Feb. 16, 1971 V. MLADYENOVITCH 3,564,567

BUILDING METHOD FOR MULTISPANS STRUCTURES

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Fig. 1

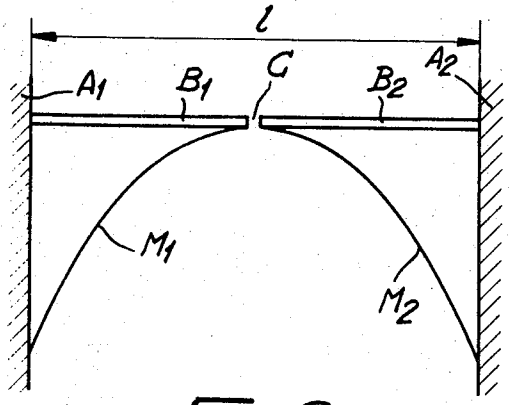


Fig. 2

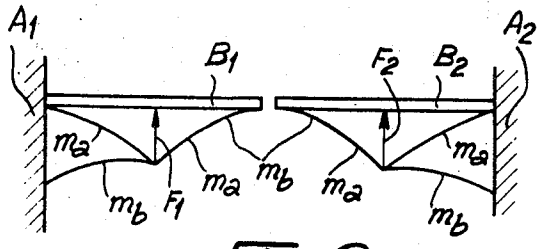


Fig. 3

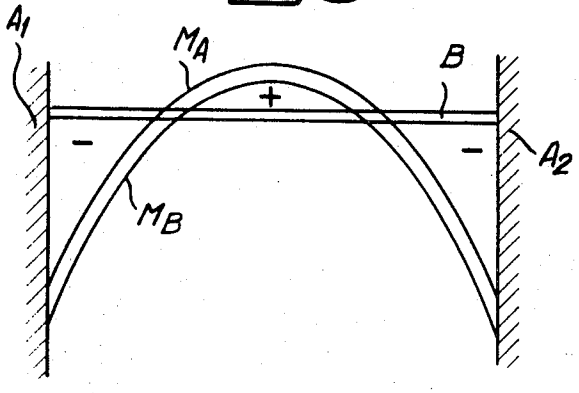
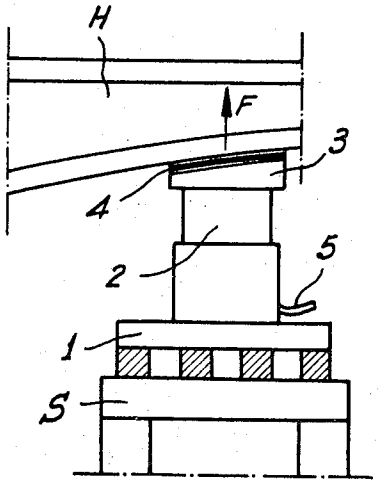


Fig. 9



BUILDING METHOD FOR MULTISPANS STRUCTURES

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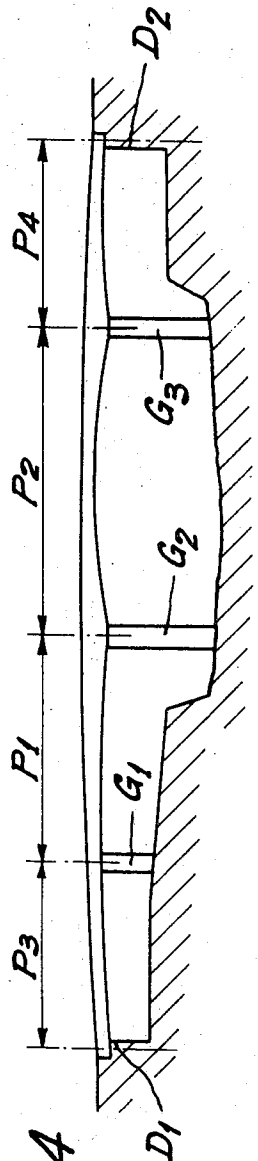


