

Discussion

Mr H. C. Adams observed that the Northam Bridge had been constructed on the most up-to-date principles, in spite of the fact that its design had been started 5 or 6 years previously.

The timber bridge built about 1800 had a width between parapets of 24 ft which was still sufficient for the wrought-iron bridge built in 1889, the cost of which was given as £9,000. The width of the present bridge was 65 ft between parapets and the total cost was sixty or seventy times that of the previous bridge. Those differences drew attention to the size of the problem that faced Britain today. In 1889 the vast majority of bridges had already been built and were still being used. The problem of their reconstruction, so far as engineering was concerned, was not very great; all the material and technical resources were available. The problem was entirely a financial one.

There might be members present who thought that they had just as pressing claims as Southampton had; he called attention to a statement made in the Paper: "From the date it [the wrought-iron bridge] was taken over by the Council, it was realized that the structure did not come up to modern standards." That was surely a masterpiece of understatement!

Mr Adams referred to the chemical consolidation around the base of the foundation forming a box to reduce the spread of the foundation bed, and to the method of sealing the cofferdams and keeping track of the water pressure below the base. The flexible columns inside the piers reminded one of Waterloo Bridge, for which the same consulting engineers had been responsible.

Referring to the feature of continuity over the whole of the bridge, Mr Cuerel had said, when introducing the Paper, that he was not sure if there was any appreciable economy in making the structure continuous. Mr Adams suggested that, even if there had been no special economy in that, so long as there had been no appreciable loss in using that feature there was a very big advantage in eliminating the expansion joints over the piers. It was in such joints, whether they were expansion joints or merely construction joints, that the flexing and the resultant opening and cracking and fretting away of the wearing surface allowed infiltration of water with the consequential troubles that involved. It was a problem that arose in many bridges, and it was a very difficult one to deal with. The advantage of eliminating that problem at the beginning was very important.

By arranging the flexible piers monolithic with the superstructure the consulting engineers had managed to do away with any form of rollers or small rockers, which often caused trouble. There were no rockers even at the end of the bridge, where there was a single expansion joint.

