The shuttering and concreting of long span reinforced concrete girder bridges

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The Shuttering and Concreting of Long Span Reinforced Concrete Girder Bridges.

Rüstung und Betonierung bei weitgespannten Eisenbetonbalkenbrücken.

L'échafaudage et le bétonnage des grands ponts en poutres de béton armé.

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Engineering work in the last few years has proved the possibility of building reinforced concrete beam bridges on piers of medium height across spans of 30 to 65 metres, without difficulty either from a constructional or an economic point of view, which are able to compete with steel bridges. By adopting the special measures discussed in the Preliminary Report[1] a further considerable increase in their scope is to be anticipated. This increase in span has hitherto been attributed by many to the adoption of higher stresses, and it is true that by adopting higher stresses in the concrete and in the steel the limiting span can easily be forced up to a high value. To a much greater extent, however, the problem is one of taking suitable statical measures to eliminate excessive bending stresses, or, ultimately, to eliminate cracks; at the same time, it is a problem which affects the whole constructional operation.

In work of this kind the question of scaffolding and concreting has already become important and will be more so as the size of the structure is increased so as to involve greater masses in proportion to area, greater depth of beams, and correspondingly greater cross sections. The proportions hitherto in use have varied between 0.6 and 1 m^3/m^2 of area, and portions of the structure which were statically and constructionally independent have been concreted in a continuous process covering 400 to 900 m^2 of ground area, the maximum values being in the case of continuous girders (for instance, the Saubachtal bridge and the Denkendorf viaduct for the Reichsautobahn, and also the bridge over the Oder near Oppeln).[2] In constructions of this kind the rate of concreting is limited by technical and economic factors, and difficulties may arise through lack of space, complication of girder design and overcrowding of the reinforcement. An output of about 15 m^3 of solid concrete per hour might be regarded as the upper limit. In beam bridges it is indeed not impossible, as in arch construction,

[1] *Dischinger:* Preliminary Report, page 775 foll.

[2] See *Pistor:* Die neuere Entwicklung des Baues weitgespannter Eisenbetonbalkenbrücken in Deutschland. Die Bautechnik 1936, N°. 43, page 630 foll.

to subdivide monolithic parts into layers, but in the case of beams which are stressed mainly by bending and shear the practice is highly undesirable if not altogether inadvisable in view of the heavy reinforcement against shear, and of the narrow neck of the beam which increases the practical difficulties; hence concreting in one integral piece which includes also the roadway slabs is the desideratum to be sought.

The precondition for continuous concreting is immobility of the falsework. This, however, is practically unattainable on account of the variations in load along the length of the girder, deformations will arise which differ both in magnitude and in the time of their incidence, and these are combined with questions of ground supports, timber connections and other factors. The false-work for beam bridges is in itself heavily loaded, and with present practice as regards bridge design, favouring a limited number of large main girders, the load on a line of falsework may be between 5 and 8 tons per metre. In large bridges the deformations which arise as the loading is increased by the deposition of fresh concrete upwards from below, on top of concrete which has already set and hardened, cause an undesirable distribution of the stresses and may cause cracking. The measures to be taken for the avoidance of harmful effects have been known for a long time, and are:

a) Concreting in strips.
b) Continuity of the falsework with a view to avoiding local irregularities of the supports.
c) Pre-loading of the whole of the falsework and elimination of the deformations before concreting.

All these methods are in use. Concreting in strips has mostly been carried out by closing with shuttering those portions of the beams which are over the supports and filling in these directly after the girder is finished, or by closing the gap after an interval of a few days. This method was used in some of the new bridges — for instance, in the Denkendorf viaduct[3] for the Reichs-autobahn and in the cantilever beams for the Saale bridge at Bernburg[4] — and a similar method was adopted for making the suspended girders. In this way the influence of the varying amount of stiffness as between the supporting piers and the spans themselves is eliminated — though at the cost of the homogeneity of the girder, since the resulting construction joints, when they extend into the tension zone, must be regarded as cracks produced beforehand. Within the span, if the falsework has been properly designed and is not too heavily loaded, it is true that fairly uniform settlement may be counted upon, but there can be no guarantee against local deformations due to yielding of timber connections, etc.