Fig. 4

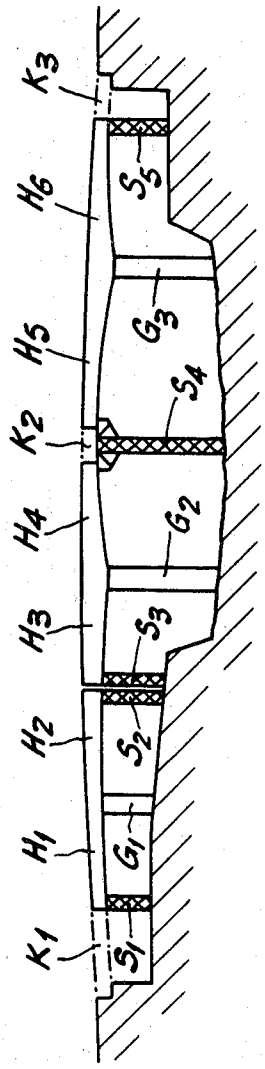


Fig. 5

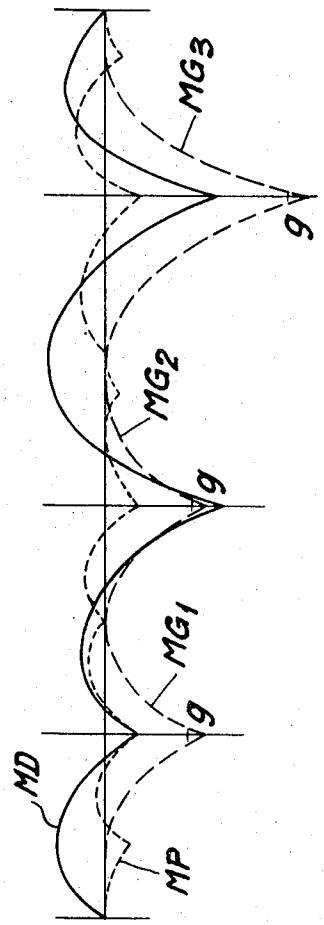


Fig. 6

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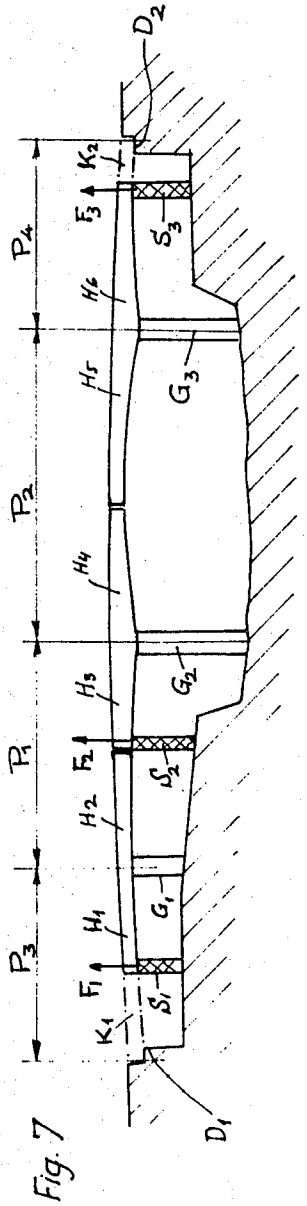


Fig. 7

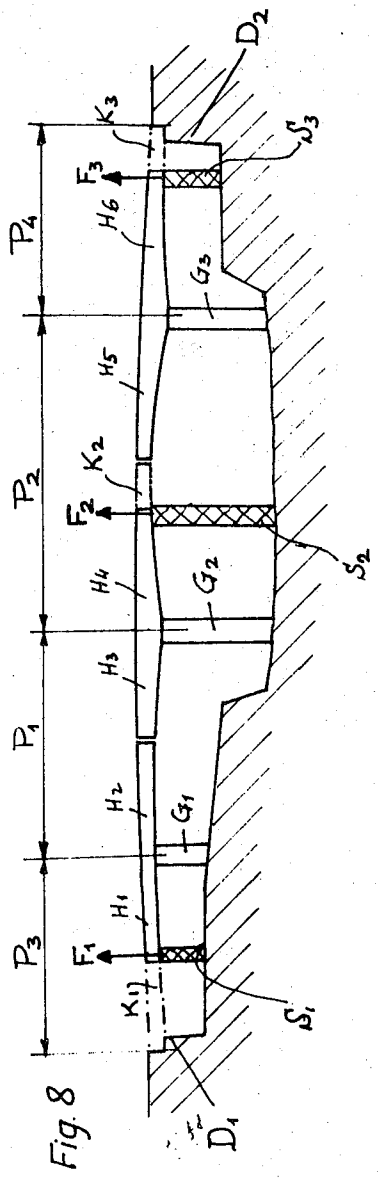


Fig. 8

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3,564,567

BUILDING METHOD FOR MULTISPANS STRUCTURES

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Int. Cl. B23p 19/00
U.S. Cl. 29—429 4 Claims