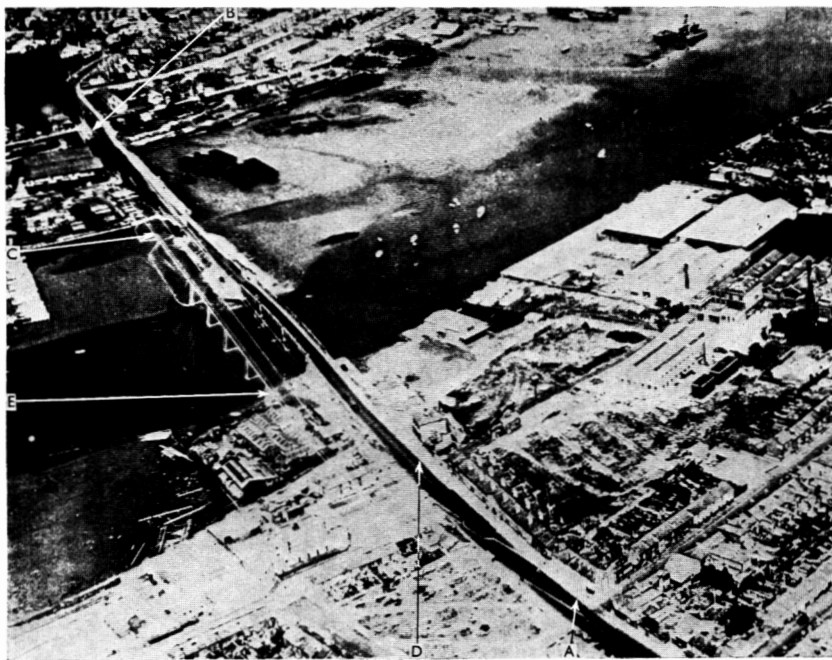


FIG. 16.—AERIAL VIEW OF SITE



FIG. 17. AERIAL VIEW SHOWING AREA OF CONSTRUCTION YARD

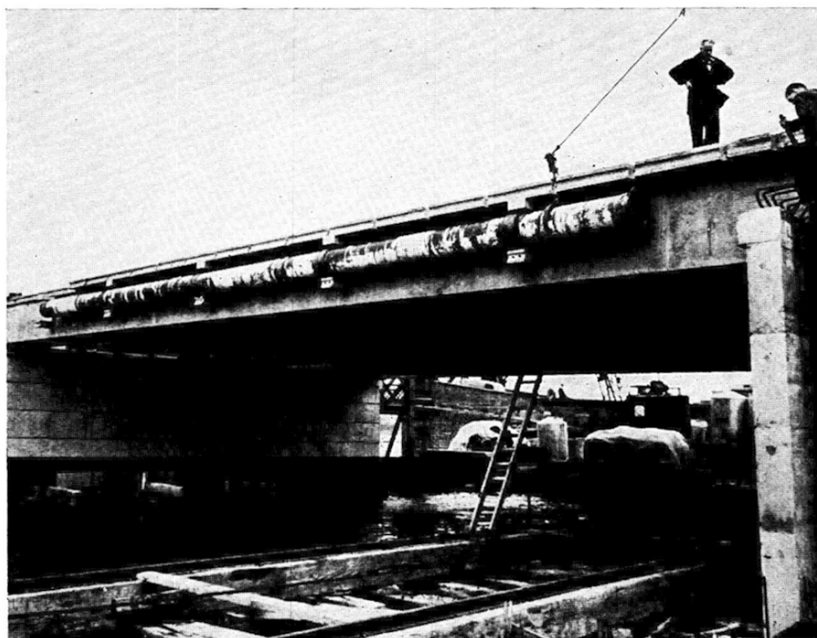


FIG. 18.—18-INCH GAS MAIN SLUNG IN POSITION

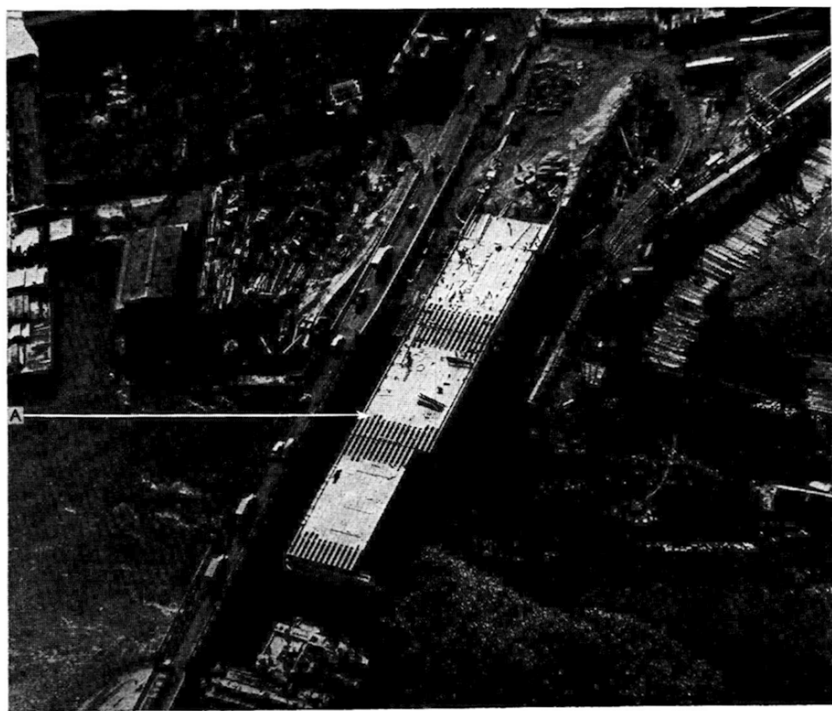


FIG. 19.—AERIAL VIEW OF PARTLY COMPLETED BRIDGE

It would be interesting to know more about the expansion device in the roadway surface—a matter which had been very well managed in the Northam Bridge.

The bend anchors were an interesting feature which had enabled heavily stressed wires to be concreted into the beam without the need for subsequent grouting. It was always a big advantage if that could be done. During the examination of the beam which had been tested to destruction, had there been any opportunity to break away the concrete and find out the condition of it at the points where the heavily stressed bars had their bends? Could the Authors give any information on that point?

