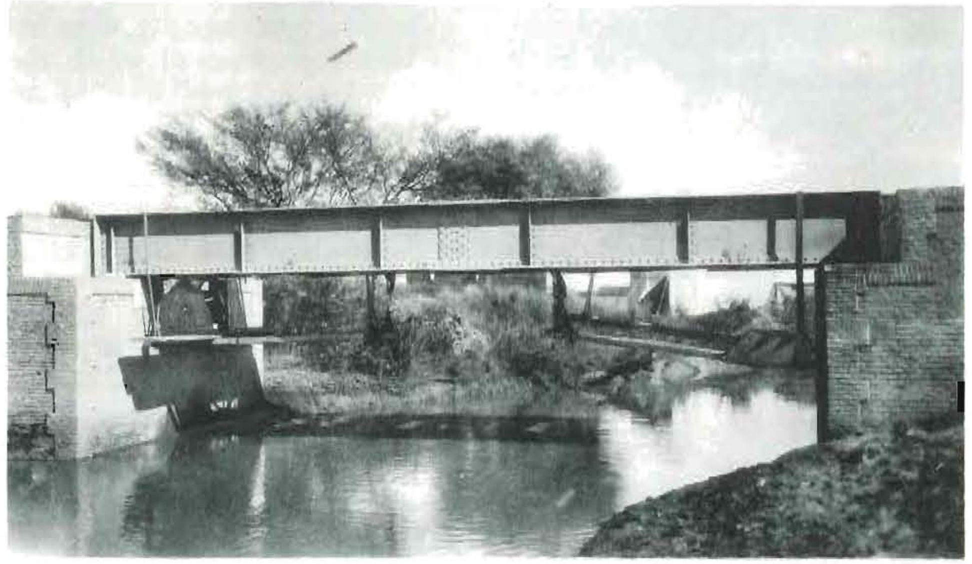
The total weight of steelwork and other metal parts amounted to approximately 3,800 tons, and was manufactured by Messrs. Dorman Long & Company at their Middlesbrough Works.

The contract for this bridge was signed between the Egyptian State Railways and Messrs. Dorman Long on November 21st, 1925, and work was commenced on the following day. It was completed in thirteen months despite the heavy handicap imposed by the Coal Strike which lasted for seven of these months. This was five months less than contract time, by which rapidity of work a saving of approximately £E.30,000 was made by the Egyptian State Railways.

The Bridge was formally opened on February 12th, 1927, by His Excellency, Mohammed Mahmoud Pasha, Minister of Communications.

SPAN No. 10





THE SHERBIN-KALLIN BRIDGES

TYPICAL OF THE SMALLER CONTRACTS UNDERTAKEN BY THE COMPANY.

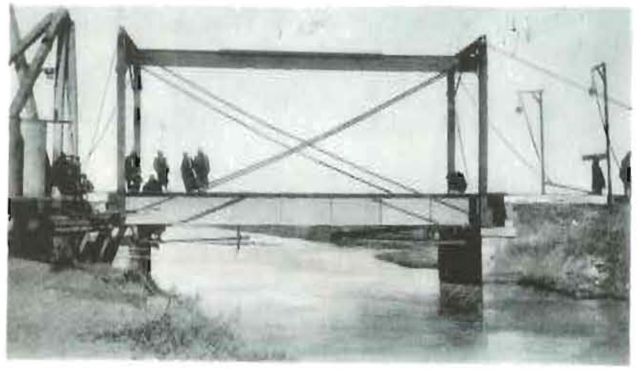
A glance at the map on page 21 will show the importance of the Sherbin-Kallin line of railway across the Nile Delta. This importance will be considerably enhanced when the proposed new line from Edfina to Sidi Ghazi is put in hand, thus giving direct communication between Alexandria and Rosetta, on the extreme Western side of the country, and Mansura and Damietta on the Eastern side. Apart from these considerations, the weight of traffic using this line increased recently to such an extent that in May, 1928, the Egyptian State Railway decided to renew fifteen single span bridges between Sherbin and Kallin. It was, however, quite impossible to close the railway line for the demolition and rebuilding of the old bridges, on account of the consequent dislocation of traffic, so that the problem presented required very special attention.

The existing bridges were all found to be of the through girder type with abutments of somewhat inferior brickwork and rubble masonry, the foundations of which, however, were considered by the Administration to be sound enough for the increased weights. In order that these existing abutments might be used to carry the new bridges, it was decided in each case to build a reinforced concrete beam across between the bearings of the old bridges upon which the new bearings would be placed and which would distribute the loads over as large a section of the abutments as possible.

The existing spans varied from 23 ft. to 46 ft. between centres of bearings, and the distances between truss centres varied from 8 ft. 3 ins. to 11 ft. 6 ins. The new bridges were, therefore, designed as deck spans with the distance between girders varying from 4 ft. 11 ins. to 5 ft. 5 ins., and in this way it was possible to prepare the bearings for the new spans without disturbing the traffic.

In order to fulfil the conditions of the contract, which required that the line should be open at all times necessary for ordinary traffic, the new spans had to be substituted for the old in the short time of five hours--the minimum period of idleness at any point on the line—during the night.

The new bridges were dumped at each site one by one from the field yard and erected by one gang. The rivet gang followed close behind, and the change-over gang came last of all to carry out the actual night operations and clear up the sites. Thus the work, including demolition of abutments and concreting



GANTRY IN POSITION OVER OLD BRIDGE PREPARATORY TO COMMENCEMENT OF NIGHT OPERATIONS

was carried out simultaneously at four points along the line. As the length of the line between the first and last bridges is 60 kilometres, transport problems were no mean item in the general arrangements. Heavy material, including all new steelwork and some items of plant, had to travel by rail and all loading and unloading had to be carried out by manual labour between wagon and track levels: however, even girders up to 10 tons were successfully handled in this manner. The railway system proving too inelastic to deal with the rapid progress of approximately one bridge a week, a motor lorry and trailer were put into commission for moving the lighter items of plant, all timber, and also camp equipment. Owing to the exceptionally heavy rains experienced during the 1928 winter in Northern Egypt, transport was gravely hindered as the local mud roads are quite impassable when wet, though the strenuous efforts made enabled the programme to be carried out with the loss only of a few days, and the work was completed within a week of contract time.

For the purposes of each actual change-over, a 5-ton hand crane, with water kentledge, was erected by the old bridge and, as the railway track is carried on an embankment, a large amount of timber cribbing was always necessary. This crane was used for the erection of a temporary overhead gantry of simple construction, placed over the bridge abutments, and which was designed to clear the loading gauge in order that it might be put up the day before the main operation. On the night selected, two differential chain runner blocks, of 25 tons total capacity, were fitted on the gantry beam by means of which the old bridge was lifted and towed forward on to the railway track. The new bridge, after being moved sideways from where it was put together, onto the line, was then run underneath the gantry and lowered into position; the old bridge, meanwhile having been cleared sideways for the passage of trains. Both spans were fitted temporarily with flanged wheels to facilitate these movements. The whole change-over was usually accomplished in about three hours.

The contract included the breaking up of the old bridge and loading of it on to trucks by means of the crane.

The girders used in the new spans are of the single web type, 2 ft. 2 ins. over angles, with flange plates 19 ins. wide. There is a single system of lateral bracing in the plane of the top flanges, consisting of single angles, and intermediate cross bracing is provided to carry the lateral forces from the bottom flanges of the girders to the lateral bracing.

The total amount of steel used in these spans exceeds 150 tons, all of which was made and fabricated in the Middlesbrough Works of Messrs. Dorman Long & Co., Ltd.

The time allowed in the contract for the completion of the work was 10 months from May 15th, 1928, and the work was completed a week before expiry of contract time.

A further contract for four exactly similar bridges on the same line followed on the first. In this case the contract time was beaten by four months.

ONE OF THE NEW SPANS SHOWING RIVETING, PAINTING AND FIXING OF SLEEPERS IN PROGRESS AT THE SAME TIME ON DIFFERENT PARTS OF THE GIRDERS

THE ZAWIET GHAZAL BRIDGE

A TYPICAL SMALL SWING SPAN

The Mahmudieh Canal lies well to the North of the Egyptian Delta, and at one time roughly represented the limit of cultivated land towards the sea. In recent years, more and more of the Northward tracts have been drained, irrigated and brought under cultivation, and the further reclamation of this portion of the Behera Province is part of the latest programme of the Ministry of Public Works. There being no road communication across a length of about 30 miles of this canal, it was decided to build a substantial road bridge at Zawiet Ghazal, capable of carrying the heaviest agricultural tractors and ploughing engines. This bridge is of immediate benefit in providing direct access from the main Alexandria-Cairo road to the town of El-Atf, which lies on the junction of the Mahmudieh Canal and the River Nile, and also to the King's Estates at Edfina.

At the point chosen, the canal has a regular section and, in the centre, a uniform depth of about 13 ft.; there is, however, a certain amount of silt partly filling the excavated channel at the sides. The canal carries the entire water-borne traffic of the country between Alexandria and Cairo, and is the sole outlet for more than half the cotton growing area of the Egyptian Delta. A daily passage of some 300 native barges and steam lighters is not uncommon during the cotton season. During construction of the bridge, therefore, it was of the utmost importance that this traffic on the canal should not be interrupted. A bridge was therefore designed having two clear openings of 37 ft. each, and a total span of 116 ft. It was also necessary that the centre pier should be the support for a swing span, so that the final design consisted of two short approaches and a central swing span of 40 ft. radius, carried on rollers running on a circular cast steel track 12 ft. in diameter.

The bridge was designed to carry the following loads which can be classified under three headings:—

(*a*) A uniform load of 102 lbs. per sq. ft.

(*b*) A moving load of 19.7 tons divided between the axles, 11.8 on one, 7.9 on the other.

(*c*) A string of closely marching laden camels.

The span is a Pony truss of the Warren type with special bracing in the centre panel. The depth of the main trusses is 8 ft. 3 ins., and their distance apart is 27 ft. $5\frac{3}{4}$ ins. The chords, vertical web members and diagonal members are all composed of two 6 in. angles of varying thickness.

The cross girders are single web members, 33 ins. deep, built into the posts, while the roadway stringers are plain 15 in. joists about

3 ft. 6 ins. apart. A single system of lateral bracing is included, in which the cross girders act as struts and two single angles as diagonals. The decking consists of two layers of 9 ins. by 4 ins. oak planking, laid diagonally and crossing at right angles.

Each approach span has four 18 in. joists as stringers to the reinforced concrete deck, spanning from the approach abutment to a cross girder 16 ft. long between the end piers of the swing span. This girder is a single 16 in. compound beam.

The rollers under the swing span support the load through the medium of an upper circular girder to which the load is taken by special stringers in the centre bay, framed into two massive cross girders each weighing about 5 tons.

To steady the bridge under live load, two plain 18 in. beams are cantilevered from each side of the centre pier and carry plain wedges at either end to support the trusses at their centres when the span is closed and under live load.

Special wedging gear was required by which all operations of wedging and turning could be worked from the centre of the swing span. There is the usual capstan arrangement and spur gearing to a rack on the outside of the roller path for the turning movement, which can be carried out by two men only, and a second capstan was fitted for working the eccentric wedges by means of bevel gearing and a longitudinal shaft and worm gearing to two cross shafts located under each end of the swing span. This wedging gear also automatically operates gates on the approach spans by means of cam levers, bevel gears and links. The total weight of steel used in the construction of this bridge is approximately 100 tons. Work was commenced in March, 1927, and completed to contract time by December of the same year, though the bridge was not finally opened to traffic until February, 1928.

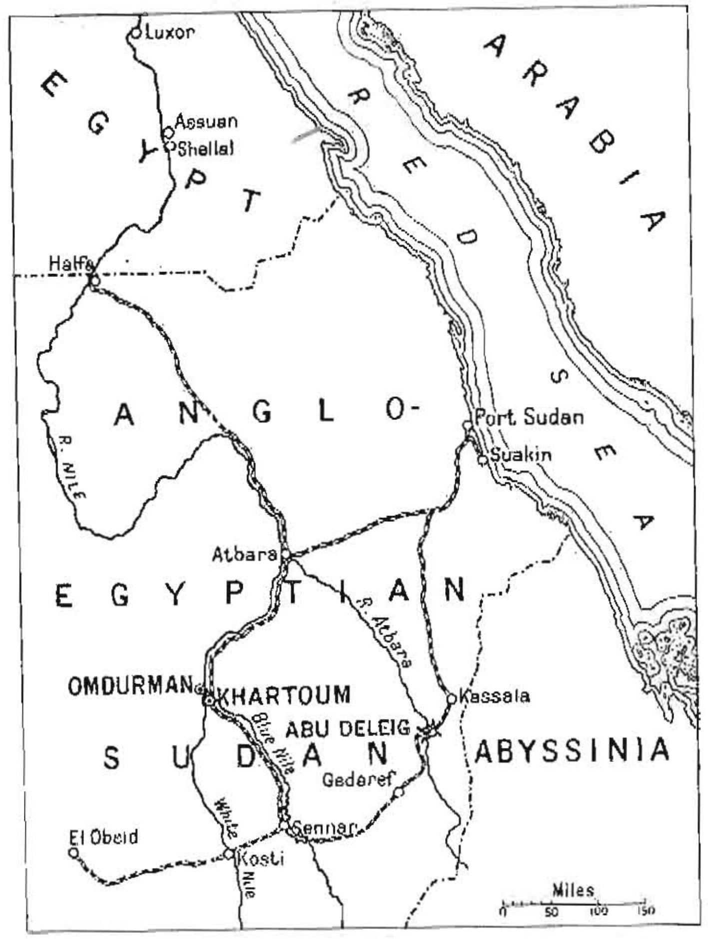
The foundations consist of steel cylinders, supported on concrete piles. The swing span pier was first placed in position and sunk to the required level by excavation on the inside; in it were then driven concrete piles about 40 ft. long, and a layer of concrete about 3 ft. thick was placed round them below

THE BRIDGE IN ITS OPEN POSITION

water level. Using temporary bracing where required, the remainder of the cylinder was then pumped out and filled with concrete in the dry, care being taken to ensure a good bond with the projecting heads of the piles.