ABSTRACT OF THE DISCLOSURE

A method of building a continuous girder lying on intermediate supports and two end supports, which consists in building symmetrically on each side of each intermediate support girder sections according to balanced cantilever principle, and reducing the negative bending moment on each intermediate support by using temporary supports providing upwardly directed forces on chosen girder section ends before connecting the ends of said sections, and lastly building the end sections of the girder.

In order to reduce or dispense with scaffolding used in the construction of bridges, it has already been suggested that they be constructed to jut out cantilever-fashion, the two overhanging portions of bridge, built towards each other, then being joined at the middle of each span of the structure.

Not only are metal bridges made in this way, but also bridges of reinforced concrete and pre-stressed concrete, constructed by a succession of arch-blocks, whether these be prefabricated and then placed in position one after another and held in overhung state by pre-stressing, or are cast in situ, one by one, using scaffolding which is itself overhung from the part of the bridge already constructed.

Building bridges by this cantilever method, however, has drawbacks and difficulties, particularly when the successive spans of a structure are not of equal length.

The principal drawback, in the case of a bridge which is designed to have continuous beams when completed, is that during the carrying out of the construction, the negative bending moments on the supports are quite considerably greater than the bending moments which arise when the continuous beams are in use. Particularly in the case of a concrete structure, this necessitates giving the beams an excessive depth at the supports. On the other hand, decreasing the bending moment due to the overhang by reducing the depth of the beams at the centre of the spans may result in reducing the depth of the beams below that which may be considered necessary on aesthetic grounds.

Furthermore, this beam outline might have the disadvantage of super-elevating the carriageway of the structure which, in the case of an urban bridge, may not be acceptable.

The method of construction according to the invention overcomes these disadvantages.

According to the invention, after construction of beam sections of the structure by the balanced cantilever system, these sections are allowed to rest, through the intermediary of bearing members which provide an adjustable upwardly directed force, on temporary supports placed between permanent supports of the structure.

It is sufficient to place such temporary supports in a number at least equal to the number of spans minus one, that is to say in a number equal to the degree of hyperstatism of the beam for vertical loads.

Thus, until continuity is completed, the construction

remains at least partially isostatic and it is possible to apply to it temporary stresses to achieve the desired distribution of bending moments at the permanent intermediate supports.

The bearing members on the temporary supports are devices capable of developing measurable and adjustable forces in order to compensate for settlement of the supports. They may advantageously consist of conventional hydraulic jacks.

For each span of the structure there may be used two temporary supports, each accommodating one of the sections of the structure being built towards each other, cantilever-fashion.

Alternatively, a single temporary support may be employed, which may comprise, if necessary, an upper portion extending symmetrically, cantilever-fashion, towards the two sections of the structure.

Preferably, the temporary supports should be so positioned that, at maximum overhang, the bending moment at the permanent support is just equal to the maximum moment to which the structure is likely to be subjected at this support. This moment may be the maximum moment arising under conditions of use, or the moment which is acceptable in the provisional state. Thus, the stage of construction at which this maximum bending moment arises is also a partial test of the finished structure.

The temporary supports are advantageously timber-work piles or piers. By virtue of the bearing members, it is possible to maintain the constancy of the auxiliary upwardly directed force applied, even in cases of shrinkage and creepage of the concrete and of settlement of the temporary supports.

Moreover, by regulating the upwardly directed force provided by the temporary supports, the bending moment at each of the intermediate permanent supports may be adjusted to the final value which has been chosen by regulating the level of the supports. In certain cases, the upwardly directed force may be more or less oblique in order to allow this result to be achieved more readily.