Could the Authors say how an estimate had been made of the amount of transverse prestressing that was required in the deck?

It was interesting to note that ordinary Portland cement had been used in preference to rapid-hardening cement. It had been quite satisfactory and obviously cheaper, and had considerably reduced the shrinkage of the concrete—a problem which always had to be faced.

He thought the reference to loading on p. 278 was perhaps not precise; it stated: "The bridge was required to be designed to carry Ministry of Transport Standard Loading plus Abnormal Loading Class C." He thought that what was probably meant was that the bridge had been designed for Ministry of Transport normal loading and then, as an alternative, checked against abnormal loading; i.e., there was not the addition of the two, but both conditions had to be met in that case as alternatives.

Referring to the raking out of the beech blocks underneath the beams at the tops of the piers he wondered if it had been quite as simple an operation as the wording in the Paper suggested.

Mr C. W. Pike showed a number of lantern slides to amplify some of the points mentioned in the Paper.

Fig. 16 was a view of the area rather than of the site itself. It showed how close to the old bridge the new bridge had been sited. On the Southampton side, the bridge alignment joined on to the existing road as shown (A). On the north side it carried right through as indicated (B), the whole of the outer stretches being embankment, to a total length of about 2,000 feet. The scour span mentioned in the Paper was shown. Its purpose was to preserve the foreshore levels in the timber pond upstream of the bridge. The embankment over the tidal flats between the scour span and main bridge was also shown. The railway, which had been diverted, originally ran behind the cinema, straight across the road at D and on through the works area. The diverted route was from a point behind the cinema, over the made-up foreshore to the railway span E, and thence *via* a cutting through the old bridge approach.

Fig. 17 showed the casting yard (A) in which the beams had been made and the journey they had had to make out to the bridge. First, they had

had to cross the existing railway line which had been still in use, so that a temporary removable bridge had been made necessary. The beams had been taken into a stacking area and subsequently to the landing stage, where they had been picked up by the derrick barge and transported to the job.

Fig. 18 showed one of the 18-inch gas mains slung over the side of the beam. Each pipe had been slung before the next beam was brought in. The slings consisted of mild-steel straps anchored well back into the deck; one of them could be seen at A. The straps had been so arranged that they remained in position holding the pipe clear of the diaphragms until all the transverse tensioning was completed, leaving just a small amount of concrete to be placed after the removal of the strap.

Fig. 19 was an aerial view of the partly completed job. Mention was made in the Paper of the 24-foot width of the old bridge compared with the 65-foot width between parapets of the new bridge. Fig. 19 showed that difference clearly. As a partly-constructed job, there could be seen the gaps where the flanges of the beams were curtailed for the insertion of the continuity slabs over the pier-heads. The longer gaps (A) were to allow the insertion of manholes for access to the services which were laid beneath the deck.

In the Paper it was stated that the cost of the previous wrought-iron bridge was £9,000. Mr. Pike believed that that was the cost merely of the bridge without any embankments. The £600,000 cost of the new bridge was an inclusive cost covering the compulsory purchase of ground, bridge construction, and about 2,000 feet of embankment construction. Therefore, the true comparison was rather different from the impression given.

Mr Donovan H. Lee asked whether the approximate cost of the superstructure per square foot of deck had been calculated; was there any similar calculation available for the sub-structure; and the chemical consolidation having been done, did the Authors consider that it had been good value? Cases where chemical consolidation had been valuable were well known but, in looking at the drawings, he could not help wondering what had caused the piling scheme to be abandoned.

On the question of transverse prestress, bearing in mind the recent prominence given to the question of adequacy of transverse prestress (see "*Structural Engineer*," March 1954, for instance), did the Authors consider the cost of additional transverse prestress not justified? Mr Lee added that the transverse distribution in that case did not appear to be below the average.

