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Typical methods of erecting four bridges across main rivers in the Netherlands

Méthodes caractéristiques de montage pour quatre ponts sur des rivières principales aux Pays-Bas

Besondere Montageverfahren für vier Brücken über grosse Flüsse in Holland

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(a) ROAD BRIDGE OVER THE RIVER LEK NEAR VIANEN

The river crossing at Vianen was first completed in 1936 as shown in fig. 1(*c*). To allow international and other traffic to pass during erection a passage of 60 m. was kept in the trestlework. To assemble the arch, with a span of 160 m., 28 m. above the flooring a movable tower-swing-crane with the underside of the arm 3 m. above the top of the arch was used.

The main span was destroyed in 1944; the spans at the south side of the river were only damaged. The traffic was kept going by a ferry and afterwards over a Bailey-bridge on barges. During ice-drift traffic was diverted over the railway bridge at Culembourg, 12 km. upstream. The increasing railway traffic made it necessary to remove the temporary wooden flooring on this bridge, and so the rebuilding of the original bridge at Vianen had to be completed in a very short time.

No girders or spans were available for building a trestlework with a suitable passage for navigation. The available time and the demands of navigation made it necessary to erect the main span in big units with floating cranes. These cranes, the Condor and the Heracles, shown in fig. 1(*a*), can lift 200 and 250 tons each.

The erection method is shown in fig. 1(*b*). Two auxiliary piers of steel sheet piling were driven in the river 60 m. apart. On these piers heavy reinforced-concrete blocks were made. The 30-m. high steel pillars were constructed of the floor-girders of the bridge.

At first four arch units, each with a weight of 180 tons, were placed with the above-mentioned floating cranes. The higher parts of the arch were built from both sides. For this assembly a floating crane had to be supplied with shear legs constructed of truss-jibs used on another work (fig. 1(*d*) and fig. 2).

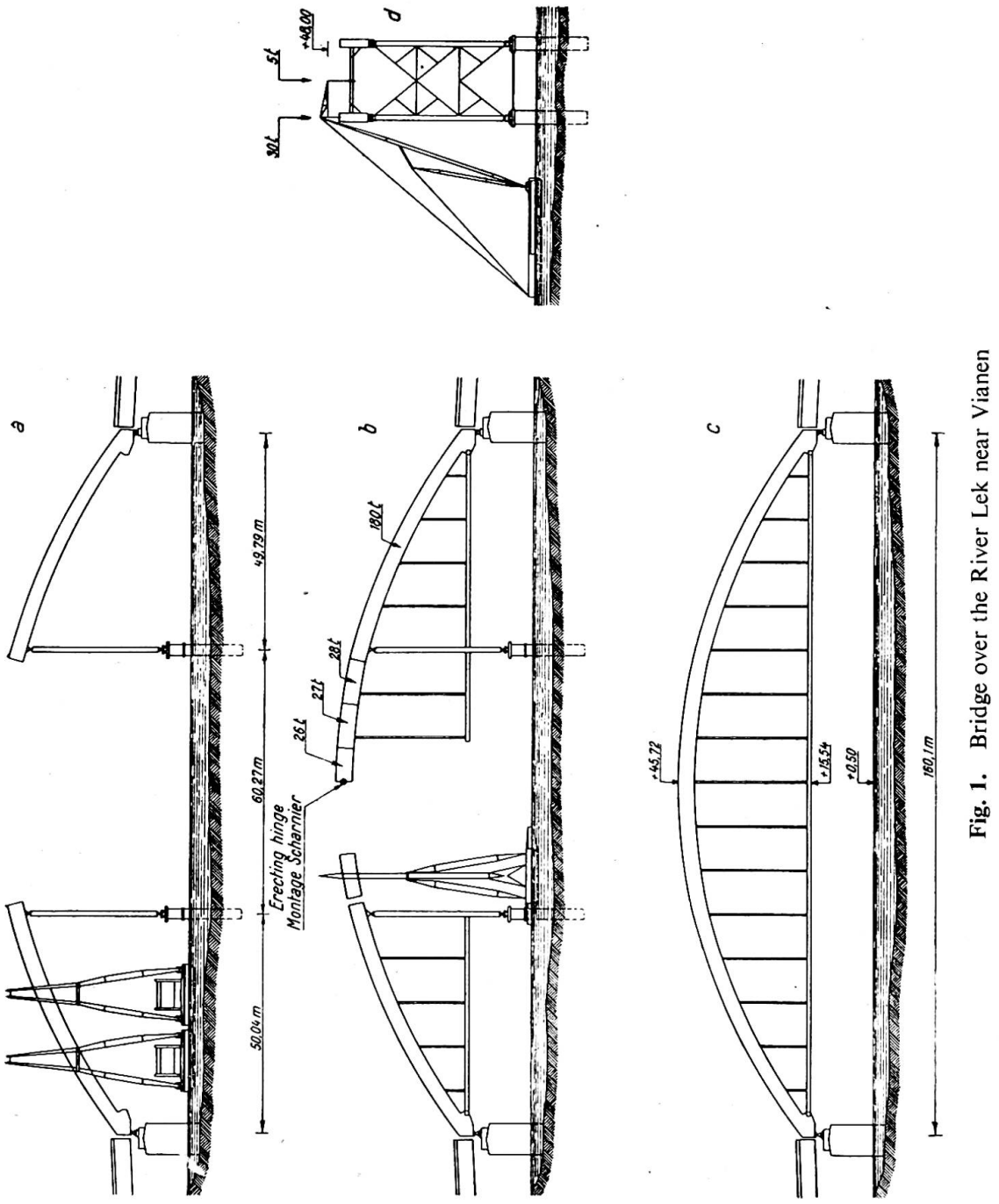

Fig. 1. Bridge over the River Lek near Vianen

In the top of the arch a temporary hinge was constructed, an opening of 300 mm. being left for this hinge; afterwards one of the bridge parts had to be rolled in to bring the two parts together. After completing the concrete flooring the two parts of each arch were joined by gusset plates thus putting the hinge out of action. Thus the main span is a three-hinged arch for the dead weight only. Special calculations were made to give the bowstring the right camber.