The invention will now be described in greater detail, by way of example, with reference to the accompanying drawings, in which

FIG. 1 is a theoretical diagram of the construction of a beam by the cantilever method, the beam being bedded in at both ends,

FIG. 2 is a similar diagram illustrating the advantage of introducing temporary supports into such a construction,

FIG. 3 is a bending moment diagram of a completed beam constructed with the use of temporary supports,

FIG. 4 is a schematic side view of a bridge comprising continuous beams of varying depth,

FIG. 5 is a diagram illustrating the construction of the bridge of FIG. 4 by the method according to the invention,

FIG. 6 is a bending moment diagram showing the bending moments observed during different stages in the construction of the bridge of FIG. 4 and after completion thereof,

FIGS. 7 and 8 illustrate two other methods of constructing the same bridge, and

FIG. 9 is a diagrammatic view of one embodiment of a temporary support.

FIG. 1 illustrates the erection of a connecting beam between two supports A_1 and A_2. The beam is assumed to be constructed on the free cantilever principle, starting from each of the two supports into which it is bedded.

The two sections B_1, B_2 of the beam, which are constructed towards each other, are assumed to be carrying a certain uniform loading p per running metre, which develops negative bending moments denoted by M_1 and M_2, the maximum value of which is $pl^2/8$, where l is the length of the span in metres. If the two beam sections

B_1 and B_2 are joined at the centre C of the span, the distribution of the bending moments obviously remains the same and this distribution is manifestly unfavourable to use of a beam formed by joining the two sections B_1 and B_2.

FIG. 2 shows the effect of arranging temporary supports between the supports A_1 and A_2, each temporary support being positioned so that it applies upwardly directed thrusts F_1 and F_2 to the beam sections B_1 and B_2. For example, if it is assumed that there is a temporary support midway along each of the overhanging sections B_1, B_2 and that the values of the thrusts F_1 and F_2 are equal to $pl/2$, that is to say to the weight of each of the sections B_1 and B_2, the graph of the negative bending moment developed in each of the sections of the beam is represented by the lines m_a. If on, the other hand, the thrusts F_1 and F_2 are less than $pl/2$, a certain residual bending moment remains at the supports A_1 and A_2, the bending moments then being as shown by the lines m_b.

If the beam sections B_1 and B_2 are connected in this condition and then the forces F_1 and F_2 removed, a beam B (see FIG. 3) is obtained in which the distribution of the bending moment is represented, depending on the value of the forces F_1 and F_2, either by the graph M_A or by the graph M_B. In other words, over a part of the length of the beam, the permanent bending moment has become positive and it remains negative only near the supports A_1 and A_2.

This distribution of the bending moment is obviously far more favourable than that illustrated by FIG. 1 and, in particular in cases where the forces F_1 and F_2 are applied in the region of C, it allows the beam B to be constructed with a constant or negligibly-varying height along its entire length whereas, in the case shown in FIG. 1, the sections B_1 and B_2 have to be very generously dimensioned at the permanent supports in order to withstand the maximum negative bending moment.

FIGS. 4 to 8 illustrate application of the invention to the construction of a bridge which, as shown in FIG. 4, has two spans P_1 and P_2 of substantially different lengths crossing a river and embankment spans P_3 and P_4 which are freely supported on abutments or end supports D_1 and D_2. The bridge thus comprises three piers or intermediate supports G_1, G_2 and G_3.

Referring now to FIG. 5, in order to build this bridge by a known method, starting from each of the piers G_1, G_2, G_3, beam sections H_1, H_2 are built from opposite sides of the pier G_1, beam sections H_3, H_4 are built from the pier G_2, and beam sections H_5, H_6 are built from the pier G_3, these pairs of beam sections being constructed symmetrically in order to be balanced at all times with respect to their associated pier.

In this way, negative bending moments are developed in the beam sections at right-angles to the pier, the negative bending moment graphs for the overhanging sections on each pier being shown in FIG. 6 by the lines MG_1, MG_2, MG_3.

FIG. 5 also shows, how in accordance with the invention, the free ends of the overhanging sections are supported by temporary supports $S_1 \ldots S_5$. The length of the overhanging sections is chosen so that predetermined bending moments are not exceeded at the piers. The presence of the temporary supports $S_1 \ldots S_5$ makes it possible on the one hand to build the sections K_1, K_2, K_3, and then to adjust the bending moments at the permanent piers to a desired value. In this way, when the temporary supports have been removed and the bridge is in use and fully loaded, the stresses will remain within the calculated limits.