Simultaneously the twin piers at either end of the swing span were erected, these being each 7 ft. in diameter while the central pier is 16 ft. in diameter. Each pier has a concrete piled fender to protect it from damage by the heavy water-borne traffic. The upstream and downstream ends of these fenders were formed by triangular groups of piles the heads of which were united by reinforced concrete beams. Down each side of the centre piers, the piles were placed in pairs, united by reinforced concrete beams, at about 16 ft. centres, and the groups were braced longitudinally by means of steel channels carrying timber rubbing strakes. The side fenders were similar, but the piles were single instead of being paired. A timber deck was erected on top of the swing span fender for the use of men navigating the barges. The abutment walls supporting the shore and approach spans are of mass concrete with wing walls having a brick parapet and piecrust concrete coping.

The work was done to the order of the Ministry of Public Works, Egyptian Government, the total cost being approximately £E. 12000, and was carried out by Messrs. Dorman Long and Company, who were responsible for the execution of the entire contract.



SUDAN BRIDGES

The latest additions to the Sudan bridges, namely the Khartoum-Omdurman and the Abu-Deleig bridges, form further links in the chain of development that has marked the policy of the Sudan Government since the British occupation.

The first of the modern Bridges to be built was the old Atbara bridge, over the mouth of the River Atbara, which was provided to carry the Sudan Military Railway during Kitchener's advance. This bridge, as far as is known, is carried on pairs of cylinders which were sunk by compressed air, and the superstructure, which has since been renewed, was erected by a firm of American engineers. In 1906, when the development of Port Sudan was well under way, and the Port Sudan to Atbara railway completed, it was decided to provide a bridge across the northern arm of the harbour, connecting the railway with the quays. In order to facilitate the passage of vessels, an opening was necessary, and the type chosen was a rolling lift span of 120 feet opening. The bridge at present carries only a single track of railway and a roadway, although provision has been made for a double railway track. This bridge was carried out under the auspices of the Public Works Department, and was completed in the autumn of 1907.

Immediately following the erection of the Port Sudan bridge, the Blue Nile bridge at Khartoum was commenced, a much more ambitious proposition than had hitherto been undertaken in the Sudan. The floods of 1908 and 1909 caused considerable damage and delay, but in April 1910 construction trains engaged in the building of Khartoum Central Station were crossing the bridge, though it was not opened for general traffic until a later date.

In order that as little delay as possible should take place in the construction of the railway to Kosti and El Obeid, it was found necessary to commence operations at the site of the Kosti bridge before the Blue Nile bridge was completed, and before the railway extension south of Khartoum had been commenced.

This bridge is of a very simple and economical design, with masonry piers carried on oval caissons sunk by compressed air. The fixed spans are of 150 feet each and the swing span gives a clear opening of 100 feet each side of the swing pier. In this case only one line of traffic is carried, and footpaths, 6 feet wide, are provided on the outsides of the main girders. The works concluded at the end of 1911 just as the railhead reached the site, so that construction proceeded westwards without interference.

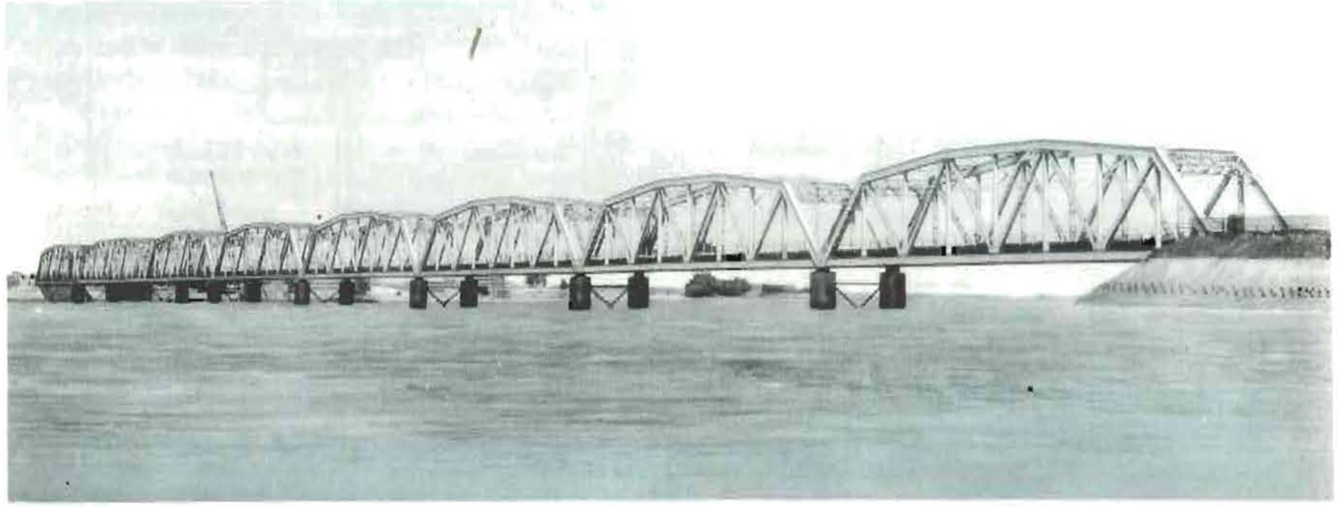
The renewal of the superstructure of the old Atbara bridge took place shortly afterwards, and marks the end of the first stage of Sudan development.

The Great War intervened, when destruction took the place of construction, and no further bridge schemes were mooted until January 1925, when a concession was obtained by a financial and engineering group, now known as the Sudan Light and Power Company, Limited, for the extension and improvement of the existing public utilities, and their scheme included the provision of a bridge across the White Nile, connecting Khartoum with Omdurman.

This bridge may well be considered to be the most interesting and significant of the bridges in the Sudan, uniting, as it does, the modern city of Khartoum with the old seat of the Mahdi's rule, and bringing the great advantages of civilisation to the 100,000 inhabitants of Omdurman.

The youngest member of this family of bridges, completed in July 1928, crosses the Atbara at Abu-Deleig and is the same length with the same number of spans as the old Atbara bridge.

The erection of this bridge enables the proposed Kassala-Sennar railway extension to be made, linking up permanent rail communication with the west, and probably marks a temporary halt in Sudan bridge-building schemes.



THE KHARTOUM-OMDURMAN BRIDGE

The new bridge which has recently been completed across the White Nile, connecting Khartoum and Omdurman, was formally opened by Sir John Maffey, the Governor-General of the Sudan, on January 16th, 1928. This bridge, the position of which is shown in Fig. 1, constitutes the most important part of the work undertaken by the Sudan Light and Power Company under the concession which was granted to it by the Sudan Government in January, 1925. The new works, in addition to the bridge, comprise a complete new electric tramway system as well as the extension of the lighting and water services both in Khartoum and Omdurman. The bridge and electric tramways now replace the steam ferry and the old Decauville steam tramways which had been in use since shortly after the British occupation. As Dorman Long and Co. Ltd., were represented in the group which forms the Sudan Light and Power Company, the design and construction of the bridge was entrusted to them.

Accommodation is provided on the roadway of the bridge and approaches for a single line, 3ft. 6 ins. gauge, electric tramway, the centre of which is placed at 7 ft. $3\frac{1}{8}$ ins. clear of the south main girder, and a roadway of 28 ft. clear between the main girders—see Fig. 2. Provision is also made for a future addition of two cantilever footpaths, each giving 11 ft. clear between parapets. The loads provided for are:—An electric tramway car weighing 16 tons with a wheel base of 7 ft. 6 ins. and two trailers of 6 tons on a similar wheel base on the tramway zone, and on the roadway 150 lbs. per square foot road surface with axle loads of a 12-ton steam roller. The levels are determined from datum fixed at 370 m. above mean sea level, which is 10 m. above absolute zero adopted at Khartoum. This datum of 370 m. is approximately lowest river level of the site of the bridge. The levels of the foundations of

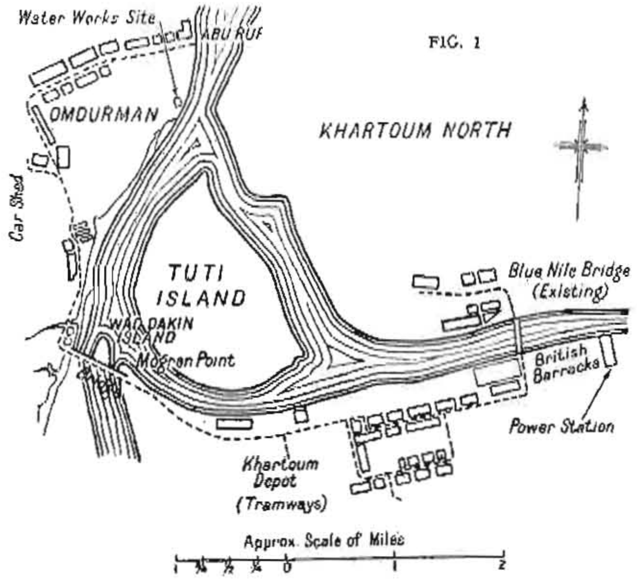


FIG. 1

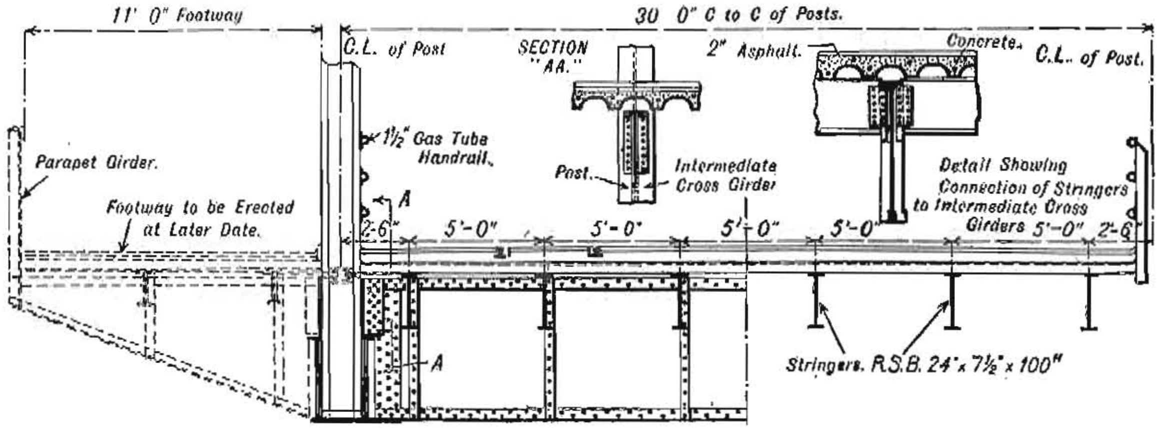


FIG. 2. CROSS SECTION OF ROADWAY OF BRIDGE

the piers were fixed by the level of the underlying rock, and range from a maximum depth of 9 m. to a minimum depth of 3.5 m.

The caissons are terminated at level 370 m. or at lowest water level, while the pier shafts are carried to level 378.70 m., which makes the underside of the bridge 379.50 m. and the roadway level 380.45 m. respectively. Thus the superstructure gives the minimum clearance of 2.80 m. above highest recorded river level.

During the progress of the work a slight departure from the original design was found necessary and the general dimensions of the bridge as completed will be seen on referring to Fig. 5. The bridge contract extended over a length of 3,466 feet, the bridge proper consisting of seven spans of 244 feet and one swing span of 304 feet, making the total length of steel superstructure of 2012 feet. The approaches to the bridge are 850 feet long on the east or Khartoum side and 634 feet long on the west or Omdurman side.

The conditions governing the selection of the site and the alignment of the bridge were suitable rock foundation, the point of approach on the west bank, and the width of the river. The site is near the junction of the White and Blue Niles and takes off from the east bank at what is known as Moghren Point, crosses Wad Dakin Island, and reaches the Omdurman bank just south of the limit of the permanent buildings on that shore. The clear waterway provided at high river during September and October is approximately 1600 ft., which is sufficient to take the maximum discharge, although the river during this period is considerably wider owing to the inundation of both the foreshores. During the low river season, January to April, the flow is confined to two channels east and west of Wad Dakin Island. The maximum current velocity occurs in February in the western channel and is about 2 m. per second. The White Nile is navigable for about 1100 miles south of this point and the western channel is used for the passage of steamers, and the swing span was consequently placed in the centre of this channel. Throughout the length of the bridge it was found by borings that the Nubian sandstone extended practically level and all the piers were carried down and founded on the solid rock.

The eastern or Khartoum approach has a gradient of 1 in 60 until it reaches the bridge, while the western or Omdurman approach is carried level throughout. The section adopted gives 10 m. between fences with a berm of 1 m. beyond, while at both ends of the bridge the embankment is widened sufficiently to embrace the cantilevers when added. The road surface is of tarmacadam on 9 ins. of soleing and is formed to camber in the usual manner. The tramway is accommodated on the south side as on the bridge.