He noted that the Authors had used a concrete mix of 1 : 1½ : 3. Both German and British practice mostly used less cement, resulting, it was fully believed, in less creep, but that would be offset by the unusually low water/cement ratio (0.3) used. He presumed that rounded gravel had been used. In his experience, notwithstanding what had been

published on concrete mix design, it was best for engineers to avoid angular coarse aggregates if they could. Had any plasticizer been used in the concrete? Plasticizers were rather popular in Germany and the United States.

Mr Lee agreed with the use of the ordinary Portland cement, but thought it had not been much used previously for pre-tensioned work. Possibly the high early strength that had been obtained was a justification. He agreed that shrinkage stresses were greatly reduced by using ordinary Portland cement.

Mr F. Irwin Childs described some interesting features of the bridge which were not apparent on a cursory examination of the completed structure.

The scantlings of the beams proclaimed that the members themselves were prestressed, and in order to achieve an economic section it had been necessary to accommodate a compact arrangement of wires, particularly taking into account the necessity to provide for reversal of stress at the ends. Fig. 10, Plate 2 showed the arrangement of the wires which, though familiar enough as a pattern for normally reinforced concrete, was unusual for prestressed work. The details of the bend anchors, as well as the arrangement of the wires, had been provided by the consulting engineers, and the hinge for locating the bend anchors automatically in their correct position when the wires were tensioned had been devised by the contractor. In fact, the way in which the contractor had entered into the spirit of the design had been one of the happy features of the contract. From the consultants' point of view, another commendable example of this co-operation was represented by the decision to adopt a water/cement ratio of 0.3 for the concrete in the beams, which had been well below the maximum permitted by the specification.

The achievement of continuity for structures composed of precast prestressed members generally presented some problems, particularly when the construction depth was limited, and there was often a great temptation not to attempt it and to leave spans simply supported. In the present instance the solution had been provided within the depth of the deck slab by using precast portions of the slab as continuity members and placing them between the main beams. He considered that Mr Cuerel's analogy of the steel cover-plate was a very interesting and suggestive one.

Referring to the structural arrangement, it would be recalled that the Paper described the method by which the bridge deck was anchored at the north abutment, supported on flexible columns within the four river piers, and finally carried at the south abutment on a flexible wall in such a manner that a limited freedom of movement for temperature effects could be accommodated. Mr Childs showed a number of slides illustrating the construction of the piers and abutments. It could be seen that between

the columns at the pier head there was a key-way which engaged with a key formed on the bottom side of the in-situ diaphragms over the piers to limit movement; each column had a copper flashing around to protect the annulus, which was only partially filled with bitumen. The function of the shrouding of the upper part of the piers was threefold: first, to protect the columns, secondly, for aesthetic reasons, and thirdly, to encourage the travelling public to use the bridge, which was at least one of the reasons for which it had been built!

Mr G. O. Kee said it appeared to him that the transference of load from the beams to the pier was carried out by transferring it from the beam to the in-situ diaphragm which ran over the columns. The ends of the beam were smooth and had only the short ends of wires and two 2-inch-diameter bars protruding. Was that considered to be sufficient to transfer the reaction from the beam on to the in-situ diaphragm? The top continuity slabs, of course, also bore on the diaphragm. Was it considered that any of the load was transferred through them?

He did not agree with the comment on p. 280, regarding a post-tensioned scheme, that "it was feared that the losses might be such as to defeat the design." The quantity of post-tensioned work being carried out at the moment surely was a refutation of that comment.

Mr A. Goldstein asked what would happen in the case of the 18-inch gas main if any replacement were required. His office had recently had occasion to discuss that matter with one of the provincial gas boards, and it appeared that those mains did sometimes leak. From the construction details given in the Paper it looked as if it might be difficult to get a faulty section of the main replaced without dismantling and removing a number of additional sections.

Mr J. R. Lowe said that one of the most useful things about such a Paper was the opportunity it gave for criticism and discussion at a later date of what might be improved in the design. Considering that the bridge had been designed 6 years ago, he considered that it was very good indeed, but he felt that nowadays consideration might be given to post-tensioning with precast units. He thought that using 0.276-in.-dia. wires and bringing all the wires into one cable would probably give much better placing of the concrete. He knew that that would mean a certain increase of dead-weight which, he believed, was some objection, but it would represent a gain in that there would not be so much worry about shrinkage losses. He thought that nowadays there would be little difficulty in grouting up afterwards.