In September the first arch parts were placed. In the middle of November the pillars could be removed. In a short time the crossbeams and some of the floor-girders were erected; over this flooring a Bailey-bridge was laid 1·80 m. above the concrete flooring (fig. 3). Traffic could pass over the Bailey-bridge on the same day

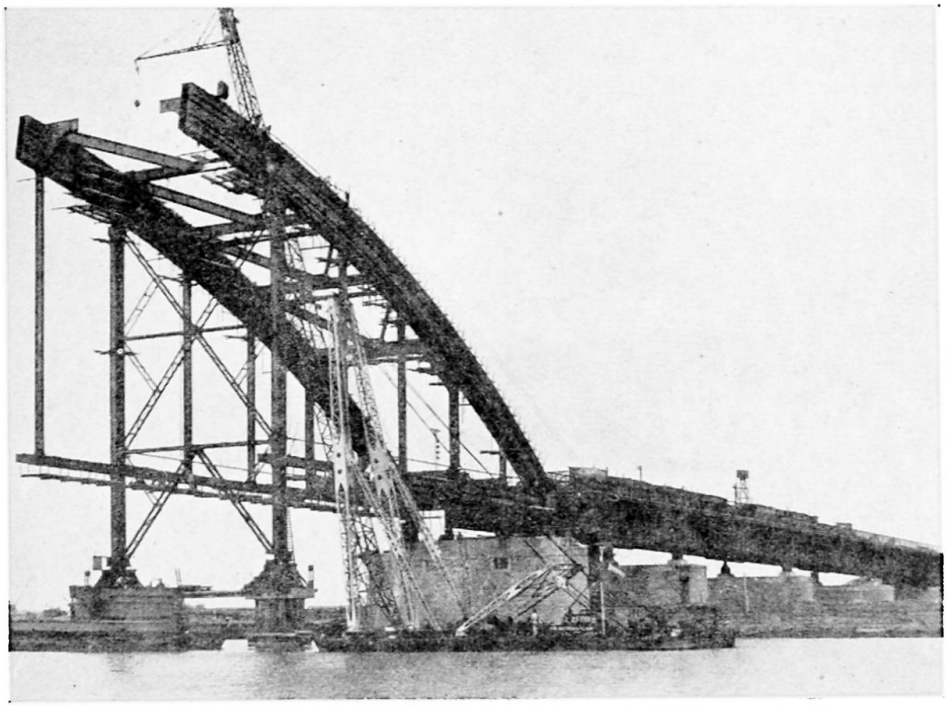

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Fig. 2. Vianen Bridge

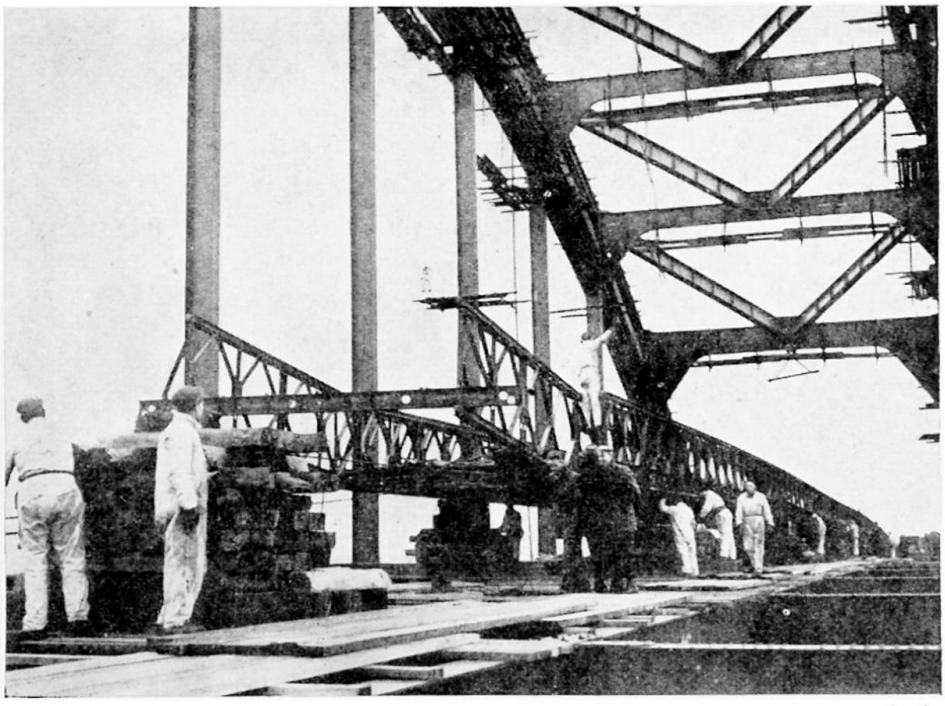

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Fig. 3. Vianen Bridge

as the floating bridge had to be removed, on 23 December 1948. The concrete floor had to be completed while traffic continued.

