Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 6 (1960)

Artikel: General report

Autor: Louis, H.

DOI: https://doi.org/10.5169/seals-7055

General Report

IVa) Progress and set-backs in construction

The dissimilar nature of the contributions to the preliminary publication was maintained in the papers presented at the working session of the Congress. The majority of these consisted of descriptions of structures that were remarkable on account of their size, one or more features of their design or the method employed in their construction. One paper dealt with a method for calculating bridges based on limiting states.

The Narrow bridge, constructed of prestressed concrete in Western Australia, was described by MM. Baxter, Birkett and Gifford; quite apart from its large size, it is characterised by a limited web thickness of 20 centimetres for a maximum depth of beams of about 3.75 metres. The longitudinal members, consisting of I beams of varying depth, pre-cast in sections 3.05 metres in length comprising diaphragm and anchorage blocks, are beams of the double-cantilever type under dead load; they are made continuous over six supports by means of short prestressed cables connecting the adjacent end blocks at each temporary hinge.

The main prestressing cables are of necessity external to the webs on account of the limited thickness of the latter and the magnitude of the prestressing force (2120 tons per beam). Over a certain distance, commencing from the supports, the webs are subjected to vertical prestress by internal cables. The fact that the web is subjected simultaneously to stresses due to the bending moment and to the shearing force seems to have raised a problem for which, according to the authors of the paper, it was not easy to find a solution. The problem in question is indeed difficult; and although several research workers have investigated it, nevertheless it is true to say that, in spite of dangerous slogans generalising the favourable effect of the vertical component of the stress in raising cables, the field of the resistance of prestressed concrete to shearing forces remains, to a large extent, unexplored.

The designers of the Narrow bridge determined the vertical prestressing force by reducing to an acceptable value the principal tensile stress arising from the shear stress, the latter being reduced, firstly, by the action of the raised cables and, secondly, by the slope of the lower flange of the main beams. This analysis of the principal tensile stress, made in the elastic range and applied to the entire section of the beam, is obviously at fault in the case of cracking of the beam caused by bending. The vertical prestressing calculated in this manner is, in fact, insufficient in this stage and, according to the authors of the design, in default of adequate information on the subject, the effect of the prestressing was completed by vertical stirrups of mild steel calculated in the manner usually employed for reinforced concrete.

A test on a model showed that the strength of the beam reinforced in this way had been considerably under-estimated because when cracking under bending appears, the stress in the stirrups is always less than the elastic limit.

We consider that this practical case encountered in connection with the construction of many bridges is deserving of attention. Indeed, although at present it may be concluded that it is necessary not to consider rupture through shear stress and rupture through bending separately, the actual problem is very complicated, especially if localised loads act either on the upper face of the beams, or on their lower face. The field is one in which many theories have been advanced, without, however, such theories confirming the experimental results. In this connection, it seems to us to be of interest to quote Professor Rüsch who in his general report on the development of methods of calculation (F.I.P. Berlin 1958) wrote: "In order to achieve a satisfactory theory of the rupture under shearing stress of prestressed concrete beams, investigations should be continued into the various factors affecting this rupture, such as the cross-sectional area, the prestressing, the range of shearing stress, the mode of action of the load and the form of the supports, the longitudinal and transverse reinforcements, the strength of the concrete and the resistance to compound stresses, to mention only the most important factors."

Mr. B. Žeželj described two large bridges in reinforced concrete and prestressed concrete constructed in Yugoslavia.

The bridge over the Tisa, with a total length of 400 metres, comprises in its central portion three spans of 50, 154 and 50 metres; the prestressed girders are stiffened in the central span by reinforced concrete arches, with a surbasement of 1 : 6.4.

The two main beams, 8.80 metre apart, with a depth of 3.15 metres, have a I shape and the web has a thickness of 16 centimetres.