The same difficulties arise when continuous scaffolding is adopted, an expedient which indeed avoids the presence of working joints in the concrete but which does not exclude the possibility of local settlements due, in particular, to concentrations of load at the supporting trestles. Every irregularity in loading, as, for instance, that which occurs in the neighbourhood of openings left for navigation and the like, is a possible source of danger. Hitherto this method has

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[3] *Schächterle:* Beton und Eisen 1936, N°. 1, page 1.

[4] *Nakonz:* Bautechnik 1936, N°. 15, page 216.

been applied only in one instance, namely, the Sophia bridge at Bamberg[5]. (Fig. 1).

The third method, that of pre-loading the falsework, enables the greater part of the deformations to be made to occur before the introduction of concrete, so that the concreting can be carried out quite continuously and there is nothing to prevent the formation of a monolithic structure. There is a further advantage in the fact that local settlement is detected at an early stage in the application of the preliminary loading, so that suitable precautions can be taken, and the desired positions of the soffits of the beam can be regulated with great accuracy after the preloading is completed.

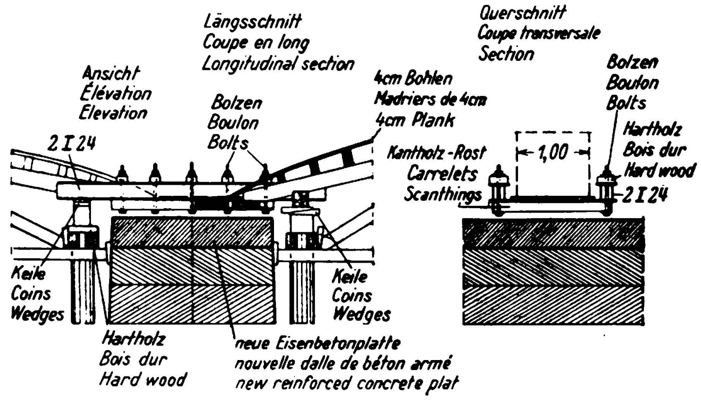

Fig. 1.

Pre-loading in this way — the first instance of its use on so large a scale and with such accuracy — was applied by the author, at the instance of the autorities concerned, in his design for the Reichsautobahn bridge over the Inn, in which a total of mare than 1000 linear metres of girders were built in this way (Fig. 2). Boxes were provided on the inside face of the shuttering of the girders, and these were filled with the gravel to constitute the loads, a weight equal to two-thirds that of the concrete being supplied. To attain the full amount of loading it remained necessary to add to the girder 0.6 m³ of concrete per metre of length, and this was possible within the time required for the setting of the concrete; not until the latter had been placed in position was the gravel removed, keeping pace with the progress of the concreting. Further relevant details will be found in the paper cited below[6] and also in the section of the Congress concerned with reinforced concrete construction.

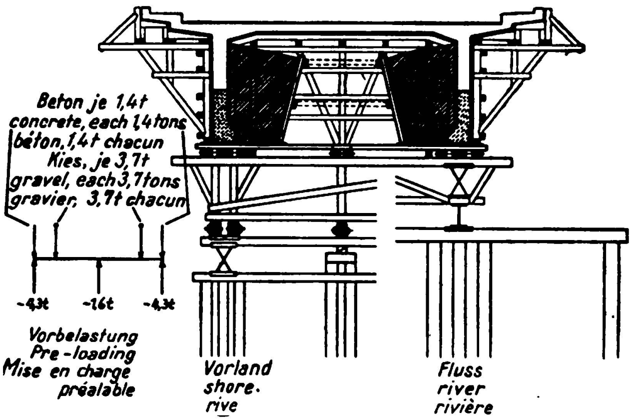

Fig. 2.