(b) ROAD BRIDGE OVER THE RIVER RHINE AT ARNHEM

The main span of the bridge at Arnhem has been designed as a bridge on four supports, with spans of 50 m. at either side of the middle span of 120 m., stiffened with an arch. The total weight of these three spans is 4,600 tons, including the concrete slab. This bridge was first destroyed in 1940, and a second time in 1944. The procedure of the erection of these arch bridges by using only a few temporary supports in the river was given in the Preliminary Publication of the Third Congress of the I.A.B.S.E.

The second reconstruction had some interesting features, as on the piers of the bridge two double-triple Bailey-bridges were laid. To reduce the span of the Bailey-bridges two auxiliary piers were placed in the river (figs. 4 and 5 (*a*)).

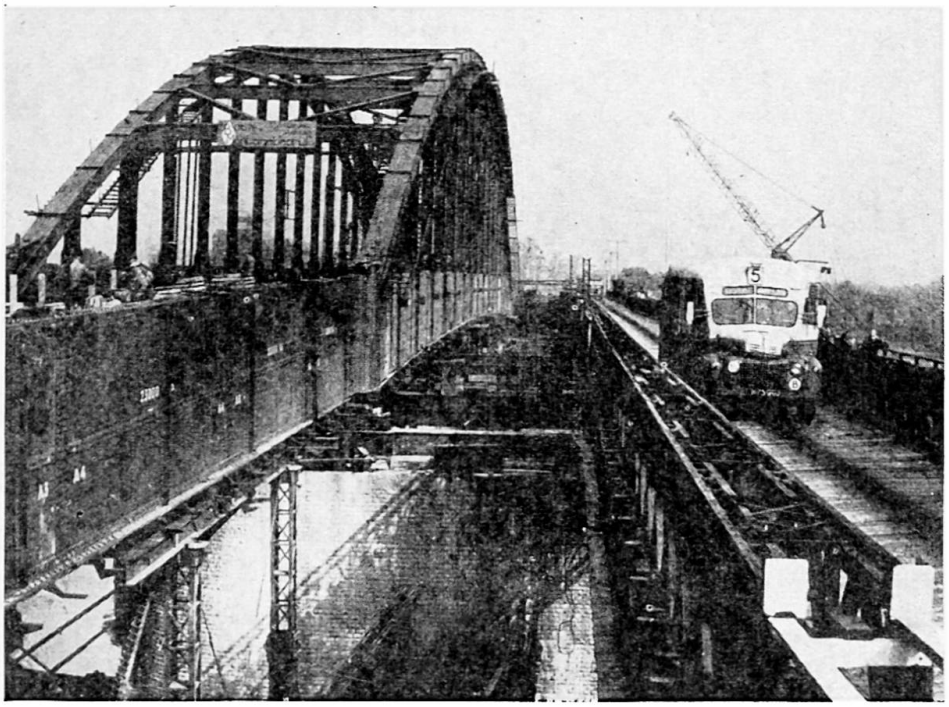

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Fig. 4. Arnhem Bridge

These piers were designed for the erection of the main girders of the permanent structure at either side of the Bailey-bridges. To fulfil this project the Bailey-bridges had to be lifted for 4·75 m. and the erection of the floor would have met considerable difficulties.

The contractor therefore proposed to build the new bridge downstream of the Bailey-bridge by enlarging the auxiliary piers and driving two piers of steel sheet piling at the downstream side of the river piers. Difficulties were met during pile driving, as parts of the destroyed steel structure were buried in the river bed at a depth of 3 m.

As the maximum weight was limited by the piling, the concrete slab could only be completed for one traffic lane (fig. 5(*b*) and (*d*)). The footway at the side of the