As considerable wave action is produced by storms during the flood season the side slopes, which are 1½ to 1, are pitched to a depth of 1 ft. 6 ins. with stone built in cement mortar. The pitching is carried about 2 m. above highest recorded flood level. At the extreme ends of the bridge the roadway is retained by a reinforced concrete ballast wall built on the cylinder foundation of the abutments, these cylinders being entirely embedded in the bank. As already mentioned, the foundations vary in depth, and the lower or caisson sections, which cease at low-water level, range in length from 29 ft. to 12 ft. The abutments and piers of the fixed spans are nine pairs in number and consist of a caisson section of 16 ft. diameter and a pier shaft section of 10 ft. diameter. The two cylinders are placed at 30 ft. centres and are braced above low-water level. At the point where the shaft section connects with the caisson it is telescoped for 3 ft. and further reinforced with eight 50 lb. rails of a length of 15 ft. The steel work of these piers is of the usual design, the caisson being provided with a cutting edge and working chamber from the roof of which spring the air lock tubes. The pier shaft is a simple cylinder of $\frac{5}{16}$ in. plate stiffened and braced internally. On completion, these cylinders were filled solid with concrete. The mixture mainly used was 7 : 3½ : 1, but at the two points of reinforcement, viz., the junction of caisson and shaft, and the tops of the shafts on which the main girder bearings rest, a mixture of 4 : 2 : 1 was employed. The aggregate was of granite broken to pass through a 2 inch ring and provided from the Gebel Royan Quarries. The sand was obtained from local sources. The swing pier had to be dimensioned sufficiently large to accommodate the roller path and mechanism and was 33 ft. diameter on the caisson portion and 30 ft. diameter on the shaft portion. These two parts were reinforced and the steel construction is of a similar nature to that of the small cylinders.

The fixed spans—Fig. 3—are 240 ft. long centre to centre of bearings and the main girders are placed at 30 ft. centres apart. The main trusses are of the simple Warren type in eight panels of 30 ft., and having a depth of 36 ft. at the centre and 30 ft. at the ends. The cross girders are secured to the posts in the usual manner and between them the flooring of inverted steel troughing is carried on a series of 24 ins. by 7½ ins. R.S.J.'s, an expansion joint—Fig. 4—of the usual type being provided on the roadway between the ends of the spans. The roadway surface is of Lithocrete, 2 ins in. thickness, carried on a bed of concrete, the minimum depth of which is 5½ ins. over the top of the steel troughing. The tramway track of 3 ft. 6 ins. gauge is of flat-bottomed rails of 75 lb. per yard, with a 4 in. by 1 in. steel bar bolted inside to form a guard rail, and the gauge is retained by tie rods at 3 ft. centres, with adjustable nuts. The lower flanges of the rails and the tie rods are embedded in the concrete and the Lithocrete surface is laid flush with the top of the rails. The outline of the swing span is made to conform with that of the fixed spans, but its length is 300 feet between end bearings, which length was determined by the clearance required to give passage for the river steamers, the fairway being slightly on the skew at this point. In order to facilitate the passage of sailing craft and also to protect the swing span when in the open position, a floating dolphin of steel construction, which reaches 235 ft. upstream and

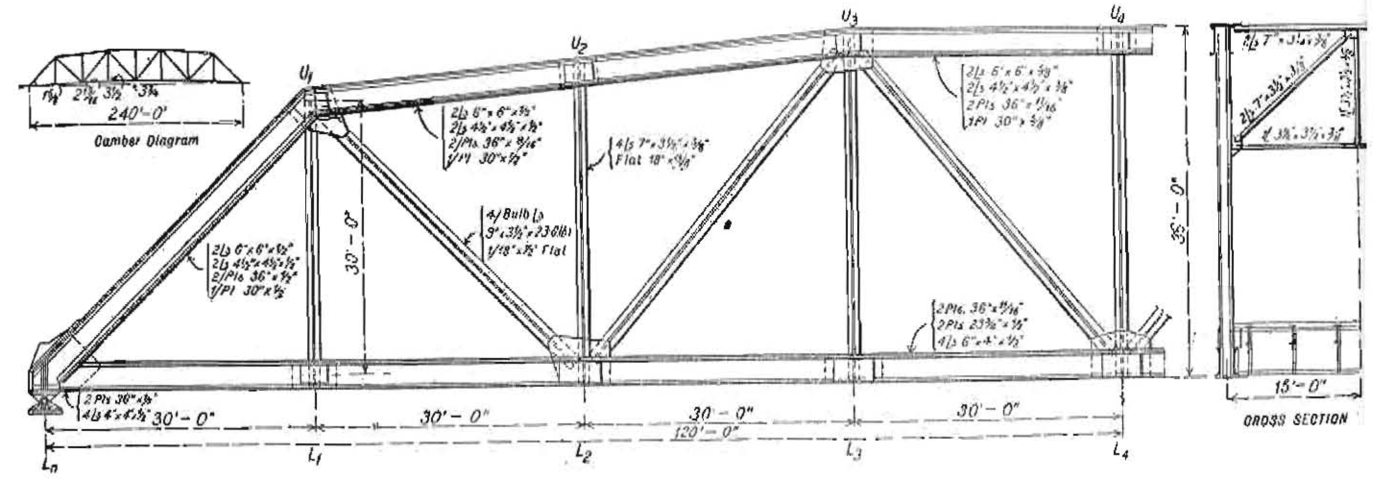
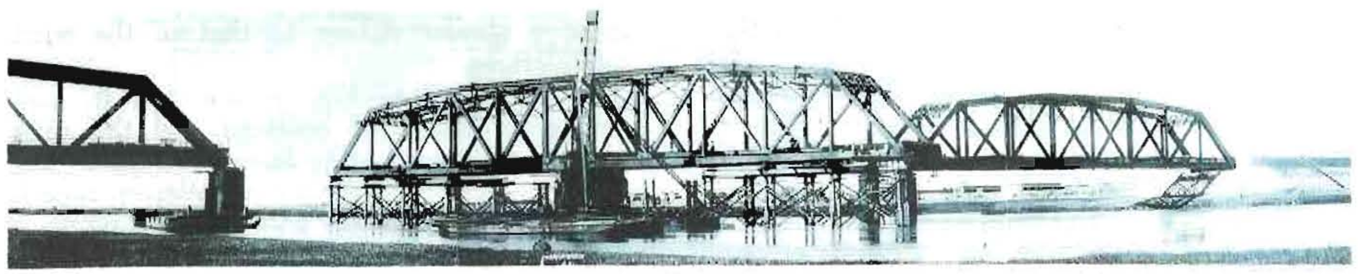


FIG. 3. HALF ELEVATION AND SECTION OF FIXED SPAN.



SWING SPAN IN NEARLY-FINISHED CONDITION

175 feet downstream of the centre line of the bridge, has been provided. This dolphin is guided on the swing pier by vertical guides and moorings at the extreme ends. It is of similar design to the dolphins generally adopted on the Lower Nile bridges.

The swing span when rotating is carried at its centre on a roller path of 25 ft. 4½ ins. diameter, 11½ inches on the face, having a frame of live rollers, while in its closed position, and when taking the load it is supported on its extreme ends by bearings on the adjacent piers of the fixed spans. These end bearings are of the usual screw wedge type, and when screwed home reduce the deflection in the ends of the main trusses by 1½ inches, and in this way adjust the stresses in the main trusses to take the working loads which are experienced when the bridge is in the closed position.

The swing span is operated electrically, and there is an auxiliary hand gear, which is capable of being thrown in when required by a simple dog clutch. The turning motor is of 20 horse-power, which runs at 500 revolutions per minute, and is geared on to the rack of the roller path.

The time required to swing the span by power through a right angle is about 3 minutes.

The wedge motors are placed on the ends of the fixed spans and are of 6 horse-power, with a speed of 1000 revolutions per minute. All the motors are operated by simple drum controllers, one being placed on a platform in the centre of the swing span, while the two operating the wedging motors are arranged in suitable refuges on the ends of the adjacent fixed spans. No buffers are provided, and the limit switches are so placed that should the operator over-run in either direction he can reverse, when the limit switches will reinstate themselves automatically. The floor of this span is of a construction similar to those of the fixed spans, and the whole span when in the swinging condition weighs approximately 650 tons.

The filling for the approach embankments was taken from borrow pits on the upstream side permanent banks, at a sufficient distance to prevent any displacement during the flood season. A quantity of 70,000 cubic yards had to be dealt with, and the banks varied in height from 23 ft. at the abutment end to about 12 ft. where it joined the public roadway. These banks were constructed entirely by manual labour, as it was not feasible to introduce machinery. The labour was imported from Egypt, and the Khartoum bank was completed in April, 1926, with sufficient loose stone pitching placed to prevent any serious erosion during the flood. The bank on the Omdurman side was not completed until the following low-water season, and the whole of the earthwork and pitching completed before the flood season of 1927.

The first of the 16 ft. diameter caissons was under air early in December, 1925, and the sinking continued without interruption until April, 1926, when it was necessary to abandon all work on the foundations until the following season. In all, twelve caissons were sunk, and the pier shaft completed during the low-water season of 1925–26. Two complete organisations were worked simultaneously, one dealing with the piers on the island and on the Khartoum foreshore, which were all pitched on dry land, and the other with the caissons which had to be pitched and sunk in the river. All the caissons were sunk by means of compressed air. The locks used were of the latest type, capable of handling up to 150 cubic yards per twenty-four hours in soft material. The caissons had an average penetration of 5 ft. into the rock. The excavation in hard material was very much slower and governed the time of the actual sinking operations. Steam power was used exclusively for the sinking plant. The power barges which accommodated the compressors, the steam electric lighting sets, and provided steam for the hoisting winches, consisted of two discarded gunboats, which, in their prime, had taken part in the naval operations in support of the forces under General—afterwards Earl— Kitchener at the battle of Omdurman. These power units were in duplicate, and could be conveniently moved and moored in the river in a position as near as possible to the caisson or caissons being sunk.

The second season's work during the low-water period of 1926–27, included the remainder of the piers, viz., six of the 16 ft. caissons and the swing caisson of 33 ft. diameter This season's work was not quite as large in volume as the first season, but presented certain difficulties in being further from the base, and deeper water and stronger currents were encountered. During work on the Western channel the river navigation had to be maintained, and provision had to be made against risk of damage to the permanent construction or to passing vessels. The last of the caissons to be sunk was the 33 feet diameter swing-span caisson, which was launched on February 1st, 1927, and both caisson and shaft were completed by the middle of April, 1927. The lower portion of this caisson is shown in half-cross section and half elevation in Fig. 8. It will be seen that the cutting edge proper consists of plate, 10 ins. wide and ⅝ inch thick. Five segments of this plate go to make up the circumference of the 33 ft. diameter caisson. The ring thus formed is attached to the main shell of the caisson, a 4 in. by 4 in. by ⅝ in. L section and ⅞ in. rivets, countersunk, being employed for the purpose. The shell plates, of which there are five to the round, are ½ inch thick. The pressure or excavating chamber, which is 8 feet deep, is lined with inner shell plates, $\frac{5}{16}$ inch thick in the manner seen in the engraving, and is heavily braced above its roof by steel angles. Two openings, one 3 ft. 7 ins. and the other 2 ft. 7 ins. in diameter respectively, were arranged—intersecting one another—for the fixing of the air locks. Circumferential stiffness was ensured by thirty radial angle iron girders. The roof plates were $\frac{5}{16}$ in. thick.

The means adopted for the sinking of the caissons varied according to conditions. Those on dry land were assembled over their exact positions and concreted and sunk by cranes placed on a travelling steel staging, which carried all the air lock equipment and steam winches working the excavating cranes. This stage had to be about 15 ft. above ground level to give the cranes sufficient headroom to lift the shafts into position, and also to place the concrete in the shafts. For the river piers piled stagings took the place of the steel travelling stage and fulfilled the same purpose. The lower sections of the river caissons were assembled on land, launched and floated into position in their stagings, but no pressure was taken on the stagings to keep the caisson in position while being pitched, this being provided for by special moorings operated by winches from above water, attachment of these moorings being so designed that they could be released as soon as the caisson was finally pitched and before excavation was commenced. This method was found much more reliable and more accurate than the usual method of supporting and wedging from the temporary stage. The large caisson for the swing span was pitched in 12 ft. of water and had a total penetration of 17 ft., 8 ft. of which was in solid sandstone.