The pretensioning of the beams was carried out in several stages by means of external cables. The adjustable alignment of these cables was adapted to each construction stage of the bridge. Allowance was made for shrinkage and creep by maintaining the arches by jacks placed at the crown for a period of several months; this compensation, however, could only be partial, because the deck had not been constructed at that time on account of the small section at the crown. The arch is, in fact, of reduced dimensions and the stress permitted in the reinforced concrete was 150 kg/cm^2.

The deck-elements, the hangers and the pre-cast wind-bracing are of prestressed concrete. The system of three spans externally isostatic under dead load is made continuous by blocking two hinges provided in the side spans. The bridge in question is a fine and important structure and the programme of execution of the work — complicated, but in conformity throughout with the design hypotheses — made it possible to consider, with mastery, efficiency and safety, successive elementary systems which eliminated the occurrence of phenomena termed secondary, but which have a considerable influence in such a structure.

The second bridge described by Mr. Žeželj will cross the Danube at Novi Sad by means of two fixed arches of reinforced concrete having spans of 211 and 166 metres respectively, and a surbasement equal to 1/6.5.

The foundations for the supports are constructed with reinforced concrete caissons for the abutments and in prestressed concrete for the pier; behind the abutments, the thrust of the earth was made gradually active by means of reinforced concrete walls bearing on the supports by means of jacks.

This structure presents several interesting features both in regard to design and to the method of construction.

The centering of the large arch has a span of only 108 metres; its thrust was transmitted by beams to the abutments; it was erected in sections hinged together and blocked, after adjustment, by means of vibrated mortar and bolts.

The centering supports only 40% of the weight of the arch; since the arch has a box-section the lower flange was first concreted, the centering was removed, and the beam maintained by jacks. Then the upper flange of the box-section was concreted without bonding to the first part; the longitudinal shells were then constructed shortly after the centering had been removed from both flanges and were bonded to them by prestressing.

The structure is to remain subjected to the action of the jacks at the crown for a period of six months in order to compensate for the effects of shrinkage, creep and displacements of the supports, at least partially, because at this stage the deck has not been constructed with the exception of the hangers and the main cross-members which, like the wind-bracings, are prefabricated in prestressed concrete.

Mr. Finsterwalder considered some new developments in the construction of prestressed concrete bridges which must command attention because they indicate a tendency. It would, indeed, be a mistake to believe, in spite of the real progress achieved during the past fifteen years, that the design of structures will remain fixed. New forms can still be found which, by judicious application of prestressing, will result in increased refinement and a more æsthetic appearance, without contravening the rules of safety and economy.

It will not always be possible to justify these forms by rigorous methods of calculation, but experimental technique will, more than ever, be a reliable guide for the designer in his choice and in the control of his ideas. This method of dimensioning is not thereby made easier, because it necessitates a stricter regard for the laws of statics and stability. Moreover, the applications of these laws to the functioning of a model and to its extrapolation to the behaviour of the actual structure are often difficult to discover and cause greater trouble than the deduction of conclusions on the basis of a thorough calculation which is assumed to be rigorous.

Mr. Finsterwalder was of the opinion that for elevated urban roads, which are considerated as road bridges, central pillars offer many advantages in regard to the use of the space beneath the roadway.

He gives as an example an actual structure in the form of a square mushroom-shaped slab of 32 metres side, which is connected along the diagonals to a central pillar. The slab is prestressed in two directions; the resistance to the shearing force at the junction of two slabs is provided by an adaptation of the Dywidag anchorage system employed by the author.

This solution seems to be particularly felicitous; it can be extended to road bridges located outside urban areas and we are not debarred from thinking that it is capable of further development.

Generally speaking, the principle of a continuous mushroom slab has been adopted on several occasions for road bridges characterised by the lightness of their appearance and their economy. However, certain difficulties are encountered in the calculation; here again experimental work is essential and we are happy to draw attention to the important researches undertaken on this subject by Professor NYLANDER. Members who attended the Stockholm Congress were able to visit his laboratories and appreciate the results obtained by tests made on full-size models.