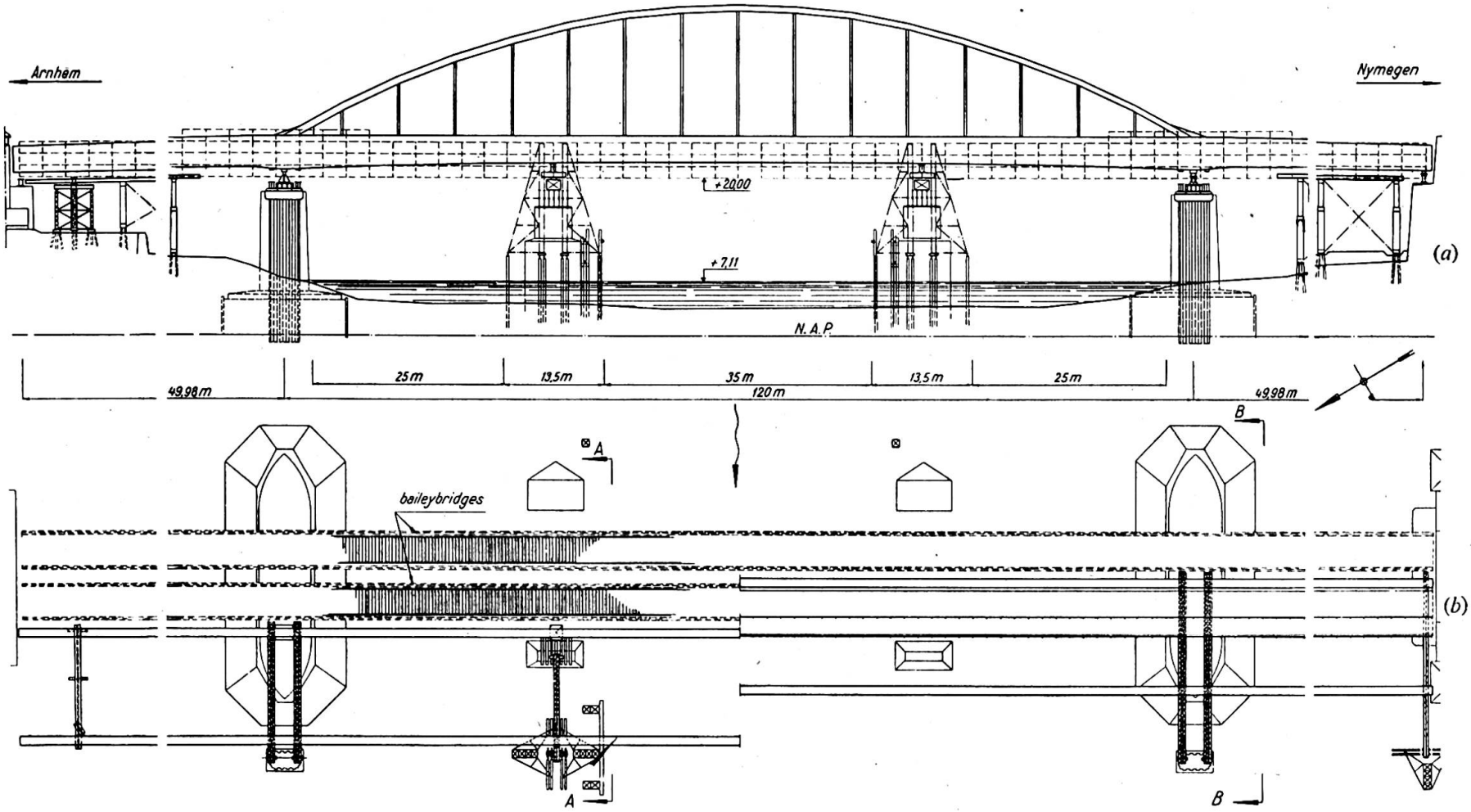


Fig. 5. Bridge over the River Rhine at Arnhem

Bailey-bridges was not yet built and the footway at the other side was partly completed and provided with a wooden floor as a temporary passage. At this stage the Bailey-bridge downstream was removed and the new bridge was pushed sideways by hydraulic jacks over a distance of 7·40 m. Traffic could now use one Bailey-bridge

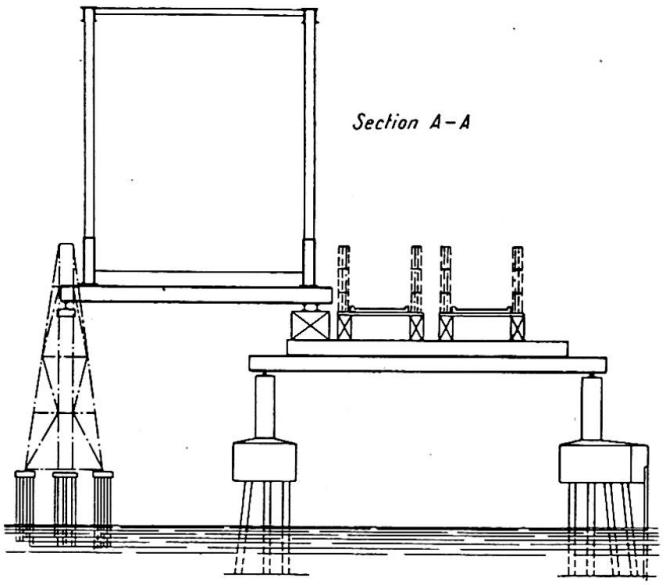


Fig. 5 (*c*).

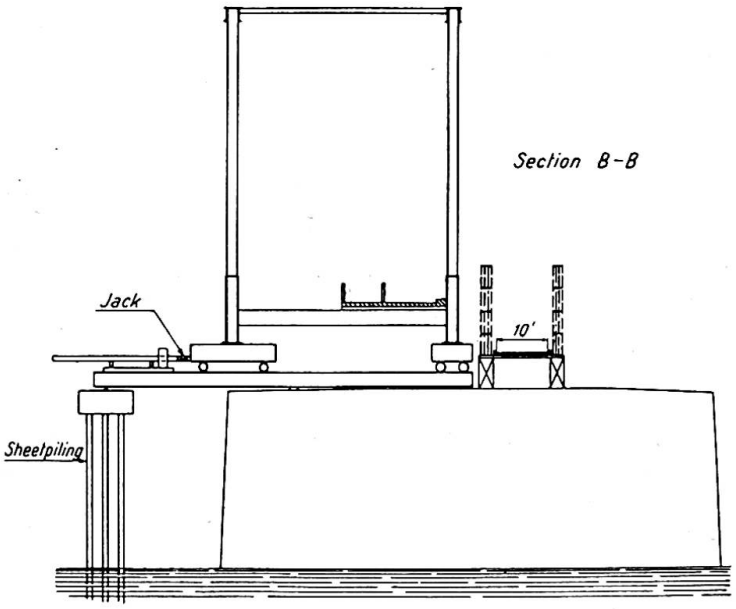


Fig. 5 (*d*)

and the concrete floor. The second Bailey-bridge was removed and the permanent construction pushed into the right place while traffic continued. The total distance of rolling was 14·80 m. The force needed to roll the bridge totalled 75 tons divided over four jacks. Finally the concrete floor and the footways were completed.

(c) RAILWAY BRIDGE OVER THE RIVER OUDE MAAS NEAR DORDRECHT ON THE ROTTERDAM–DORDRECHT SECTION

During the provisional repair in 1945–46 of the bridge over the River Oude Maas near Dordrecht, both the double-track truss-bridges that lay originally between the two swing-bridges were replaced by a single-track span, released from the temporary arrangements used during the construction of the new Waterloo Bridge in London, and a single-track Type D Callendar-Hamilton span with triple main girders. Both these spans were erected in the downstream track, that is, the track nearest to the road bridge.

