April 20, 1954 L. COFF 2,675,695

COMPOSITE STRUCTURE OF METAL AND CONCRETE

Filed June 10, 1950 2 Sheets-Sheet 1

Fig. 1

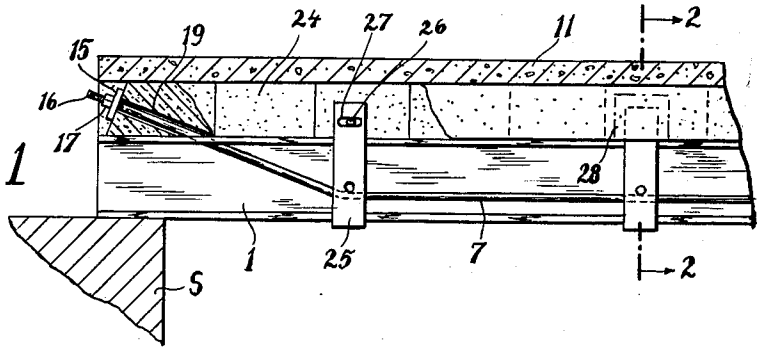


Fig. 2

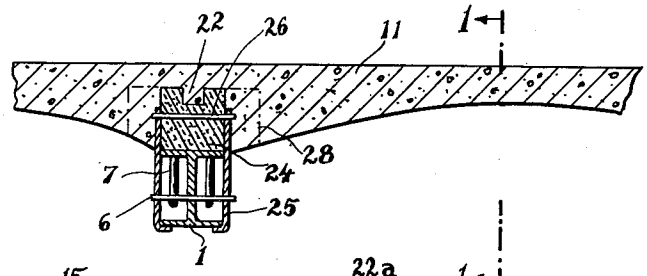


Fig. 3

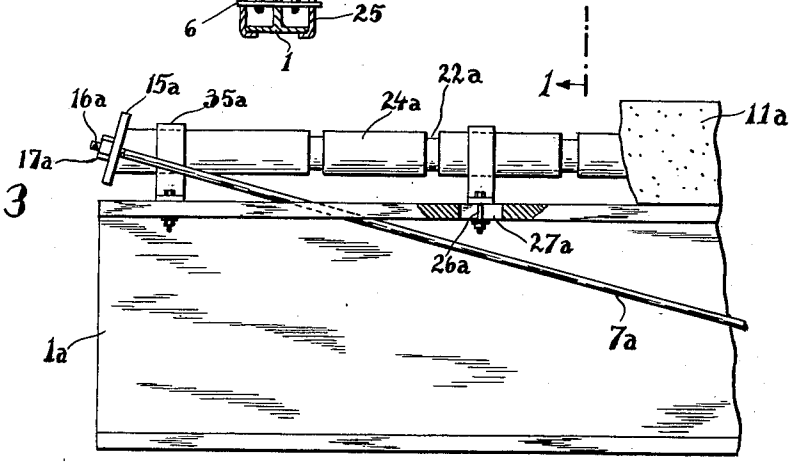
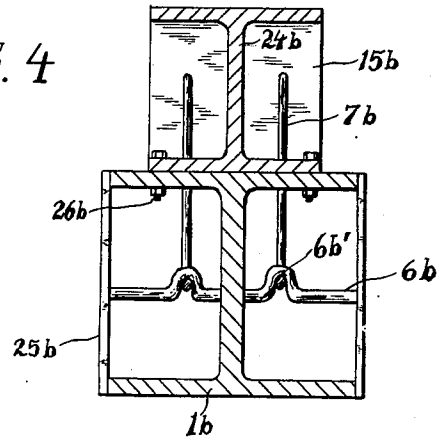


Fig. 4



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Filed June 10, 1950 2 Sheets-Sheet 2

Fig. 5

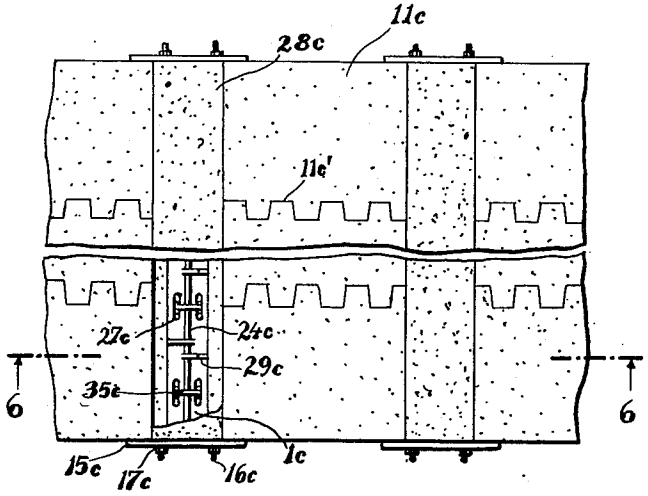
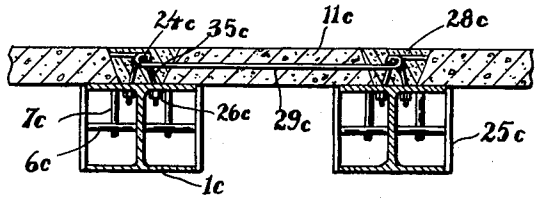