Mr. FINSTERWALDER then described a prestressed lattice bridge, continuous over three spans of 90, 108 and 90 metres, built at a height of 60 metres above the Mangfall valley. The lattice was designed in the shape of a St. Andrew's cross on account of its lightness and its appearance. Prestressed concrete is greatly to be preferred to reinforced concrete — which necessitates anchorages of considerable length for the reinforcements in order to transmit the tension forces at the junctions — and readily lends itself to this type of construction because the stresses in the bars are directly concentrated at the junctions by the localised anchorages of the prestressing cables. The bridge was erected by cantilevering out; the piers were made integral with the main lattice beams in such a manner that the structure behaves as a portal frame.

In conclusion, Mr. FINSTERWALDER gave a report on the preliminary plans for a structure over the Bosphorus, which he rightly regards as a new type of suspension bridge made possible by the conception of prestressed concrete. The bridge in question has a total length of 1200 metres and is continuous over three spans of almost equal length. The preliminary plans provide for four intermediate supports having a height of 53.3 metres and comprising one or two prestressed cantilevers 100 metres in length. A tie beam-slab, serving as a deck and having a length of 200 metres and a thickness of 30 centimetres, is fastened to these cantilevers; the deflection of this slab is 1.45 metre under dead load, and 1. 85 metre under total load and a rise in temperature of 15° C.

A structure of this type foreshadows possible new designs to which we made reference earlier; is it not, in fact a sort of extrapolation of the solutions adopted by Mr. FINSTERWALDER for elevated roads? It exhibits a great simplicity of form, design and "function", that is to say, three qualities towards which prestressing makes it possible in most cases to tend, if not to achieve.

Professor SMITKA gave the result of a study of the classification and standardisation of reconstructed bridges in Czechoslovakia. This study determined the design to be provided for these structures in relation to their size and to economy; the majority of the bridges are constructed with prefabricated beams of reinforced or prestressed concrete, the rectangular I-shaped or open or closed box-beam form of these beams being dependent on the span of the bridge.

He then described[1]) the abutments, comprising the initial portions of the springing in concrete, and the end pillars of a steel arch with a span of 330 metres. He also commented on the plans for two prestressed concrete bridges, 252 metres in length, having four unequal spans constructed with cantilever girders. Each bridge is in the form of a box beam with two compartments of varying depth. A special feature is the anchoring of the cables and their protection; they are concreted directly from the upper slab of the box beam, with which the protective concrete therefore appears to form a monolithic structure.

In conclusion, Professor SMITKA gave a detailed description of a new device developed in his country for the fabrication of prestressing cables with a force of 100 tons and consisting of 24 wires having a diameter of up to 7 millimetres. He did not indicate the technical advantages of the use of these high strength cables in structures.

It seems to me advisable to draw attention to the fact that Mr. DUMAS, Chief Engineer, Highways and Bridges, France, has designed and fabricated cables and jacks capable of reaching a force of 180 tons comprising 30 wires, 7 millimetres in diameter, in a duct 62 mm in diameter[2]). The chief advantage of these cables according to Mr. DUMAS is the considerable saving in space which they make it possible to achieve as compared with the usual bundles of wires. These cables, which are associated with others of smaller section, absorb the greater part of the bending moments; they are located in the lower portion of the beams and are practically rectilinear. Their small section has the effect of increasing the leverage, which, for the same working load, enables a reduction to be made in the depth of the beams.

Furthermore, using the method of prior cold-working of the wires before tensioning, Mr. DUMAS has demonstrated that the use of cables comprising thirty wires enabled him to obtain a gain of 30% on the subsisting tensions as compared with the subsisting tensions which exist in a beam where the wires were tensioned at 120 kg/mm^2 without previous cold-working and with the standard blocking processes.

In his paper, Mr. MULLERSDORF was mainly concerned with practical means for reducing the unfavourable effects of creep and shrinkage in continuous structures.

---

[1]) Will appear in one of the next numbers of the "Bulletin".

[2]) F. DUMAS: High strength cables. Association Scientifique de la Précontrainte. 4th Study Session, 10th and 11th March 1960, Paris.