In the final reconstruction in 1949–50 these auxiliary spans had to be replaced by a double-track span on three supports. This bridge was assembled on the upstream side and then rolled in. The temporary spans had to be rolled out at the same time.

As the traffic on this section is very dense and many international trains coming from Amsterdam or the Hook of Holland cross this bridge, the inevitable interruption of the traffic had to be restricted to a minimum. It was possible to execute the replacement in eleven hours, from Saturday evening, 5 August 1950, at 21.30 hours, until Sunday morning, 6 August, at 8.30 hours, by observing the following procedure:

(1) the erection programme had to be planned in such a way that it was possible to put the bottom castings of the bearings of the new bridge into position *before* it was rolled in, and

(2) the height by which the new bridge had to be jacked down upon its final supports after it had been rolled in had to be kept as small as possible.

In addition to the above, it was obligatory to avoid any obstructions in the navigation channel in the form of temporary supports. For the same reason also, the use of floating cranes had to be restricted to as short a duration as possible. Finally, no speed restrictions at all were allowed over the bridge.

The erection was executed in the following sequence:

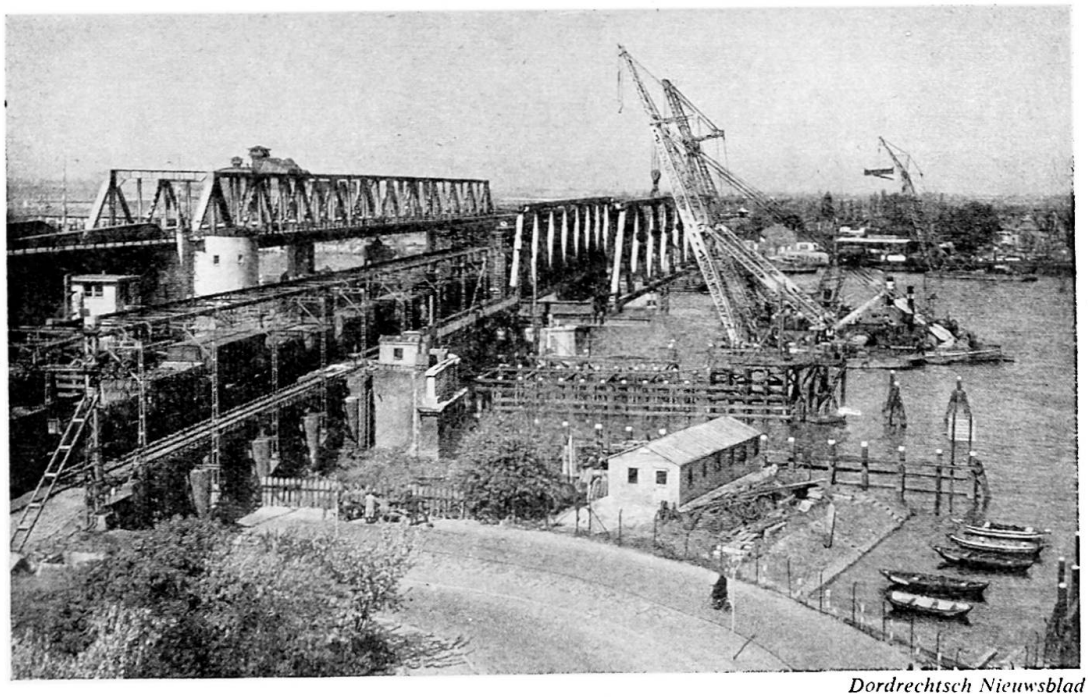
(1) The uppermost parts of the three piers were replaced by reinforced-concrete slabs, the top of which had to be kept at a lower level in order to get the necessary room for the bearings of the new bridge which are much deeper than the old ones.

(2) On the upstream as well as on the downstream side of each pier temporary steel trestles were erected on the existing foundations.

(3) As all the spans were to be rolled in or out, roller paths were constructed of wide-flange beams at the same level as the top of the bottom castings of the bearings. For the middle pier three such paths were constructed (one for the new span and two for the temporary ones) and one for each of the two other piers.

(4) Each of the main girders of the new span was erected in two parts by floating cranes (fig. 6). The first part of each main girder was placed on roller-frames that were already mounted on two of the roller paths, and the second part was connected at the points 1 and 2 with the first part by means of pins and then lowered by the floating cranes till its other end came to rest upon the third roller-frame (fig. 7). The four big parts of the main girders were riveted in the factory and the rivet holes of the connection-points 1 and 2 were reamed there also. By executing the erection in this manner it was possible to induce into the members of the main girders the same dead-load stresses as provided for in the calculations. The downstream main girder was fastened to the temporary spans and the upstream main girder was coupled to the downstream one.

(5) The cross-girders, the stringers and the bracings were erected with a crane moving on rails laid on the top chords of the new span.



Dordrechtsch Nieuwsblad

Fig. 6. Dordrecht Bridge

(6) In order to enable the rolling out of the temporary spans, the rails and the electric-traction conductors were disconnected, the spans were jacked up, their bearings were replaced by roller-frames and the spans lowered on to them.