Another question that he wished to ask was why such a low water/cement ratio had been used. He thought it would have been much better to have used a concrete with a higher water/cement ratio, which was allowed, provided that the strength could be obtained. It would have been much easier to place.

He thought he had understood Mr Cuerel, in his opening remarks, to say that the cover-plates ought now to be made standard. Mr Lowe considered that there were other methods that were very suitable. Bent cables or bars could be used and ought to be considered.

With regard to the abnormal load, he asked whether or not any tension had been allowed in the concrete. He believed it had been stated that a figure of 15% had been used for losses. Had any attempt been made to check the shrinkage and creep losses afterwards?

**** Mr A. D. Holland** referred to the statement on p. 280 regarding losses, which had been assumed for design purposes to amount to 15 tons per square inch. That represented 21·4 per cent of the initial stress of 70 tons per square inch and the Authors had said that observations which they had taken indicated that that allowance was generous. Information of that nature was of value to designers when considering the extent to which provision should be made for loss of prestress, and it would be useful if the Authors could indicate the basis for the conclusion which they had formed.

The extent to which the variation in concrete strength could be minimized in the production of high-quality concrete at bridge sites was another matter where it was helpful to know of results which had been obtained in practice. On p. 281 it was stated that concrete strengths of 5,000 lb. per square inch and 7,000 lb. per square inch had been obtained at the date of release and at 28 days respectively. Presumably, in both cases those were minimum strengths and it would be interesting if the Authors would say how they compared with the mean strengths which had been obtained.

Mr Wooldridge, in reply, agreed with Mr Adams's remarks about the co-ordination that there had been on the job. There had indeed been complete co-ordination. He had not said very much about the condition of the old bridge, but there had been a time-limit for getting the new bridge built. There had been co-ordination on the part of everybody who had had anything to do with the bridge—the harbour board and in particular the engineers to public utility authorities. They had had to learn a new technique, and the fact that they had done so was now a matter of history.

Mr Pike had referred to the cost of £9,000 for the old bridge. Obviously the original embankments for the timber bridge had still been there, so that that figure had not included the embankments. The sum of £9,000 had been for the wrought-iron structure only. As Mr Cuerel had said, the figure of £600,000 for the new bridge included compensation for land, demolition of the old bridge, construction of the railway track, a new car park for the cinema, and so on. What the actual cost of the new bridge was he was not going to say at the moment. They had not paid the final

**** This contribution was submitted in writing upon the closure of the oral discussion.—Sec.**

account. And for that reason he was not going to give any breakdown figures.

Mr J. Cuerel, in reply, thanked Mr Adams for his remarks and for pointing out an error in the paper; the bridge had been designed for the standard loading with a check for the abnormal load.

Not as many critical guns as he had expected had been fired off. With regard to the concrete, there had been some criticism of the low water/cement ratio; that was a novel experience. The development of the mix had been fully described in the Paper, and he could only refer those who had raised this point to the Paper. Obviously, they had wanted the lowest possible water/cement ratio consistent with compaction in the work; the ceiling had been set at 0.4, and it had been found possible to work down to 0.3, helped by the rounded aggregate. Notwithstanding the very low water content, the maximum size of the aggregate and the large number of closely spaced wires, full compaction had been realized and a better example of prestressed concrete did not exist. Plasticizers had been tried at the beginning and had been discarded as being ineffective. Ordinary Portland cement had been found to give an early enough time for release, and its use had led to fewer shrinkage troubles.

The question of cost had been largely dealt with; the total of £600,000 included acquisition of land and property, long approaches, road works off the site, and so on; and the actual cost of the bridge proper was much less than half of that total sum.

Reference had been made to the chemical consolidation and to the abandonment of the piling scheme for the piers; these matters had been covered in the Paper, which was one of such wide scope that it just was not possible to go into all the details fully.

Questions had been asked with regard to the transverse prestressing; the amount had been computed in a simple and rather generous manner on the basis of the dispersion required. He was aware that theories were being propounded as to what the transverse prestress should be; but theories were no better than the assumptions, explicit and implicit, on which they were based. Some time ago a bridge deck had been tested and it had been clear to him that the results confounded the theories—notwithstanding that the bridge tested did faintly conform to a fraction of the assumptions.