In one structure 330 metres in length, with spans of 26 metres, the main beams were pre-cast to this length of 26 metres and prestressed by the Hoyer system; at the ends of the beams the upper part was bevelled for the purpose of bonding on site with the adjacent beams.

An initial precaution was taken for the purpose of reducing the unfavourable effect of the straight shape of the prestressing reinforcement, and consisted of the provision of a complementary prestressing reinforcement located in the upper part of the beams.

The second precaution was to arrange a construction programme comprising intervals between successive stages such that continuity was only achieved after a considerable proportion of the creep had already taken place. The author gave diagrams showing the stresses at the central point of a span and on a support, at the various stages in the construction of the bridge. By this procedure, the effects of residual creep are unfavourable at the mid-point between the supports and improve the state of tension on the support.

In a second bridge, the spans had a length of 17 to 18 metres; the deck, consisting of four rib-longitudinal girders covered by a slab, comprised a stout cross-member on the supports.

The longitudinal girders of pre-cast reinforced concrete were placed on the piers against the cross-members; the upper slab was concreted for a certain distance on either side of the piers and subsequently in the span. Prestressing was then applied at the supports. In this case, creep had the effect of aggravating the state of tension at the support and improve it in the span.

This adjustment of the stresses by means of the method of construction regarded from the point of view of the redistribution of the stresses as a result of the effects of shrinkage and creep was carried out in a particularly thorough manner by Mr. MULLERSDORF. Undoubtedly, the majority of bridge constructors are accustomed, in principle, to undertaking the execution of the work in stages, in order to reduce these effects, but it is only by attempting, as Mr. MULLERSDORF has done, to characterise the state of tension proper to each stage in the construction that fresh knowledge will be acquired and that structures will be able to benefit from the rational methods employed in their construction.

During the open discussion held in Stockholm, Mr. WITTFOHT described the various stages in the construction of a motorway bridge built over the Main, near Bettingen. In addition to its large size: 310 metres with three continuous spans of 85, 140 and 85 metres, this structure has a curved shape in plan and is a skew bridge. In cross-section it consists of two independent box-beams, of rectangular section, with a variable depth, comprising cantilevers of considerable size. The bridge was built in sections starting from the piers and resting on movable scaffolding.

The main prestressing reinforcement is provided by 100-ton cables passed through the sections and subsequently tensioned.

Professor EVGRAFOFF, in his paper, summarised certain of the special features of the calculation of bridges by the method of limiting states which has been adopted in the U.S.S.R. since 1955. The limiting states are determined by the strength of the construction, the deformations of the whole structure and the localised deformations.

The method is based on the statistical knowledge of the factors capable of exerting an influence, in the widest meaning of the word, on the behaviour of the structures.

The most important of these factors relate to the variability of the loads, of the properties of the materials, and of the working conditions.

The possible variation in the loads is taken into consideration by adopting a coefficient which varies from 1.15 to 1.4 for moving loads, depending on the size and type of the bridges, and is taken as being equal to 1.1 for the permanent loads.

The variability of the properties of the materials is characterised by a coefficient of uniformity equal to the quotient of the minimum value of the strength of the material — which is itself equal to the mean value, determined by tests on the material in question, reduced systematically by the value of three root-mean-square deviations — and the standardised value of this property.

The value of k is obviously lower, the greater is the scatter of the mechanical property of the material; k is of the order of 0.6 for concrete and 0.85 for the elastic limit of steel.

Allowance for the variability of the working conditions assumes the form of a coefficient, frequently taken as 0.9, which takes into account both the tolerances on the dimensions and the method of calculation adopted.

The condition to be achieved is obviously that the value of the function determining the stresses should be less than the value of the function characterising the strength of the construction, the elements of stress or resistance occurring in both these functions being affected by the above-mentioned coefficients which characterise the possible variations in these elements.

The method of calculation by a consideration of the limiting states is mainly applied to reinforced concrete bridges.