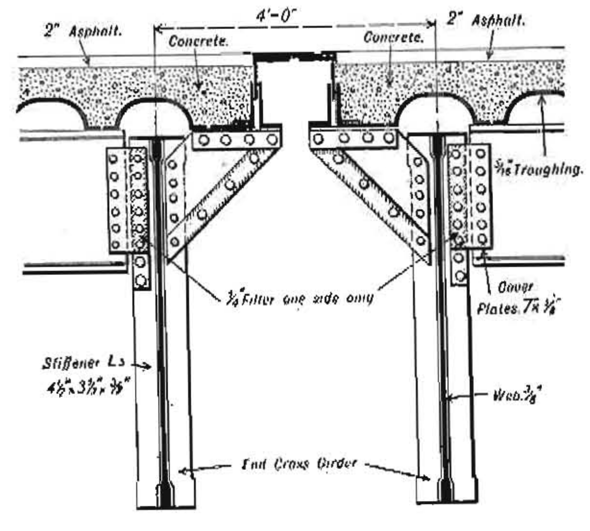


FIG. 4. EXPANSION JOINT BETWEEN FIXED SPANS

As most of the work on the erection of the superstructure had to be carried out during the flood season, timber staging was adopted for the six eastern fixed spans. This staging consisted of bents at 30 ft. centres formed of six piles abreast. Four of the piles carried the steel work, while the two outer piles, placed at 42 ft. centres, carried an electric Goliath crane. These pile bents were headed with timber and securely braced with steel angles, but the longitudinals consisted of six lines of 24 ins. by $7\frac{1}{2}$ ins. rolled steel joists, borrowed from the permanent steel work, with special junction pieces to bring the bearings exactly to 30 ft. centres, being the centres of the bents. The Goliath track joists carried no rails, as special wheels were provided on the Goliath to suit the upper flanges of these joists. The crane was electrically worked on all motions and current was collected from bare wires strung on the staging. As soon as the span was self-supporting the camber blocks were withdrawn and the timber utilised for re-driving, the steel work being brought under the Goliath by a temporary track laid on the spans which had been previously erected. The various members and pieces of steel work were carefully prepared and as much as possible of the field riveting completed in the yard before delivery to the erection Goliath; by this means considerable time and trouble were saved in the actual erection. The construction of the stage and its preparation for the Goliath occupied by far the longest time. Under favourable conditions a span could be assembled in just under five days, though sufficient time had to be allowed for riveting before the span was self-supporting and the staging could be relieved. The weight of steel work in each fixed span was about 400 tons.

As the navigable channel had to be maintained for steamer traffic at all times, the swing span was built in the open position, and for this span and also for the last or western fixed span a floating crane was used. This crane was a standard $7\frac{1}{2}$ ton steam derrick with 120 ft. jib mounted on two standard steel barges. The stagings used in this case were similar to those adopted for the seven fixed spans, but without the outer piles for the Goliath track. The swing span was designed without any compensation for distortion or error in level during

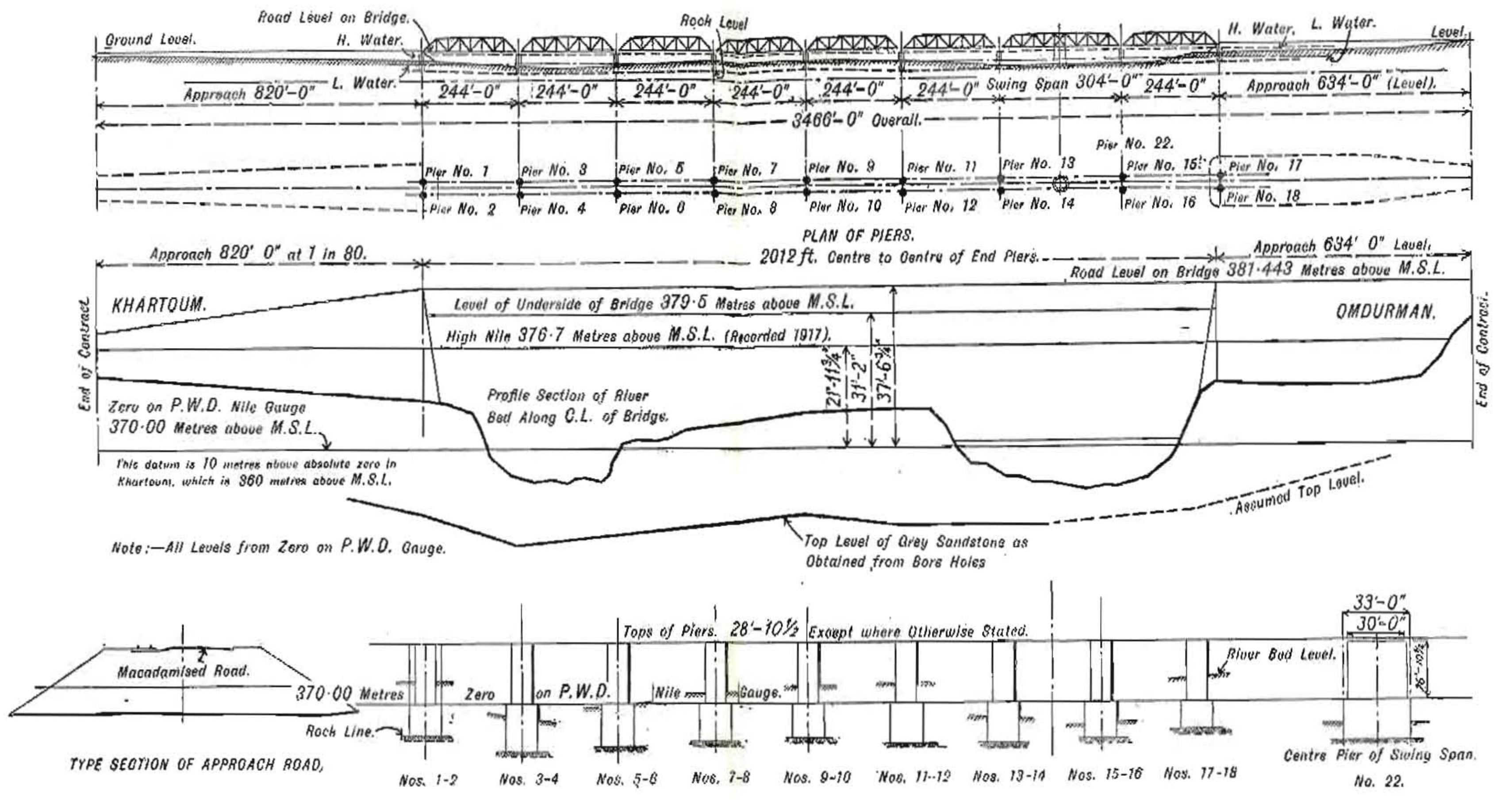


FIG. 5. PROFILE AND PLAN OF BRIDGE SHOWING POSITIONS OF PIERS

construction and the minute adjustment which was found necessary when the span was completed and swung was made by means of lowering or raising the ends of the adjacent fixed spans. All the gear was completed by the time the steel work was erected and the span was rotated by hand until the roadway was completed and the electrical equipment installed.

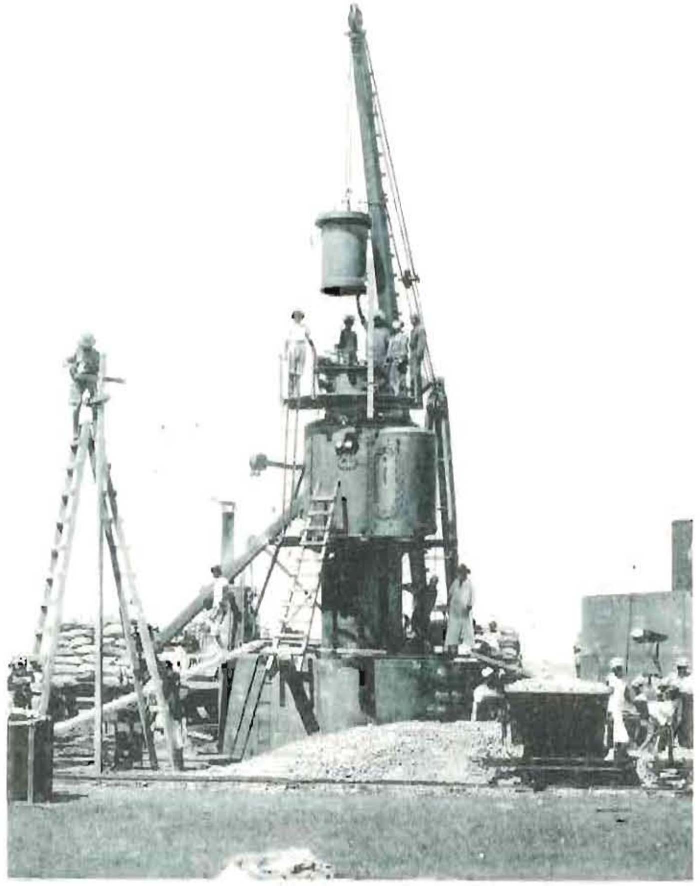
On completion of the main members of the spans the troughing and the tramway track were placed, and the concrete and asphalt surface followed automatically. During the cool season of 1927 and 1928 the steel work of the swing span was completed and it was found that, owing to the sun temperature on the south main girder and the fact that the north bottom chord was in shade, the span distorted laterally about 1⅝ inch. The maximum distortion occurred at 4 p.m. and disappeared during the night. This distortion, naturally, would affect both the wedging gear and the tramway track connection. After the placing of the concrete floor the distortion was reduced to ⅝ inch, but even with this small deflection it was necessary to make provision at one end of the span to give the necessary clearance to the pins of the wedging gear and also to construct a special platform on the adjacent fixed span so that the alignment of the tramway track could be adjusted at any stage of the distortion.

As all the material used in the construction, with the exception of the sand, was delivered by rail a storage yard equipped with sidings and handling plant had to be provided. The steel work arrived from overseas in large consignments and as much as 2000 tons of steel work had to be stored. The nearest site to the works where sufficient space was available and which was not liable to inundation at high river level, was situated near the old steam ferry landing at Moghren, which was about 500 yards distant from the bridge site. The steel work was handled in the storage yard by an electric overhead crane carried on a gantry constructed chiefly of 24 ins. by $7\frac{1}{2}$ ins. rolled steel joists, which were afterwards used in the floor system of the spans. A $7\frac{1}{2}$ ton travelling Smith crane was also used for dealing with plant, caisson material and ligher steel work. The concrete aggregate, of which 12,000 tons had to be handled, was usually transfered from railway trucks to lighter wagons and hauled by a light locomotive to the site. A reserve of stone, however, had to be maintained in case of late deliveries from the quarries.

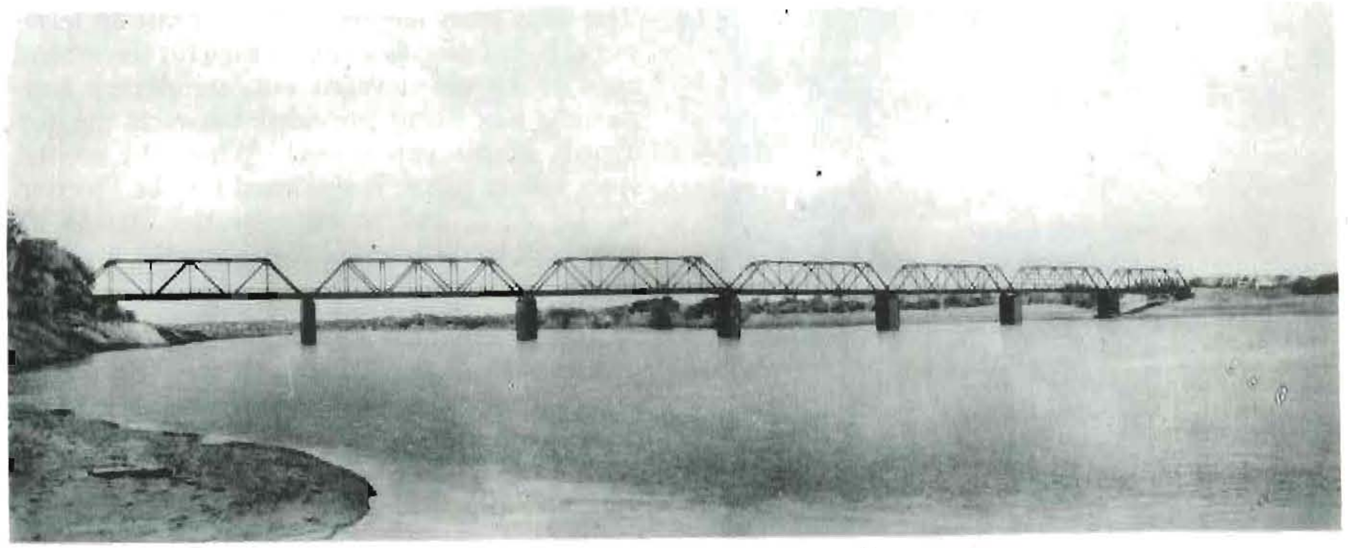
The broken stone for concrete, as well as most of the stone for pitching, was of granite obtained from the Gebel Royan Quarries situated on the main line about 40 kiloms. north of Khartoum. At the commencement of the construction there was no electrical power available from local sources, so that a small generating plant, consisting of duplicate Gardner Lancashire four-cylinder paraffin sets had to be installed. The engines were direct coupled to the dynamos on the same bed-plate and were capable of generating a total of 60 kW at 250 volts direct current, which was sufficient to drive the electric overhead crane in the yard and the Goliath crane on the bridge staging. A certain amount of current was also required for lighting and small power tools. All the lighting for the caissons, however, was generated from their own steam sets, the voltage being in this case 110 direct current. In this yard, also, the company's offices were established, as well as store sheds, workshops and other details incidental to a contract of this nature.

As already explained, the work on the foundations of the approach banks could be undertaken only during the winter or low water season, and was completed in two working seasons. The steel work, being independent of water transport, was carried on throughout the year, although during the summer, work was slow and disagreeable owing to high temperatures, dust storms and the disadvantages encountered during the tropical hot weather season. The order for the construction of the

bridge was placed in March, 1925, but no part of the permanent work could be commenced until December, 1925. In the interval, preliminary measures, such as housing for the staff, the assembling of plant, and the laying out of the yard and buildings were completed.
The work on the permanent structure was actually commenced in November, 1925, and was carried on without interruption until the summer of 1926, when the general strike in this country delayed operations for about two months owing to shortage of steelwork. In order that the completion of the bridge should synchronise with the putting in service of the first section of the electric tramways, certain subsidiary work had also to be completed, such as relaying of the tramway track on the Blue Nile Bridge and the construction of two small bridges crossing Khor Anga and Khor Fitihab in Omdurman. All these works were carried out by Dorman Long and Co. Ltd.
The contract time allowed for completion was due to expire on June 30th, 1928, and the bridge was actually put into service on January 16th of that year or about five and a half months ahead of contract time.
The consulting engineers for the Sudan Government were Messrs. Coode, Wilson, Mitchell and Vaughan-Lee. The designs of the bridge were prepared by Mr Ralph Freeman, M.Inst. C.E., who was consulting engineer to the contractors. Mr F. W. Stephen, Assoc. M.Inst. C.E., acted as agent in charge of the construction.