(7) The rolling in of the new span (1,600 tons) and of both the temporary spans (600 tons each) was accomplished simultaneously by means of two 10-ton and two 5-ton hand-winches, all mounted on the floor of the new span near the middle pier. With each of the smaller winches one end of the new span was pulled sideways, with both the bigger winches pulling at the centre. The new span rested on six and

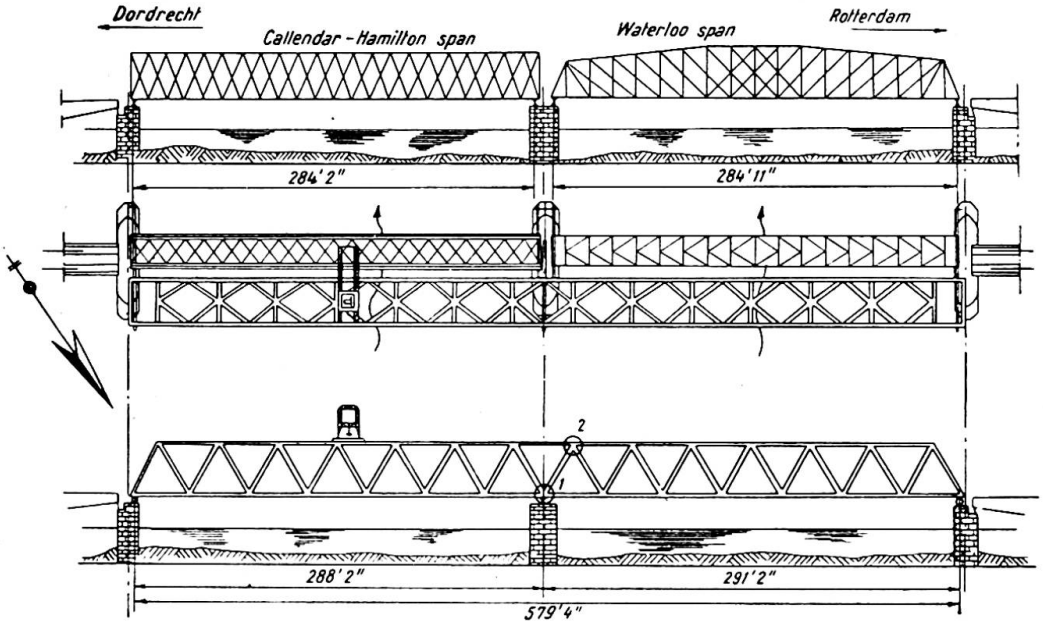


Fig. 7. Railway bridge over the Oude Maas near Dordrecht

each of the two temporary spans on four roller-frames. These two spans were pushed aside by the new span. In order to be able to control the movement, signal-lamps that could be worked from all the piers were mounted near the winches, and telephone connections were made between the piers and the post of command near the winches. In addition an arrangement was made by which a rod, suspended in the middle of the new span, moved out of its normal horizontal position as soon as one of the ends of the new span moved faster than the other.

(8) After the new span had been rolled into position it was jacked up, the roller frames were rolled out, the new bearings were mounted on the bottom castings and the span was lowered upon its bearings. In order to speed up the mounting of the heavy bearings they were rolled in sideways on small rollers. Then they were jacked up and lowered upon the bottom castings.

(9) Finally the tracks and the electric-traction conductors on the swing-bridges and the new span were connected. This took rather a long time, as the new span is situated between two swing-bridges, which necessitates rather complicated connections. The work described in (6) above was accomplished between 21.30 and 23.55 hours, that described in (7) between 23.55 and 3.00 hours, that described in (8) between 3.00 and 3.45 hours and that described in (9) between 3.45 and 8.30 hours. Provision was made for an adequate reserve of winches, jacks, lamps and electric generators.

After the new span was opened to traffic both the temporary spans had to be removed. This was impeded by their being situated in the rather narrow space between the road bridge and the new railway span, which made it impossible to use big floating cranes. The removal was accomplished in the following sequence:

(1) The floors and the bracings were taken away by the crane running on the top chords of the new span; the downstream main girders, which still rested upon the roller-frames, were rolled inwards and fastened to the upstream main girders. This made it possible to remove the downstream girders piecemeal by the crane.

(2) After the upstream triple girder of the Callendar-Hamilton span had been fastened on the new bridge, two of its three girders could be removed in the same manner, the remaining part always being strong enough to support its own weight. The last of the three girders had, of course, to be suspended on the new span before it could be removed piecemeal by the above-mentioned crane. Its weight was so small that this could be done without overstressing the new span.

(3) The upstream main girder of the Waterloo span, which could be considered as scrap, was securely fastened to the new span at a point situated at one-third of its span. A small floating crane having taken over a part of the dead load, this girder was flame-cut into two pieces, a small one, slung from the crane, and a big one, still suspended on the new span and resting on the pier. Then the middle of this big part was fastened to the new bridge, and this part was cut into two pieces that were removed one after the other by the small floating crane. By dismantling the last main girder in this manner there was no uncertainty about the extra stresses induced in the new span. These extra stresses could be permitted, provided that two heavy trains were not allowed to be on the bridge at the same time.

(d) Railway bridge over the River Waal near Zaltbommel on the Utrecht–'s-Hertogenbosch section

Before the war this bridge consisted of two rows of single-track spans resting on common piers and abutments. Looking from the south each row consisted of three 408-ft. curved-flange trusses over the river, and eight 196-ft. truss spans, with straight

top chords, over the land between river and dike. At the time of liberation all the spans, except one small span, and the north abutment were found to be destroyed.

In 1945–46 all the spans of the western row were permanently repaired, except the big one over the northern channel of the river. For want of steel, the southern part of this span was replaced by a Type D Callendar-Hamilton span with double main girders and its northern part by the only small span left intact, which was moved from its original position on the adjoining opening of the eastern row of bridges. This solution necessitated the construction of a temporary pier, which has still not been removed. The eight small spans of the western row were replaced by three spans, two on four supports, and one on three supports.