Pre-loading on a very simple system was applied in the construction of the Sophia bridge at Bamberg,[5] making use of crane rails. Another application, similar in form to that employed at the Inn bridge, was made with a view to eliminating the effects of the deflection of the *Melan* girder built as a suspended span, 27.0 m long, in the bridge over the Saale at Bernburg[4] (Fig. 3). The work

[5] *Berger:* Bauingenieur 1932, N°. 21/24, page 305 foll. — *Berger:* Final Report of First Congress, Paris 1932, page 359.

[6] *Endrös:* Beton und Eisen 1935, N°. 3, page 27 foll.

at the Inn bridge showed that the costs of pre-loading are low and are out of all proportion to the increase in safety during construction so obtained. The complete freedom of the bridge from cracking must be attributed largely to the elimination of the deflections in the falsework.

Of the thirteen long span reinforced beam bridges[2] which have been built since 1933, it appears, so far as can be established, that two were built by pre-loading, four by temporary interruption of concreting over the supports, and seven were built by continuous concreting without special precautions. It must be recorded that even in the last of these categories it was found possible to build the bridges completely free from surface cracks, despite the fact that not inconsiderable settlements of the falsework were observed. It appears, however, that the latter occurred at the right time, before the concrete had began to set, and the more so because in continuous concreting at first a kind of division into strips was practised. The success obtained in these particular bridge works cannot, however, be held to rebut criticisms of the method.

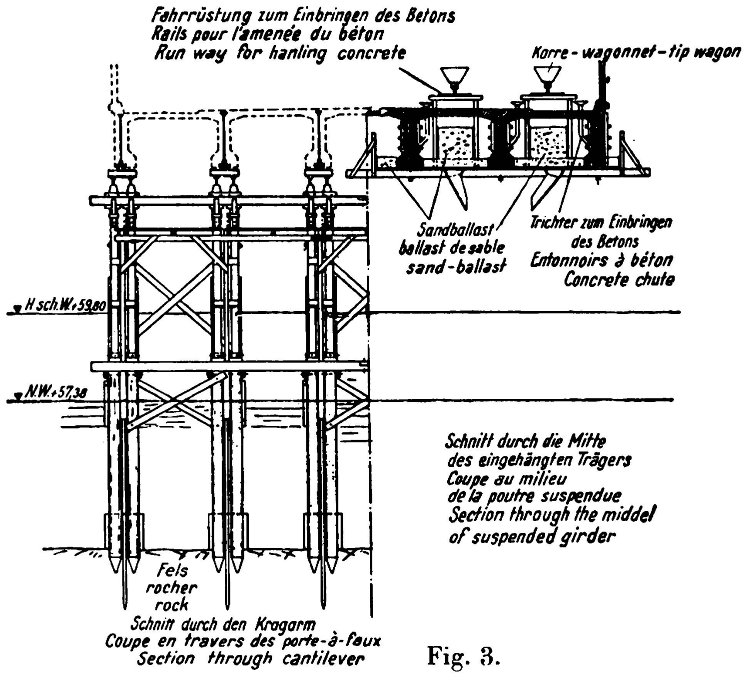

Fig. 3.

Where the work is notably larger in size, and especially where it consists of continuous girders, it will be impossible to avoid the necessity for subdivision into zones even with the precautions mentioned above. However, any large increase in size will probably require the adoption of pre-stressing on technical and economic grounds, and since, if this is the case, bending tensile stresses are completely or largely eliminated, there will be no objection to working joints if suitably situated. The advantages of pre-stressing apply here again in regard to the execution of the work.

Conclusion.

In the consruction of large reinforced concrete beam bridges which are mainly stressed by bending, continuous concreting should be practised on those portions which form statical units.

The harmful but unavoidable deformations of the falsework (or of stiff reinforcement) must be compensated. This can be properly ensured only by pre-loading the supporting scaffolding work as was practised in the case of the whole of the Inn bridge, and in the case of the suspended span in the Saale bridge at Bernburg. The method is simple and relatively cheap. Its application as a matter of principle would mean a further step towards the elimination of uncontrollable influences, and would increase the likelihood of successful construction.