There had been protests from the post-tensioning interests about his remarks in the Paper on the considerations leading to the choice of the stressing system. In anticipation, he had exercised great care in the writing which, unfortunately, had not been matched in the reading. His remarks had been made for the benefit of engineers who were prepared to consider the relative merits of the different systems and to judge them in an unbiased manner. The experience had strengthened his opinion.

Various questions had arisen as a result of mis-reading the Paper and

misunderstanding of his opening remarks. Dealing with these and sundry others, he observed that the transference of load from beams to pier was described in the Paper, the end portions of the beams were *embraced* by the diaphragm and keyed thereto; the 2-inch bars had no function in that respect. He had not said that cover-plates should be standardized but that, depending on circumstances, similar devices had become accepted practice; the use of cables or bars had been considered as he had explained. When checked for abnormal loading a small tension was calculable, but he doubted if any would in fact arise. As stated in the Paper, the loss of stress in the steel had been assumed to be 15 tons per square inch (not 15 per cent), observations indicated that 10 tons per square inch would have been ample in the circumstances obtaining. The gas mains could be replaced in a simple manner using a floating stage.

Finally, he would like to place on record that in all his experience of civil engineering he had not been associated, in any capacity, with a happier job than the construction of New Northam Bridge.

Mr Hauch, in reply, referred to Mr Adams's remark that a great deal more could be said about the cofferdams and the underwater concrete in the piers. The system of underwater concreting was one which Mr Hauch's Company favoured and which he thought was extremely useful, particularly where sub-soil conditions such as those at Northam existed. It should always be remembered that water exerted its full pressure and no chances could be taken. They had kept a check on the pressure underneath the concrete base by means of the pipes described in the Paper and that simple gadget had proved its worth in indicating when there was a danger of the bottom lifting. Had the foundation lifted and the bottom been disturbed they would have run into considerably more trouble.

With regard to Mr Adams's remark on the bend anchors in the beam which had been tested to destruction, none of the bend anchors had, in fact, been cut out. They had cut back from the point of fracture to both sides for some distance until the concrete had been found to be intact. They had not reached the first bend anchor and there had been no marks on the beam to show that at the position of the bend anchor anything particular had happened.

Mr Adams had asked how the beech blocks had been removed. Before a decision on the use of those blocks had been taken a couple of the blocks had been tested by compression in a testing machine and it had been found that if they were made $\frac{3}{8}$ inch thick they would compress under the load to approximately the $\frac{1}{2}$ inch required. It should be remembered that although the beech block had been compressed it was not at the time of removal under compression, for the beam was then carried through the columns on to the pier. Although the wood had been compressed it would not close up on the tools used for removing it. They had, therefore, used an electric drill of a fairly small diameter and drilled several holes through

the blocks, after which it had been possible to rake out the bits between the holes.

The question of the water/cement ratio had been dealt with by Mr Cuerel and Mr Irwin Childs. The question was in part related to the matter of Portland cement versus rapid-hardening cement. It was a complex question but the major consideration was reduction of shrinkage. There had been found, in the first beams cast with rapid-hardening cement, a very considerable number of cracks. After using Portland cement cracks still occurred but to a smaller extent. Had they used a higher water/cement ratio or rapid-hardening cement more trouble would have ensued so they had used the lowest possible ratio that could be worked into the beam. It had been extremely hard going but by severe vibration of the concrete and by exact control the beams had been cast. On several occasions two beams had been cast in one day but for most of them it had taken 6 or 7 hours per beam in order to make absolutely sure that the concrete was vibrated right down to the bottom.

Additions to the concrete had been tested both with regard to strength and workability and it had been found that there was very little difference when using the low water/cement ratio that had been decided upon so no additives had been used, first because they did not appear to be economical, and secondly because he was convinced that additions to concrete were not sound, whether they were a help in placing or not.

CORRESPONDENCE on the foregoing Paper is now closed and no contribution, other than those already received at the Institution, will now be accepted.—SEC.