According to a particular feature of the invention, it is advantageous for the length of cantilever-constructed beam, as far as posible, to be such that, on each side of a pier and adjacent thereto, negative bending moments arise in the beam which are equal either to the maximum bending moments envisaged under conditions of use or, if applicable, to the maximum provisionally tolerable bending moments. In this way the beam is tested even before it is completed. Thanks to the use of the supports $S_1 \ldots S_5$, the bending moments in the beam, just prior to establishment of continuity, may be represented by the dotted line MP (FIG. 6) which has downwardly directed cusps at each of the supports, the magnitude of the corresponding moment being adjusted by regulating the thrust provided by the temporary supports.

Finally, after continuity has been established, the intermediate supports $S_1 \ldots S_5$ are dismantled and the graph of the bending moment is represented by the line MD, the shape of which is then conventional for a continuous and homogeneous beam lying on a plurality of supports. The supplementary bending moments created by the complement of dead weight and the overloads of the structure are calculated according to the formulae for continuous beams and are added to the bending moment represented by the line MD.

In the case shown in FIG. 7, it has been assumed that only the construction of the spans P_3 and P_4 by cantilever methods requires the employment of temporary supports S_1 and S_3 in order to balance the bending moments on the piers G_1 and G_3 during construction of the portions K_1 and K_2. The support S_2 serves to regulate the force F_2 during the establishment of continuity of the span P_2, and also serves as a support while continuity is being established in the portion D_1–S_2 of the bridge. First of all, continuity is achieved in the span P_2, then the forces F_2 and F_3 are applied; the parts K_1 and K_2 of the bridge are then built and continuity established between the portions H_2 and H_3 of the span P_1; finally, force F_1 is applied.

In the case of FIG. 8, it has been assumed that the cantilever construction requires temporary supports at the spans P_3, P_2 and P_4. The first stage is to achieve continuity of the span P_1; the forces F_1 and F_2 are then applied; the ends K_1, K_2 and K_3 are built and continuity established in the span P_2, after which the force F_3 is applied, which reduces the bending moment at the pier G_3, and finally the bearing pressure on the abutment D_2 is adjusted.

Of course, in the case of a pre-stressed concrete structure, in order not to exceed the admissible stress limits, it is essential to proceed in a parallel manner with tensioning of the cables and increasing the forces F_1, F_2 and F_3. Then during tensioning of the cables, which are anchored to the abutments D_1 and D_2 at the ends of the beam, the forces F_1 and F_3 will be progressively reduced.

FIG. 9 shows one possible construction of the temporary supports S. Referring to this figure, the support S shown is a timber-work structure carrying at the top distibuting bearers **1** on which rest jacks **2**, for example hydraulic jacks. By means of appropriate wedges **3**, these jacks support the beam section H; advantageously, a stack **4** of flexible sheets and rigid intermediate sheets is placed between the jack and the beam in order to allow almost free horizontal movement to the section H. By adjusting the pressure inside the jack **2** by means of an adjusting lever **5**, it is possible to regulate the reaction force, that is to say the upwardly directed force F which the intermediate support applies to the structure, and it is thus possible to compensate for any subsidence of the support at any time and the stresses brought about by shrinkage and creepage of the concrete.

To regulate the level of support on a pier or an abutment, the structure may be supported on either side of this pier or in the vicinity of this abutment by supports carried if necessary by a temporary structure.

Of course, the method according to the invention may be applied to structures other than bridges, for example buildings, reservoirs, halls, warehouses, theatres etc.

What is claimed is:

1. A method of building a structure comprising a continuous beam lying on two end supports and at least two intermediate supports, which comprises symmetri-

cally building first beam sections in cantilever fashion on each side of each intermediate support, adjusting the negative bending moment on each intermediate support to a value approximating that calculated assuming the beam is built up as a whole and lays on perfectly levelled supports by erecting temporary supports contacting each first beam section adjacent its free end to apply a substantially upwardly directed force of predetermined value to said beam section, building a connecting beam section interconnecting adjacent facing free ends of said first beam sections to obtain a continuous span over the intermediate supports, and thereafter building end beam sections between said end supports and the ends of the first beam sections adjacent the end supports, whereby a continuous beam is formed.

2. A method according to claim 1, in which the number of the temporary supports is equal to the number of spans minus one.

3. A method according to claim 1, further comprising regulating the level of the intermediate and end supports.

4. A method according to claim 1, wherein said continuous beam is made of prestressed concrete.

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CHARLIE T. MOON, Primary Examiner

U.S. Cl. X.R.

14—1, 7; 52—741