SINKING A CAISSON



THE ABU-DELEIG BRIDGE

In the early part of 1926 industry in the Sudan to the east of Khartoum had developed to such an extent that, in keeping with the progressive policy adopted by the Sudan Government, and in continuance of their scheme of operations, it was decided to build a bridge across the Atbara at Abu-Deleig enabling the railway to be extended from Kassala to Gedaref and Sennar, and eventually linking up with the railway to El Obeid and the West.
Abu-Deleig is situated about 250 miles east of Khartoum, 40 miles from Kassala, and at this point the River Atbara, though unsuited for water transport, has a width of 1050 ft. which is rather more than the width of the Thames at Waterloo Bridge. On October 20th, 1926 a contract was signed between the Sudan Government and Messrs. Dorman Long for the supply and erection of a steel railway bridge on this site.
This bridge, for which Messrs. Coode, Wilson, Mitchell and Vaughan-Lee were the engineers, consists of seven spans, each 147 ft. between bearings, or 150 ft. between centres of piers, the through type of bridge being considered the most economical for the work required under existing conditions.
The bridge was designed to carry a single line of railway 3 ft. 6 ins. gauge on which the rolling load specified was 2 tons per foot, and for the calculations of loads on the cross girders, a Sudan Government Loco. was taken (axle loads 16 tons, total weight 126 tons). Impact was assumed at 50 per cent. and wind as 50 lbs. per sq. ft. with an additional 300 lbs. per lineal foot on the bottom chords of the main trusses, treated as live load for wind pressure on an advancing train.
The main trusses are 24 ft. 6 ins. deep and 17 ft. 0 ins. centre to centre, and have a complete lateral system in the planes of both chords consisting of double angles for the cross members and single angles for the diagonal members. Portal members and sway-frames are double angles. The cross girders are built into the trusses and are of single web construction, 42 ins. deep, while the stringers are built into the cross girders and are 33 ins. deep. The decking is made up of steel plates and cleats and the rails are clamped immediately above the stringers without any timber ties. All bearings are of the rocker type, one fixed and one sliding to each span.
Caissons for each pier and abutment were sunk under compressed air to a foundation in basalt, and on each caisson was built a steel casing, the whole being filled with concrete to form the pier. Round each pier at ground level heavy aprons of hand-packed rubble were built, about 15 feet wide on all sides.
The River Atbara being liable to sudden and violent floods during the rainy season, it was

THE ABU-DELEIG BRIDGE

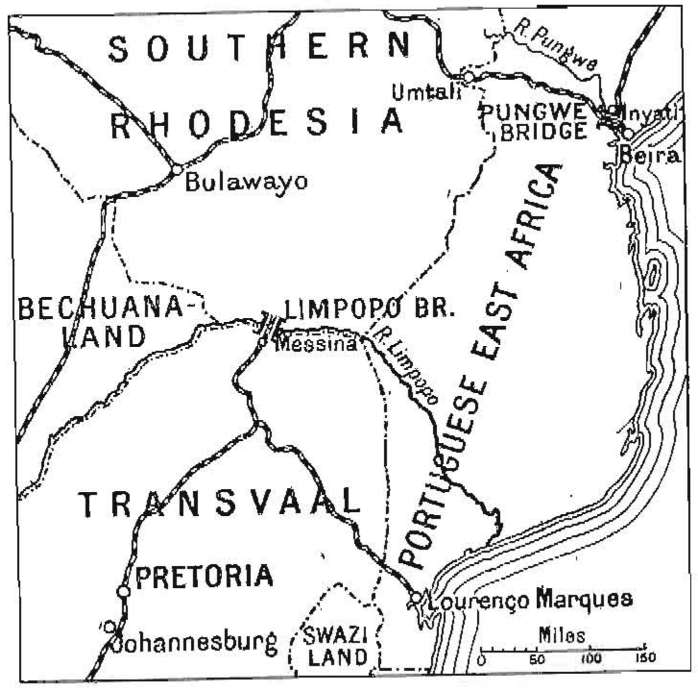
necessary to devise a scheme of erection calling for the minimum amount of temporary work in the river that might be swept away.

The first span having been built out on falsework, it was used as an anchorage for the second span to be cantilevered out, temporary supporting ties being provided between the top chords of the two spans. When the second span was in place, it was used for the erection of the third, and so on. By this means all falsework was dispensed with after the erection of the first span.

In order that there should be no interruption in the railway construction during the period occupied by the building of the bridge, a temporary steel deck bridge at a lower level, and situated downstream to the permanent bridge, was provided to carry the construction traffic. This temporary structure was supported on piles and trestles and being only serviceable during the low river season, was therefore dismantled before the flood was due in the early part of May.

The inclusive contract price was approximately £100,000 and the time permitted, 26 months from the date of the contract. This allowed for completion by December 15th, 1928, but in spite of certain difficulties encountered, the Contractors were able to announce the successful termination of their work on July 5th, 1928, five months ahead of contract time ; actual site operations having been commenced in November, 1926.

The total weight of steel used in this construction is approximately 1400 tons, all of which was manufactured by Messrs. Dorman Long and Company in their works at Middlesbrough.



RHODESIA

Two bridges have recently been completed by the Company which can be said to have safeguarded the export trade of one of the Empire's most progressive Colonies. With a population of less than a million on an area of 150,000 square miles, Southern Rhodesia is actively engaged in almost every branch of the mining and agricultural industries. Rhodesian tobacco, asbestos, copper and gold occupy important positions in the world's market, whilst the annual export of maize, the country's staple agricultural crop, averages one million bags. Of vital importance therefore to this great Colony is the safeguarding of communications with her natural trade outlet, the port of Beira, whose export tonnage has now increased to approximately one million tons per annum, placing her third in the ports of South Africa. The Pungwe Protection Works have made this line of communication safe from interruptions caused by abnormal rains, and the main route from Northern Transvaal across the Limpopo River has also been improved by the erection of a rail and road bridge which will enable the railway to be extended from Messina, the present railhead, across the border to join with the existing line from Bulawayo to West Nicholson.

These two works may therefore be said to have ensured the future of Southern Rhodesia as far as her exports are concerned, and the Company are justly proud of their contribution to the development of so progressive a Colony.

THE PUNGWE BRIDGE AND VIADUCTS

Numerous interesting works have recently been undertaken on the Beira and Mashonaland Railway in order to guard against a repetition of the extensive flood damage which has been sustained periodically ever since the line was inaugurated. Running from Beira, in Portuguese East Africa, into Rhodesia, the Beira and Mashonaland Railway handles practically the whole of the import and export trade of Portuguese East Africa, Northern and Southern Rhodesia, and the Congo—a vast hinterland, the trade of which is increasing at an unprecedented rate. The line crosses the Pungwe River, some 36 miles from Beira, and the Pungwe Flats, a treacherous expanse of swampy ground extending on both sides of the river for approximately 14 miles. For a considerable time the railway undertaking suffered severe annual loss owing to washaways caused by the floods in this area. The devastating flood of 1926, which submerged about 12½ miles of the line, isolated Rhodesia from her natural outlet. As a result, the Pungwe protection works were taken in hand, a scheme which, at a cost of about £300,000, had as its object the raising of the permanent way above maximum flood level across the whole breadth of the Pungwe Flats.

The plans, which were drawn up by Mr Ralph Freeman, of Sir Douglas Fox & Partners, included the provision of a new bridge across the Pungwe River, giving a clearance above the estimated highest future flood level of 3 ft. to the underside of girders; a series of eight viaducts of varying lengths, providing sufficient openings in the embankment to allow for the escape of flood water; and the raising of the track throughout the whole length of the Pungwe Flats.

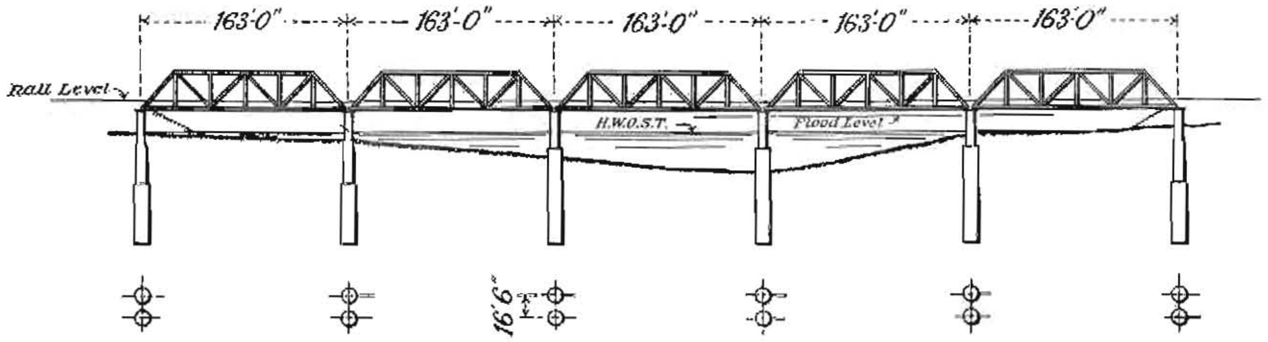


FIG. 1. GENERAL ELEVATION OF BRIDGE

The building of the bridge and eight viaducts was entrusted to Dorman Long and Company, who started work about the end of May, 1927, and completed the contract by the end of 1928. The new bridge across the Pungwe consists of five fixed spans, each being 160 ft. between centres of bearings and 163 ft. between centres of piers. The girders are of the "through" type, with Warren trusses, and are 26 ft. 8 in. deep, and 16 ft. 6 in. between centres. The bridge carries a single line of 3 ft. 6 in. gauge railway track, rail level being 7 ft. 3 in. above the underside of the bearings. The top chords and end rakers consist of two 15 in. channels, plated on the top, whilst the bottom chord is of the double web type, made up of four angles and two plates, with lacing top and bottom. The diagonals and verticals, single web members 12 in. deep, are made up of four angles and a 7/16 in. plate. There are two railway stringers at 4 ft. 6 in. centres, these, and the cross-girders which occur at each panel point, being ordinary plate girders. The lateral bracing consists of single angle diagonals on the top and bottom booms, with single web end-portals and sway-frames on all the verticals.

SPAN No 2. UNDER ERECTION, SHOWING TEMPORARY TOP CHORD TIES

The foundations of the bridge consist of six piers, each comprising two cylinders. The lower 80 ft. of each pier consists of ⅜ in. steel shell, with a diameter of 11 ft. and a 2 ft. lining of concrete, whilst the top 20 ft. is a 6 ft. diameter cast-iron cylinder filled with concrete. All cylinders were sunk to the same level, to a bed of hard sand, and were sealed with concrete plugs, 10 ft. deep. The river cylinders were lowered to the river bed from timber staging by means of hydraulic jacks and guided off the piling. The first cylinder

ONE OF THE EIGHT PUNGWE VIADUCTS

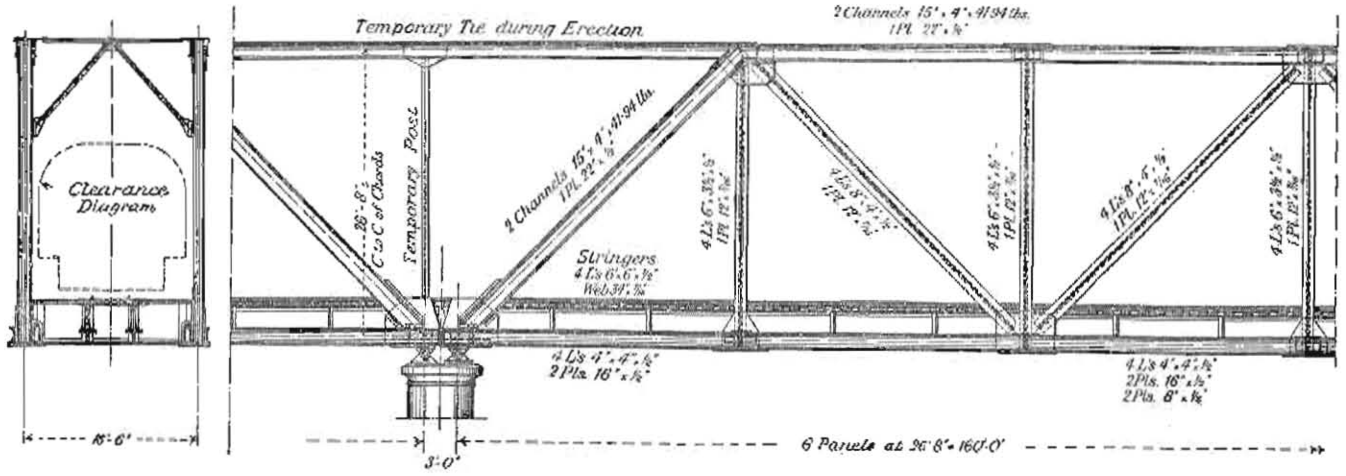


FIG. 2. ELEVATION AND SECTION OF A TYPICAL SPAN

section was pitched on September 1, 1927, and the piers were finally completed by the end of November, 1928, although owing to the risk of flood during the first wet season, no work was started on the river piers until March 1928, and arrangements were made to remove all plant from the site at the first signs of approaching danger. Except for this delay, work was able to proceed without interference, and was completed just before the big floods at the commencement of 1929.