In order to complete the repair of the whole bridge, four big spans had to be built, one to replace the two small temporary spans in the western row of spans and three for the eastern row, in which the land between river and dike was bridged by one new span on three supports, five old spans that could be repaired, and the span that had been temporary used in the western row of bridges. Two of the big spans were erected in 1950 and two in 1951. To avoid interference with the navigation—the upstream river traffic uses the middle channel and the downstream traffic the southern one—all the spans were assembled over the northern channel (fig. 8).

The first span was assembled on a falsework under the future eastern track by means of a floating crane. After completion it was rolled sideways clear of the eastern row of spans; this was executed in the night of Saturday/Sunday 29/30 July 1950. On that Sunday the Callendar-Hamilton span was put on four coupled barges by two floating cranes, and the small span was first rolled eastward and

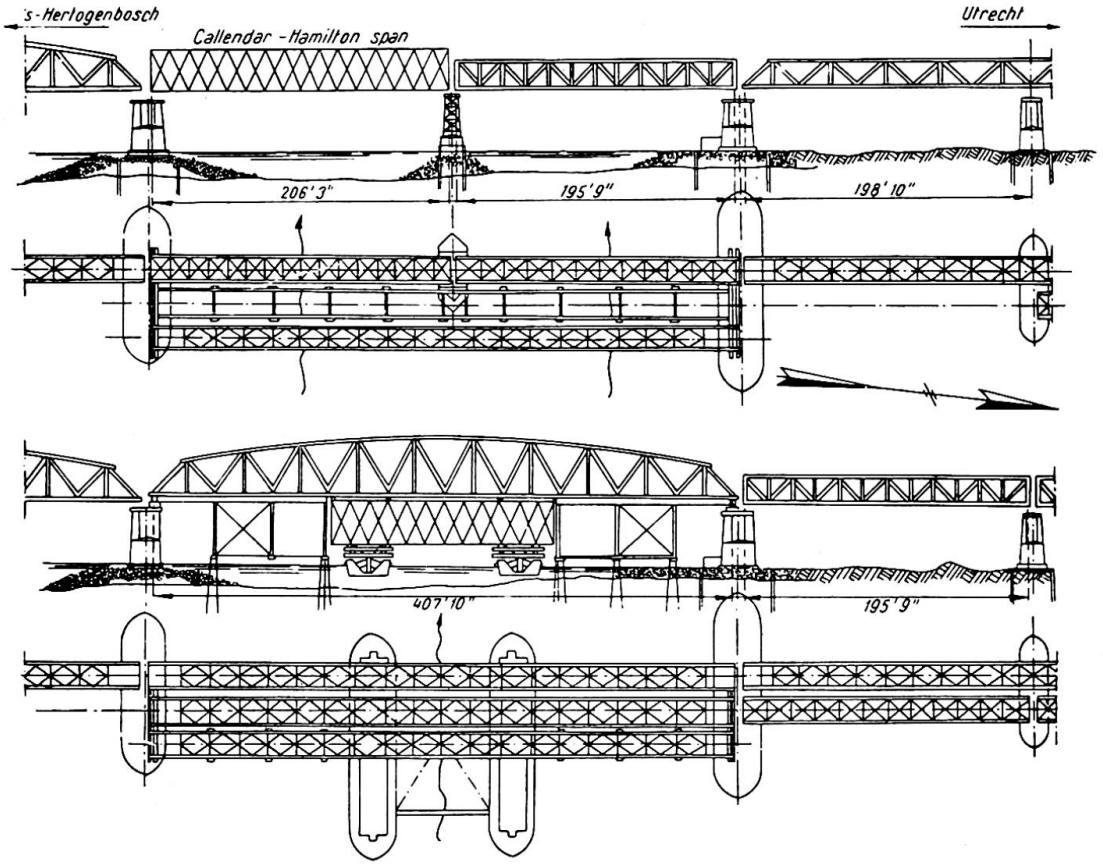


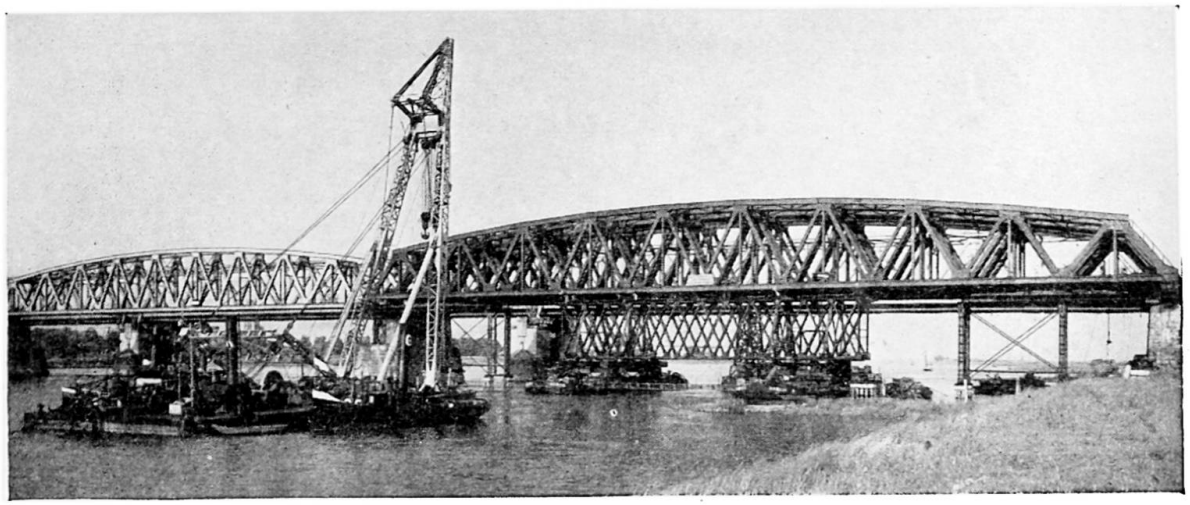
Fig. 8. Railway bridge over the River Waal near Zaltbommel

then northward into its original position in the eastern row of spans. To enable this, roller paths were constructed on the northern part of the falsework as well as on the land. On the roller-frames, moving on the last-mentioned paths, trestle supports were erected on which the span—for obvious reasons—was supported at its last-but-one bottom-chord connection points. Then, the same day, the big span was rolled westward into the western row of spans.