In the subsequent portion of his paper, Professor EVGRAFOFF summarised the method of calculation to failure, already well known, which is employed in the U.S.S.R. for dimensioning reinforced concrete structures. The principles of this method are at fault where a fatigue calculation is concerned; the author of the paper pointed out that in such cases other formulas were employed, but he did not indicate what they were.

However that may be, the method of limiting states is widely employed in the author's country for the calculation of bridges and is justified by the favourable results of tests on wide-span beams, resulting in rupture through bending or shear stress, and of fatigue tests.

It would have been interesting to learn the ideas of the author in regard to several questions:

— Is the method of calculation he advocates applied to hyperstatic systems; is there any information as to the effects of redistributions of stresses due to shrinkage and to creep?
— What information is available at present for structures, calculated in this manner, in regard to the effects of loads of long duration (permanent loads) and of repeated loads?
— What are the limits prescribed for general deformations and local deformations (cracking)?

IVb) Safety

The only paper presented at the Congress which can be regarded as dealing with the safety of structures is that by Dr. Abeles on the subject of the permissible tensile stresses in prestressed concrete bridges, based on the cumulative effects and the magnitude of actual stresses through fatigue.

The author, on the basis of the results of tests now being conducted in Great Britain, showed that it is possible to envisage greater tensile stresses than those generally accepted at the present time under the maximum live load assumed in the calculation, since this load is very seldom applied during the life of the bridge.

Fatigue tests show that no visible crack makes its appearance for a limited value of the tensile stress, such as results from the application of ordinary live loads, even after fissures have occurred, opened and closed again during the previous application of several million loadings and under the action of higher tensile stresses. The author gave a detailed description of the results of a large number of tests which are of interest not only in relation to the aim that was pursued, but also from the point of view of the experimental procedures employed. Although no magnitude is indicated for the permissible tensile stresses, the general suggestion put forward by Dr. Abeles seems to be reasonable provided that these stresses can always be accurately determined by calculation, which appears to be disputable, at least in certain cases of continuous beams, if reference is made to the work of MM. Guyon and Lebelle.

* * *

In conclusion, and in spite of the rather heterogeneous nature of the papers on Theme IV submitted at the Congress or which had already appeared in the preliminary publication, and in spite of their excessively descriptive character which results perhaps, from the limitations of time and of text imposed on the authors, but which it would be advisable to ameliorate, it does appear that closely related considerations are becoming a matter of concern in most countries. Everyone attempts to solve the problems that arise by means of his own, governed by his personal knowledge and ability. Progress undoubtedly results, but it is necessarily slow and lacks conformity.

We consider, on the contrary, that a really fruitful development in the fields of the design, dimensioning and analysis of the behaviour of bridges and engineering structures can only result from work directed to definite ends and with a carefully designed programme which would cover precisely those difficult questions which each of us propounds to himself in connection with the difficulties we all have to face or for the purpose of making fresh advances.

In our general report, which appeared in the preliminary publication, when presenting that report at the session of the Congress, and in the present report subsequent to the Congress, we have drawn attention to many problems whether or not they were mentioned by the various reporting members: cracking of concrete, adherence of the reinforcements, reinforcement against the shearing stress in reinforced concrete by means of inclined stirrups of half-hard steel, time-lag in the deformations of concrete brought about by repeated loads, effects of repeated loads on reinforced concrete structures, method of calculation to failure for bridges, instability phenomena in the webs of prestressed concrete beams, reinforcement to counteract the shearing stress in prestressed concrete beams, particularly I beams, simultaneously affected by bending, etc.

We recall and confirm the statement we ventured to make during the meeting of the Congress to the effect that the majority of these difficult questions are the subject of most serious concern to the sister Associations, namely I.A.B.S.E., C.E.B., F.I.P and R.I.L.E.M. They could be studied progressively in common, that is to say in close and confident collaboration in accordance with strictly defined and detailed programmes drawn up by delegates from competent Commissions from the various Associations. It is not utopian to think that the work of these delegations could lead to experimental investigations conducted and financed jointly by several countries and dealing with engineering structures or with certain of their elements.

Leere Seite
Blank page
Page vide