The erection of the steelwork was commenced in July and finished at the end of December, 1928. The three river spans were erected by the same cantilever methods as had previously been employed by the company in the building of the Dessouk Bridge, with a slight variation in that the erection crane travelled along the deck of the bridge instead of along the top boom as at Dessouk. The two shore spans were erected on falsework, the bottom booms and deck being placed by a 3-ton locomotive crane running alongside the span. A 5-ton hand derrick was assembled on the deck to complete the erection of the trusses and overhead bracing, and this crane subsequently went ahead to erect the river spans. The shore span on the south bank was completed first, after which the falsework and 3-ton locomotive crane were transferred to the north bank for the erection of the other shore span. Material for these spans was handled in the yard by a 5-ton locomotive crane, after which it was carried by truck to the jetty and then transferred by a floating 5-ton hand-derrick to a small pontoon which was subsequently towed to a position underneath the erection crane.

There are eight viaducts in all, with a total length of $1\frac{1}{2}$ miles, the individual lengths varying from 425 ft. to 1,700 ft. As may be seen from the illustration on page 47, each viaduct consists of two 24 in. by $7\frac{1}{2}$ in. rolled steel joists supported on reinforced concrete trestles at 18 ft. 6 in. centres which are founded on concrete piles. The piles, of which there are over 1,400, were driven on the Vibro cast-in-situ system under license from the British Steel Piling Co., Ltd., the patentees of the system. They vary in length from 35 ft. to 50 ft., according to the nature of the ground and the set obtained.

The last viaduct was completed on November 26th, 1928, so that the whole mile and a half was constructed in a little over eleven months. The weight of the steelwork contained in these viaducts is approximately 780 tons, while in the bridge about 620 tons of steel were used, making a total of 1,400 tons.

The whole of the work, including erection and civil engineering, was carried out by the Bridge Department of Dorman Long & Co. Ltd., Mr. W. Story Wilson, B.Sc., being the Contractor's agent on the site.

THE LIMPOPO BRIDGE

Towards the end of 1927, the Beit Railway Trust decided to build a rail and road bridge across the Limpopo for the purpose of extending the railway from Messina in Northern Transvaal over the frontier into Southern Rhodesia, thus providing direct communication between these two important states.

Messina, some nine miles distant from the bridge site, is a town of considerable interest, as its inhabitants work the richest copper mine in the country and it is also the centre of one of the world's finest sporting districts ; leopard, lion, jackal, sable, guinea-fowl and partridge being a few of the species to be found. Sudden changes of temperature, however, render the climate conditions somewhat trying ; a rise or fall of 35 degrees F. in the day being not unusual, and the country is, of course, subject to the ordinary wet seasons and consequent flooding.

Like practically all South African rivers, the Limpopo, during the winter or dry season, is a tiny stream and on occasion is almost dry, but as soon as the rainy season commences, the river bed fills with amazing rapidity. The need for a bridge was therefore imperative, as all communications between the two states were suspended for three months in each year—a condition of affairs hardly conducive to commercial prosperity—and the work was consequently put in hand immediately.

The designs, which were prepared by Mr Ralph Freeman of Sir Douglas Fox & Partners, showed a deck bridge having 14 spans of 108 ft. each, carrying a single line of railway 3 ft. 6 ins. wide, and a roadway 16 ft wide. The live load specified for the roadway was a combination of uniform weight per square foot and a loading considered equivalent to a series of lorries, while the track was designed for the rolling loads specified in November, 1912 for 20-ton axle loads.

The main trusses are 18 ft deep between centres of chords and 20 ft. apart, and their construction can be followed from the accompanying diagrams and photographs. The top chords are of the double-web type, 21 ins. deep with a plate across the top 26 ins. wide,

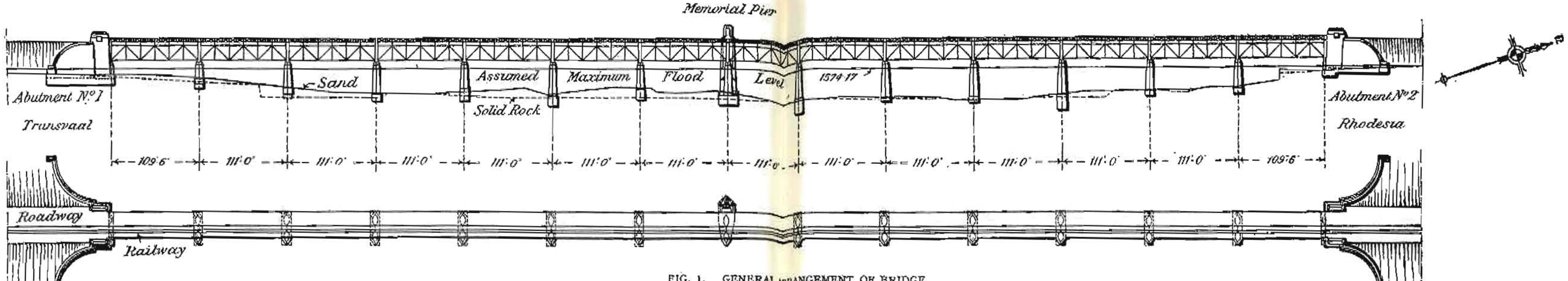


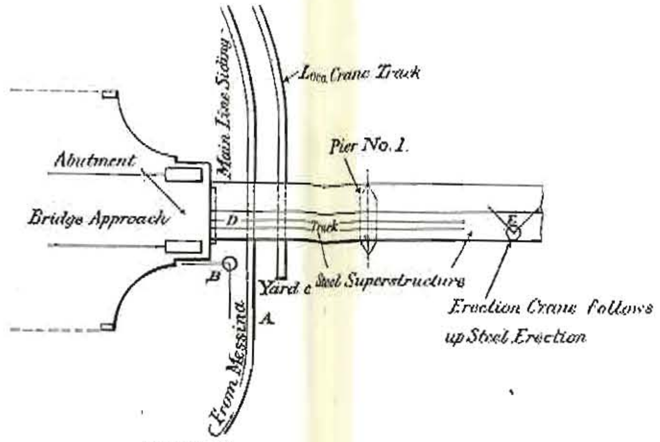
FIG. 1. GENERAL ARRANGEMENT OF BRIDGE.

while the undersides are laced with flat plates. The bottom chords are of the same type and depth as the top, but are open top and bottom, the half members being connected with batten plates. All web members are of the "H" or single web section, 14 ins. over angles, except the end diagonals which are of the double web type, 21 ins. deep, with angles turned inwards and the half members connected with batten plates. There is a complete system of lateral bracing in the plane of the

top chord, with cross frames at every panel point. Each diagonal member of these systems is a single angle, and the cross girders of the deck system act as the struts. These cross girders are of the single web type, 48 ins. deep, with a cantilevered bracket carrying part of the roadway. The railway stringers are also single web, 36 ins. deep, built into the cross girders, but the roadway stringers are 18 ins. joists on which the reinforced concrete deck is supported directly.

The bearings are all of the rocker type, there being one fixed and one sliding bearing per span.

With rapidity of construction as the main object, a scheme of erection was devised, calculated to complete the bridge within the contract time which expired on 31st August, 1929. The system used had been employed with considerable success by the Company in the erection of the bridge across the River Atbara at Abu-Deleig, where rapidity was also a necessary feature owing to the flooding of the river at certain seasons of the year. The first span was built out on a falsework and was then used as an anchorage from which the next span was cantilevered out. This span, when completed, acted as an anchorage for the next one, and so on for the total number of spans. This method gives complete freedom from falsework after the first span is erected, which is a considerable advantage in a district liable to heavy floods; as in the case of Abu-



GENERAL L.

Deleig, temporary ties were used between the top chords of the span under erection and those of the adjacent span.

The actual method of erection can best be followed by means of the accompanying diagram. All bridge material was delivered on site at the main line siding at A; it was then delivered by crane B either into the yard C or on to the bridge superstructure D. The erection derrick crane E, mounted on an undercarriage, travelled along the top of the main booms and was fed from D by a trolley moving along the completed permanent track on the bridge. Much time and trouble was saved by having a carefully arranged yard, equipped with a 5-ton locomotive crane, capable of assisting in unloading steelwork, assembling and delivering it to crane B.

The railway approaches to the bridge consist of long curved embankments terminated by two abutments of mass concrete having imposing pylons rising each side of the bridge to a height of about 12 ft. above road level. The piers have a majestic appearance, being of the cut-water type divided into two sections 12 ft. from the top, and their foundations in the river bed, where the scouring effects will be most severe, are at least two feet into the solid rock, whilst in some cases a suitably hard bottom was not struck until a depth of 27 ft. was reached. Due to fortunate climatic conditions and a judicious choice of a works programme, coffer dams for the sinking of

these foundations were rendered almost unnecessary.

Work on the excavations of the pier bases was commenced in May, 1928 and by the end of that year all excavation work was complete, the concrete had been poured in the foundations and the piers completed up to bearing level: no mean achievement in the face of considerable labour difficulties.

The seventh or central pier is of particularly interesting appearance, as it was designed to

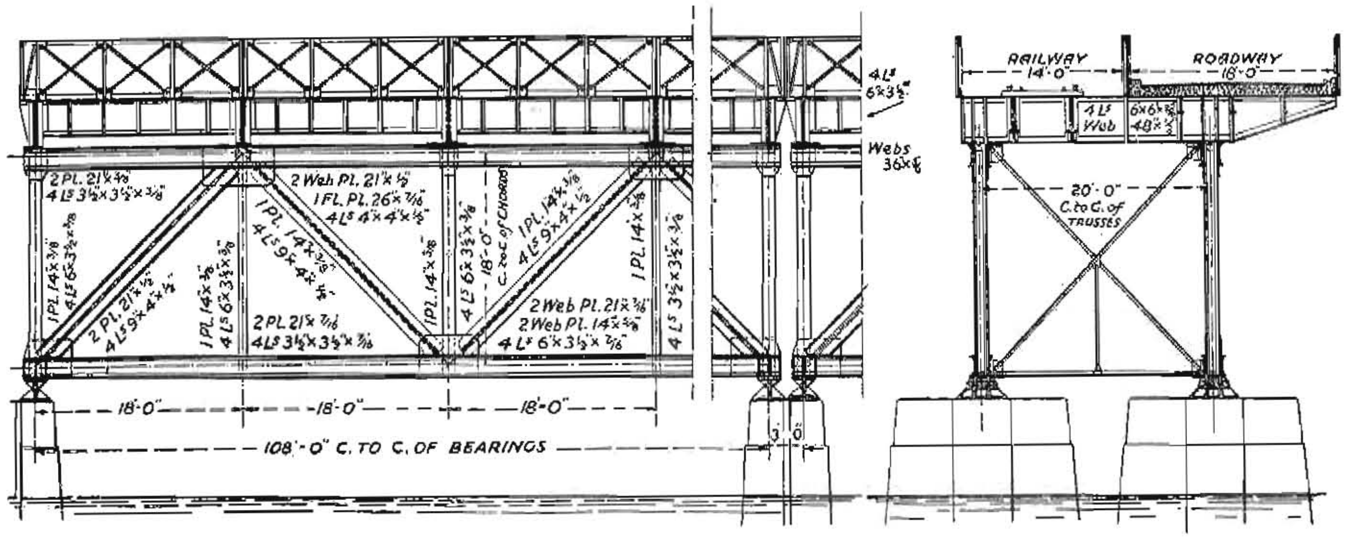


FIG. 8. ELEVATION AND SECTION OF A TYPICAL SPAN

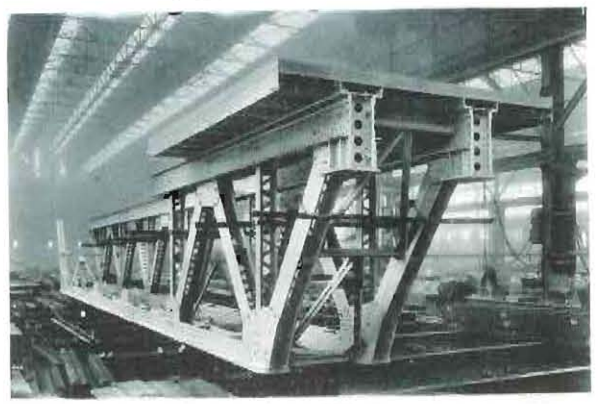
form a memorial to the late Mr Alfred Beit, and the upper 20 ft. section, which is above the level of the roadway, is constructed of the best quality Pietersburg granite inset with a bronze plaque.