It was planned to lower the span on its bearings in the night from Sunday to Monday and to connect the rails and the electric-traction conductors in the early morning of Monday, 31 July, but this did not succeed, because of the following reasons: the wooden packing under the jacks was too soft for the rather heavy load and the large lift (3 ft. approximately); neither of the electric pumps worked satisfactorily; there were only hand-pumps in reserve, and their working was very slow and strenuous and beyond the capacity of the workmen present. Traffic could only be resumed on Tuesday morning, 1 August, at 7.30 hours.

After the assembly of the second big span on the same falsework, this falsework, which was not allowed to remain in the river during the winter, was removed in the beginning of December 1950.

In the early spring of 1951 new falsework was constructed eastward of the eastern row of spans (fig. 9). The central part of this falsework consisted of the shortened and



N. V. Werkspoor

Fig. 9. Zaltbommel Bridge

stiffened Callendar-Hamilton span, so as to provide room for the barges which were to carry the second and the third big spans. On completion of the assembly of the third big span, there were at this stage three big spans over the northern channel, only one of which—on the west—was in use. The second and the third span were floated on barges to the middle and the southern channel on 12 and 14 June 1951 by means of five tugs and a floating crane. This crane anchored in the river and pulled the barges loaded with the span very cautiously upstream with its steam winches and then weighed anchor, and the whole convoy was pulled by the tugs across the river. Then the crane dropped anchor again and allowed the barges to float very slowly downstream to their destination. To control the sway of the barges in the openings hand-winches were mounted on the piers.

Before the second span was floated out, it was rolled eastwards in the place vacated

by the third span. This was done because it was considered advantageous to repeat the manœuvre as exactly as possible and also because the temporary pier under the western span would have interfered with the movement.

Each of the barges, with a carrying capacity of 1,000 tons, had a watertight compartment of a volume of 500 m.^{3} The compartments were filled with water and the barges floated under the Callendar-Hamilton span. The supports on the Callendar-Hamilton span which carried the new span during assembly had been removed after jacking up the new span, which had left quite a large gap between the two spans.

The barges, after being positioned under the Callendar-Hamilton span, were raised by pumping 200 m.^{3} of water out of each water-filled compartment, thereby lifting the Callendar-Hamilton span free of its bearings, which were then removed. The watertanks were filled again.

Across the Callendar-Hamilton span eight wide-flange beams in four groups of two were laid, on which the big span came to rest through the medium of teak packings of different thicknesses, chosen so that none of the spans was overstressed when they were lifted together.

As the big span (1,160 tons) is heavier than 1,000 m.^{3} water, pumping out of all the water would not suffice to lift it. So it had to be jacked down under its bearings to get it free of its supports. For the same reason, after the spans had been floated to their new position they had to be jacked up to free the barges.

The reason why no bigger barges were used, which would have made unnecessary the lowering and the lifting of the spans, is that the steel supports through the medium of which the load was transmitted to the barges and by which the barges were stiffened were already available, and it would have been uneconomical to replace them.

Finally, after that the Callendar-Hamilton span was replaced as part of the falsework the fourth big span was assembled and rolled westward into the eastern row of spans. The completed bridge in the eastern track was tested on 16 October 1951 and opened to traffic on 22 October 1951.

The advantages of the method of erection chosen were that the navigation had to be interrupted only on 12 and 14 June 1951, and the trans-shipment equipment could do all its work with an interruption of only one day (13 June 1951).

Summary

The paper gives in detail a description of:

(*a*) the erection of the big arch span of the road bridge over the River Lek near Vianen;
(*b*) the replacement of the Bailey-bridge over the River Rhine at Arnhem by a stiffened arch;
(*c*) the replacement of two temporary single-track spans of the railway bridge over the River Oude Maas near Dordrecht by one double-track span on three supports; and
(*d*) the erection of four big spans of the railway bridge over the River Waal near Zaltbommel.

Résumé

Une description détaillée est donnée:

(*a*) du montage de l'arc avec tirant du pont route sur le Lek près de Vianen;
(*b*) du remplacement du pont Bailey sur le Bas-Rhin à Arnhem par un pont Langer;

(*c*) du remplacement de deux travées temporaires à voie unique du pont de chemin de fer sur l'Ancienne Meuse près de Dordrecht par une travée à double voie sur trois appuis; et
(*d*) du montage de quatre grandes travées du pont de chemin de fer sur le Wahal près de Zaltbommel.

Zusammenfassung

Eine ausführliche Beschreibung wird gegeben:

(*a*) der Aufstellung der grossen Bogenbrücke mit Zugband über die Lek bei Vianen in der Strasse Utrecht-Herzogenbusch;
(*b*) der Ersetzung der Bailey-brücke über den Rhein zu Arnhem durch eine Langersche Brücke;
(*c*) der Ersetzung zweier einzelspurigen behelfsmässigen Fachwerkbrücken der Eisenbahnbrücke über die "Oude Maas" bei Dordrecht durch eine doppelspurige Fachwerkbrücke auf drei Stützen; und
(*d*) der Aufstellung vierer grossen einzelspurigen Fachwerkbrücken der Eisenbahnbrücke über die Waal bei Zaltbommel.

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