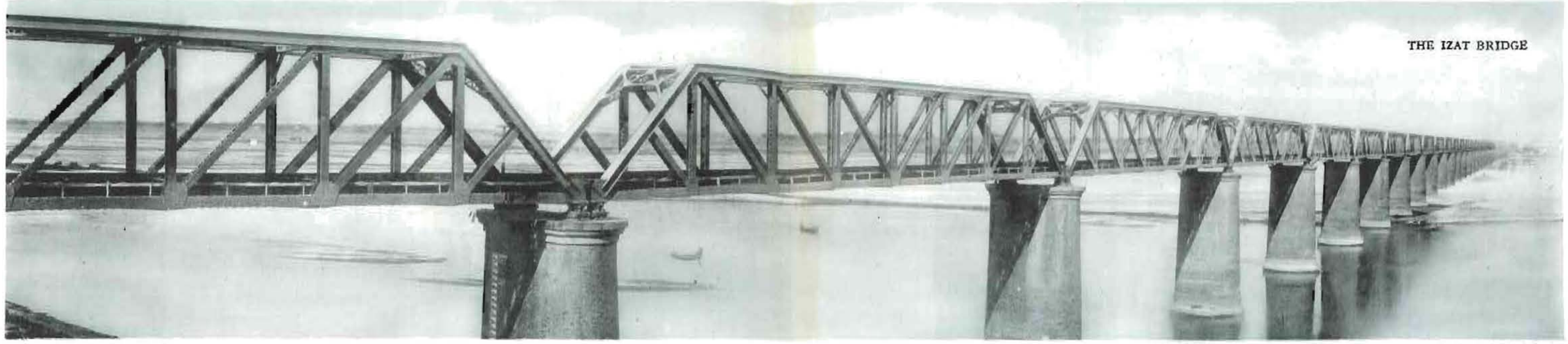
The bridge was officially opened on August 31st, 1929 by the Earl of Athlone, Governor General for the Union of South Africa, and was later presented to the Governments of the Union of South Africa and of Southern Rhodesia by Colonel E. T. Robins, D.S.O., of the British South Africa Company, representing Sir Drummond Chaplin, G.B.E., K.C.M.G., on behalf of the Beit Railway Trustees.

BRIDGE SPANS

The bridges dealt with in the foregoing pages were all built and erected completely by the Company, but there are a large number of bridges for which Dorman Long & Co. manufactured and fabricated the steel superstructure, which was subsequently shipped in sections and erected by local labour. This type of work has formed a large proportion of the Company's activities in India and Burma and spans of sizes ranging from 2 ft. to 150 ft. have been shipped to all the leading Railway Companies of India and Burma for erection by local engineers. The two examples illustrated overleaf cannot be taken as typical, since they are among the world's longest bridges, but they serve to show that with accurate workmanship no task is too big to be undertaken in this manner.

Through Messrs Rendel, Palmer and Tritton, Consulting Engineers, Dorman Long & Company have supplied steel bridge spans to the Bombay Baroda & Central India Railway, the Nizam's Guaranteed State Railway, the Bengal & North Western Railway, the Indian State Railways, the South Indian Railway, the Burma Railways and many others.





THE IZAT BRIDGE

The Izat Bridge, between Jhusi and Allahabad, at the confluence of the Rivers Jumna and Ganges, was built to the order of the Bengal and North Western Railway, and consists of forty spans, each 150 ft. 0 ins. clear.

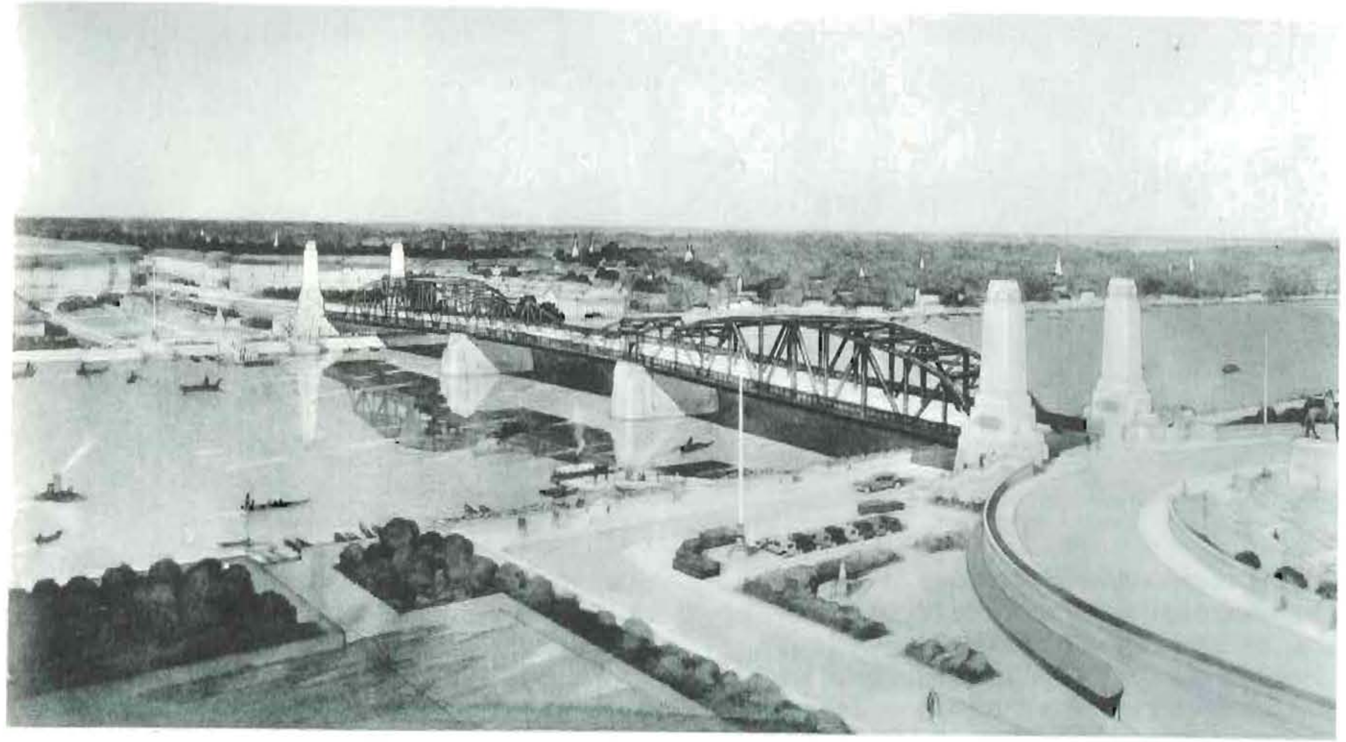
The girders for these spans, which were manufactured and fabricated by Messrs. Dorman Long and Co., Ltd., are of the single triangulation type, 156 ft. 0 ins. between centres of bearings. They have an effective depth of 19 ft. 6 ins., being spaced at 15 ft. 8 ins. between centres, and a single line of railway track of metre gauge is carried between the lower chords by stringers between the cross girders, the rails being laid on timber sleepers above the stringers. The ends of the spans are carried by the usual cast iron bearings, expansion at one end being allowed for by the provision of steel rollers placed between the cast iron knuckle and the bedplates. The lower chords are about 60 ft. 0 ins. above ordinary low water level. The weight of each span is 124 tons, and the total weight of steelwork supplied is therefore nearly 5000 tons.

The Engineers for this Bridge, were Messrs. Rendel and Robertson (now Messrs. Rendel, Palmer and Tritton). The bridge, which is named after Mr Alexander Izat, so long connected with the B. & N.W. Railway Company, was opened on 31st October, 1912, by Lord Meston, at that time Lieutenant Governor of the United Provinces.

THE UPPER SONE BRIDGE

This bridge crosses the River Sone at Dehri-on-Sone, about half-way between Moghalserai and Gya on the East Indian Railway. It is for a double line of railway, and consists of 93 openings, each 100 ft. clear, and there are two complete separate sets of girders supported on the same piers; one of these sets was manufactured and fabricated by Messrs. Dorman Long and Co., Ltd., in their works at Middlesbrough. This set is of the deck type, each complete span weighing approximately 95 tons, giving a total weight of nearly 9000 tons.

The trusses are of the sub-panelled Warren type, 6 ft. 6 ins. between centres, and 12 ft. 1⅛ ins. in effective depth. The top chords are of the double web type, plated on the top with a flange plate 2 ft. 0 ins. wide and laced on the underside, the depth being 1 ft. 10½ ins., while the bottom chord is of double web section, open at the top and plated on the underside, the depth being 1 ft. 3⅛ ins. The bottom chords are connected by horizontal diagonal bracing attached to the flanges, and there are four K-braced vertical cross frames to each span. The bearings are at 105 ft. 0 ins. centres, there being one fixed and one sliding bearing to each span. The deck is composed of steel troughing, and has a total width of 15 ft. The Engineers for this bridge, which was opened for traffic during the cold weather season of 1924-25, were Messrs. Rendel, Palmer and Tritton.



THE BANGKOK MEMORIAL ROAD BRIDGE

The contract for the supply and erection of this bridge was recently secured by Dorman Long & Company in keen competition with the leading bridge builders of other countries. It is to be built across the River Chow Phya in the middle of Bangkok to connect the two halves of that city which have a combined population of approximately three-quarters of a million, and its special object is to commemorate the 150th anniversary of the foundation of the city. H.M. the King of Siam, recognizing the unique occasion, personally presented the land on the Bangkok side, as the site selected was situated on his private property. His Majesty also desired to pay half the cost of the project from his privy purse.

The contract, which was let for a sum of £262,288, consists of the supply and erection of a road bridge approximately 230 metres in length, with a central opening span of the bascule type, giving a clear passage of 60 metres. The roadway is 10 metres wide between kerbs and the bridge also carries two footways each 2.5 metres in width. The approaches from both sides pass through ornamental gardens, and vertical embankments with pontoon landing stages are also provided at either side of the river.

The Consulting Engineers are Messrs. Sandberg, Consulting Engineers to the Royal State Railways of Siam.

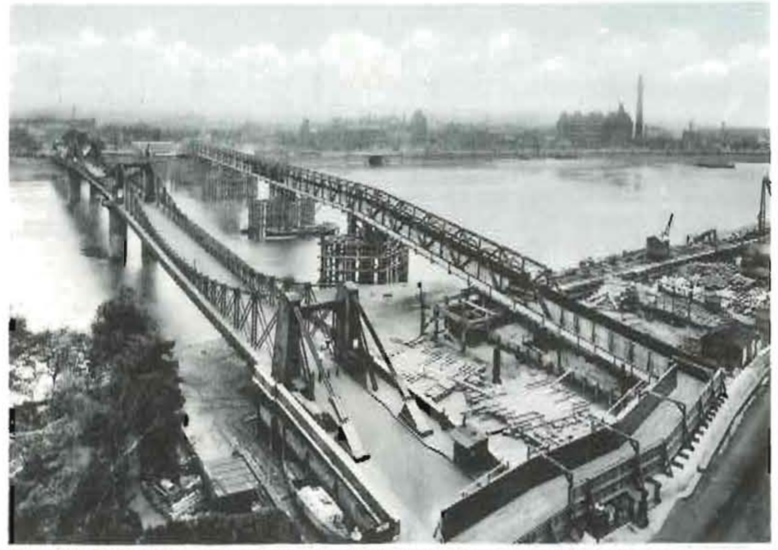


PHOTO TAKEN JUNE 3rd, 1929, SHOWING THE OLD BRIDGE AND TEMPORARY STEEL BRIDGE

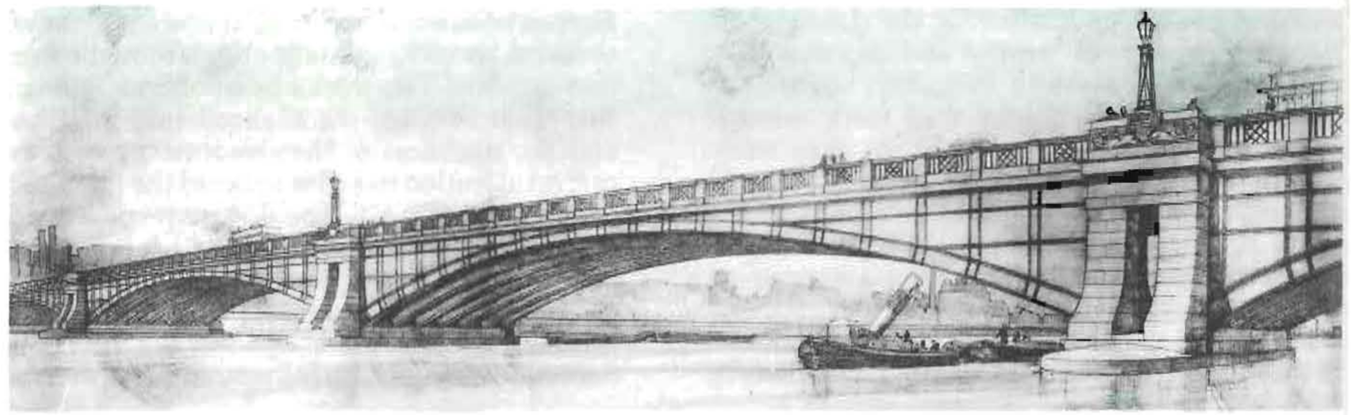
THE LAMBETH BRIDGE

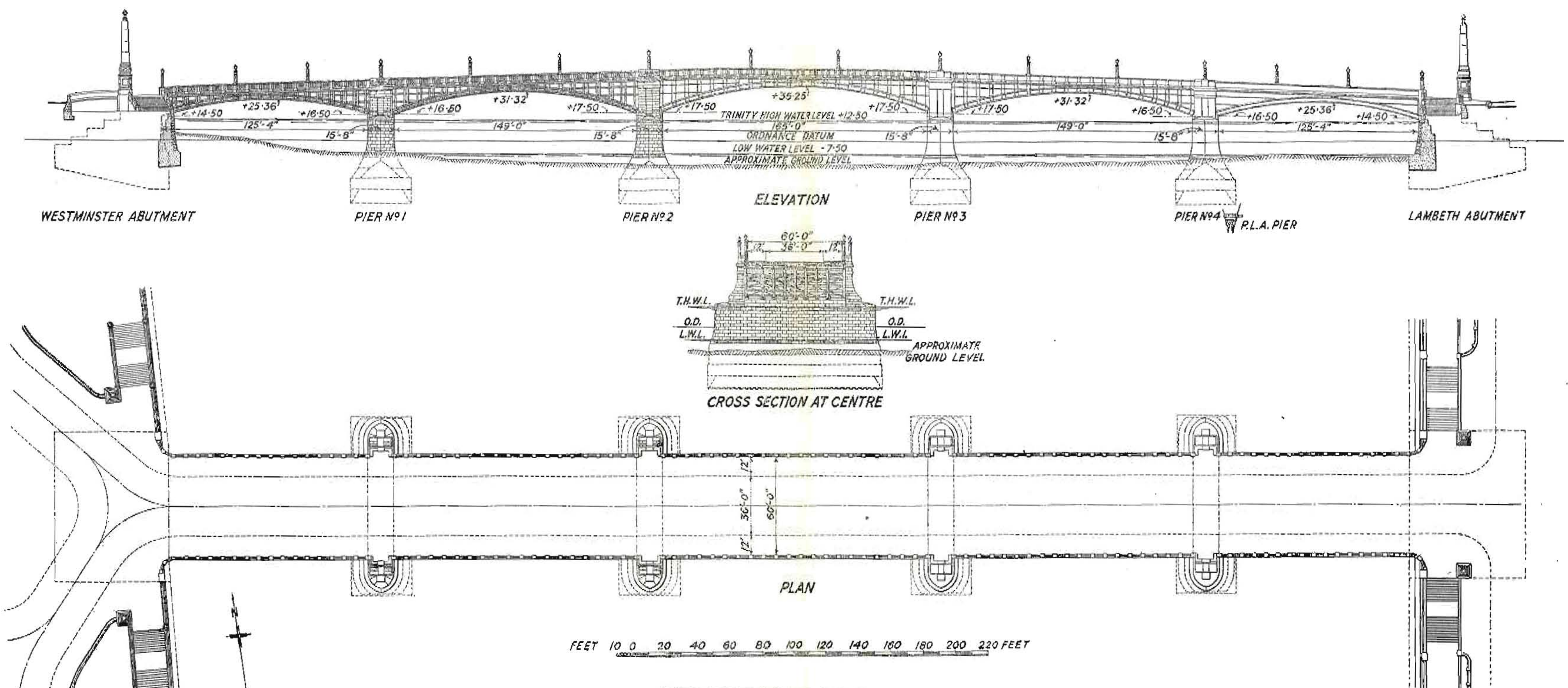
Very few of London's old familiar landmarks have managed to survive the march of progress and, in making a step towards the solution of the city's traffic problems, it was recently decided to demolish the old suspension bridge at Lambeth which had stood for 65 years.

Designed by the famous bridge-engineer, Mr P. W. Barlow, this bridge was erected under his supervision during the years 1862–3 at a cost of approximately £30,000 including the approaches, and was at that time the largest bridge in the country having wire ropes as main members. There were three spans of 280 ft. each between centres of piers, and the suspension cables formed three complete catenary curves, being anchored in the Middlesex and Surrey shores. This bridge differed from most suspension bridges in that the cables were fixed to the tops of the piers, which consequently had, under certain conditions of loading, to withstand heavy bending stress. As long ago as 1910, Lambeth Bridge was closed to road traffic and has since been used only for pedestrians, so that the new bridge will open up a fresh exit for London's traffic, and mark another step towards the solution of the problems confronting the London County Council.

The design for the new bridge was prepared for the London County Council by their Chief Engineer, Sir George Humphreys, K.B.E., under whose supervision the work is being carried out, whilst all the elevations, the approaches from the embankment and the obelisks at the entrances to the Bridge have been designed by Sir Reginald Blomfield, R.A.

PERSPECTIVE DRAWING OF THE NEW BRIDGE





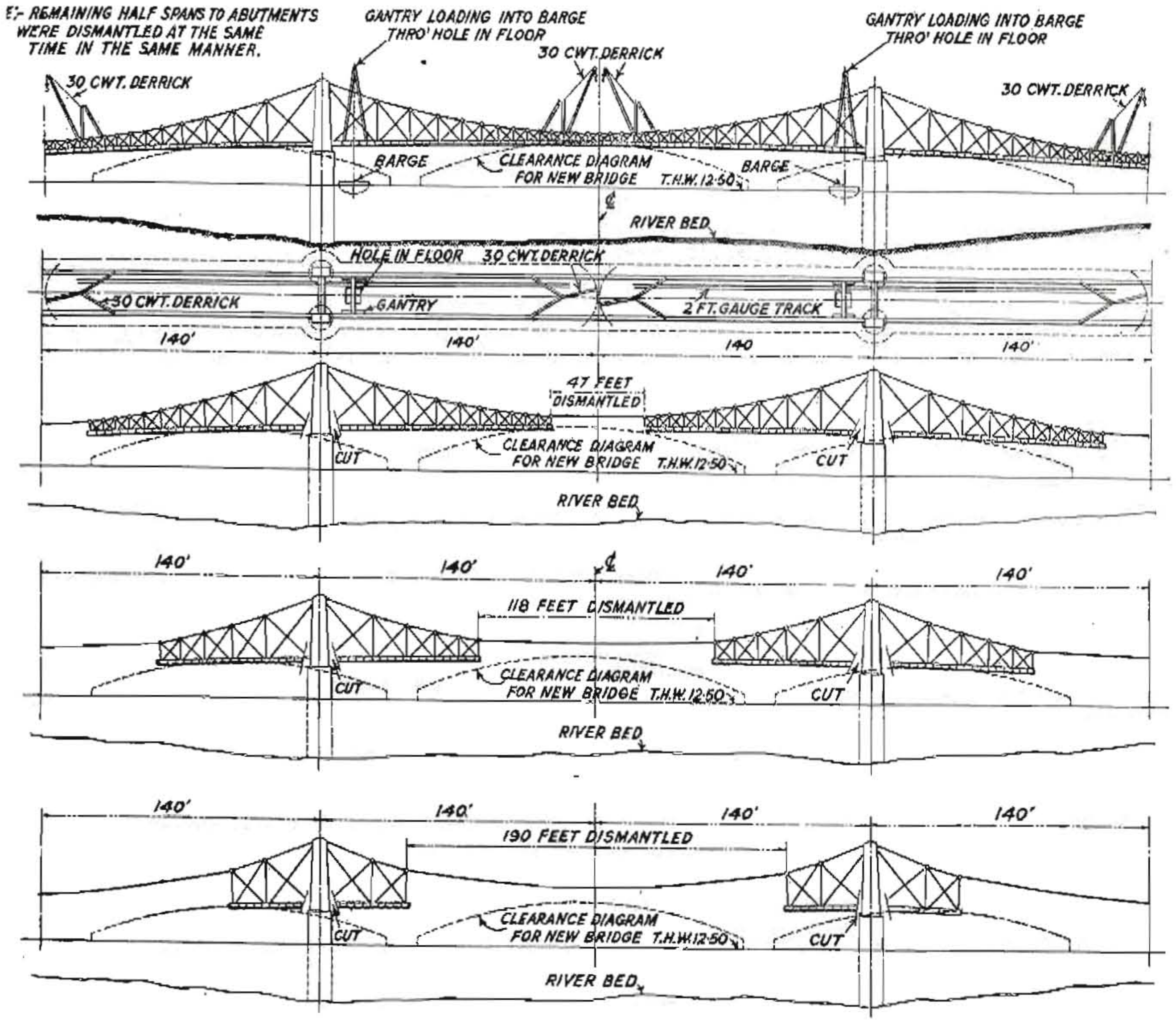
GENERAL ELEVATION AND PLAN OF BRIDGE

n collaboration with Mr G. Topham Forrest, F.R.I.B.A., Chief Architect to the L.C.C. The contract for the supply and erection of :his bridge was secured in February, 1929, by Dorman Long & Company and work commenced within a few days, Mr F. W. Stephen being the Company's agent on the site. It is estimated that work on this contract will occupy three years, including, as it does, the erection and subsequent removal of a temporary footbridge as well as the demolition of the old bridge and the construction of the new one. It is also required by the L.C.C. that the whole of this work should be carried out without interference with the river traffic a problem that will demand considerable attention from the erection experts. The work of demolition of the old suspension bridge commenced in June, 1929, and the weakness of the structure necessitated careful attention in order to avoid the possibility of a total collapse. The first step consisted in the reinforcing of the towers which were composed of angle-iron and thin iron plating, in order that they should be capable of supporting the extra loads imposed by the work of demolition. This was successfully carried out, and dismantling operations were commenced simultaneously in the centre of each of the three spans, in order that the towers should not be subjected to bending stresses due to unequal loading on the cables each side. As the material was removed from the bridge it was loaded into barges and eventually the towers were left carrying only the actual weight of the cables themselves. A cat-head was then erected over each tower and the cables were lifted one at a time and lowered across three barges that lay directly underneath, where each cable was cut at the middle by an oxy-acetylene flame and drawn in to the shore each side clear of the navigation channel. Pieces of these cables were sent to the Company's works for test, and it is interesting to note that after nearly seventy years' service, their breaking stress was shown to be 27 tons per square inch.

Demolition of the tower superstructures was proceeded with by 3-ton hand cranes erected on piled stagings built round each pier, and the removal of the four cylindrical piers was then commenced. Each of these piers was composed of cast iron segments 12 ft. in diameter with a three ft. thick internal brick lining, the

OLD LAMBETH BRIDGE

AFTER THE DEMOLITION OF THE OLD BRIDGE
JANUARY 4th, 1930



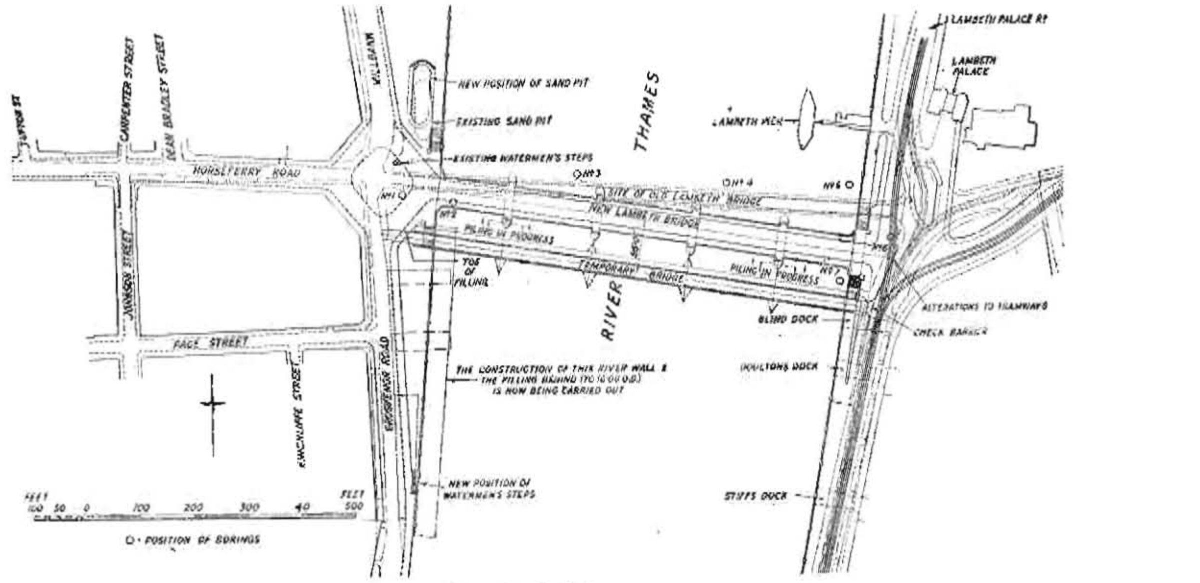
whole of which was removed except a small portion at the bottom of the cylinder which was left to form a collar for jacking purposes. The cast-iron segments were dismantled to a level slightly above high water level and the remainder of each pier was lifted up bodily by means of two 200-ton jacks, one of which operated from the staging by a system of links and the other from the original concrete foundation base, acting against girders placed across the underside of the collar of brick lining. The latter jack was used to overcome the starting friction only, and was lashed to the girders it acted against, so that it was withdrawn by the upper jack as an integral part of the pier. As each section of the cast iron cylinders was raised above water level, the segments were unbolted and removed.

By the use of the oxy-acetylene blow-pipe the work of demolition was carried out with great speed and the foundation work for the new bridge was commenced in November, 1929.

The new bridge will consist of 5 spans, the centre one 165 ft. long, each intermediate span 149 ft. long, and each approach span 125 ft. 4 ins. long. A 36 ft. wide roadway is provided and two 12 ft. wide footways, bringing the total width of the bridge to approximately 60 ft. The four supporting piers will be constructed on steel caissons fitted with concrete and sunk by means of compressed air to a solid foundation about 25 ft. below the river bed.

A considerable amount of work is anticipated in the construction of the approaches leading up to the bridge, particularly on the Westminster side, where the level of the roadway will have to be raised about 7 ft.

It is estimated that the total weight of steel in the bridge will be approximately 3,500 tons, all of which will be of entirely British manufacture at the Company's Middlesbrough Works, and the total value of the contract exceeds half a million pounds sterling.



GENERAL SITE PLAN

STEEL

STRENGTH

SECURITY

V. M. SCRIPSIT
MACBETH ET
JOHN BELLOWS
IMPRIMERUNT