Fig. 6



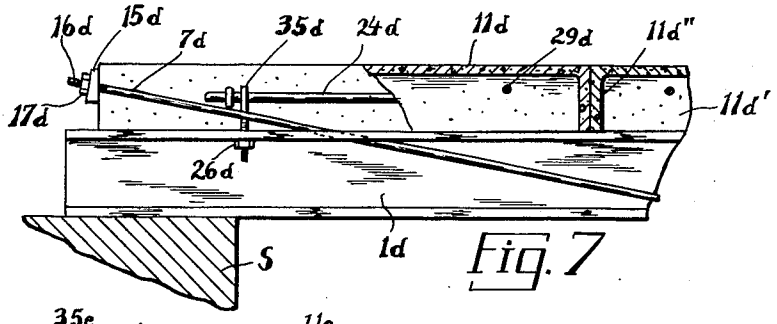


Fig. 7

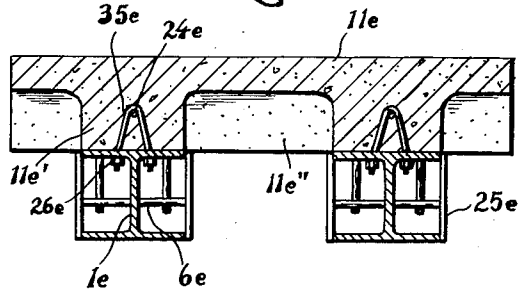


Fig. 8

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COMPOSITE STRUCTURE OF METAL AND CONCRETE

Leo Coff, New York, N. Y.

Application June 10, 1950, Serial No. 167,313

3 Claims. (Cl. 72—70)

1

The present invention relates to composite structures of metal and concrete, the application being a continuation-in-part of my co-pending application Ser. No. 649,010, filed February 20, 1946, now Patent No. 2,510,958, issued June 13, 1950.

In that application I have disclosed means in the form of a temporary or permanent reaction member for absorbing the stresses of a tensioned cable or other prestressing member, arranged to impart an upward camber to a metal shape, during the time necessary for the hardening of a concrete layer which is supported on the metal shape and to which the stress of the cable is subsequently transferred, the concrete and the metal thereafter co-operating as a unitary structure in the support of the live load applied thereto.

By way of extending the principles described in said application, and of advantageously utilizing certain features suggested but not claimed therein, it is now proposed to employ a permanent reaction member for the purpose of substantially entirely absorbing the stresses due to dead load, transmission of these stresses to the metal shape being prevented by providing for relative movement between the reaction member and the metal shape until after the concrete has been applied, whereupon the concrete layer, the metal shape and the reaction member are effectively bonded together to form the unitary structure desired. Thus, my present invention has for its principal object the provision of a composite metal and concrete structure whose deflection under dead load will be substantially nil yet which can be erected without excessive longitudinal compression of its metal shape, whereby any danger of buckling of this shape will be obviated.

A still further extension of the principles referred to leads to a structure wherein the concrete slab itself, or some portion thereof, serves as the reaction member, the essential requirement again being that effective consolidation of the slab and the metal shape be deferred until after the prestressing for dead load has been completed.

The invention will be described with reference to the accompanying drawing in which:

Fig. 1 is a sectional view, on the line 1—1 of Fig. 2, of a structure similar to that shown in Figs. 6 and 6a of my above-identified application;

Fig. 2 is a section taken on the line 2—2 of Fig. 1;

Fig. 3 is a view similar to Fig. 1, resembling that of Fig. 7a of said application;

2

Fig. 4 is a view similar to Fig. 2 but with the concrete layer omitted, the structure being similar to that of Fig. 3 but comprising a reaction member of modified form;

Fig. 5 is a fragmentary top plan view of a structure representing another embodiment of the invention;

Fig. 6 is a section on the line 6—6 of Fig. 5;

Fig. 7 is a view similar to Fig. 1, showing a modified structure resembling that of Figs. 5 and 6; and

Fig. 8 is a section similar to Fig. 2, showing yet a further modification of the structures illustrated in Figs. 5, 6 and 7.

Referring first to Figs. 1 and 2, there is shown an arched layer or slab 11 supported by a plurality of parallel, longitudinally extending steel beams 1, the ends of these beams resting on spaced supports S (only one shown). The layer 11 is partially broken away in Fig. 1 to expose a reaction member in the form of a row of pre-cast blocks 24 extending along the beam or girder 1. Side plates 25, welded or otherwise secured to the underside of beam 1, are provided at spaced locations to form anchorages for pins 6 which are underslung by a pair of cables 7, the threaded terminals 16 of these cables being engaged by nuts 17 which bear upon anchor plates 15. The anchor plates 15 bear, in turn, upon the end faces of the outermost blocks 24 and the tensioning of the cables 7 will thus keep the row of blocks in compression. It will be seen that these outermost blocks are suitably bored or channeled, as indicated at 19, to enable the unhindered passage of cables 7 which also traverse the upper flange of the beam 1 by way of suitable slots (not shown). It will be readily understood that these slots, as well as the channels 19, must afford sufficient clearance around the cables 7 to enable their displacement in planes parallel to the axis of beam 1 without the development of objectionable shear stresses in these cables.

Before the slab 11 is poured, the only positive connection between any of the blocks 24 and the metal structure is provided by the engagement of cables 7 with pins 6 and by the pins 26. The latter pins pass through certain of the blocks 24 and engage slots 27 provided in the side plates 25. The slots are sufficiently elongated to enable relative movement between the blocks and the steel beam 1 when these blocks are placed in compression by tensioning of the cables 7 preparatory to the application of the dead load, as well as after the slab 11 has been poured but before it has hardened. No substantial compression will,

therefore, be communicated from the blocks to the steel so that any danger of buckling of the shape 1 will be obviated.

The blocks 24 are preferably scored or indented, e. g. as indicated at 22, to afford interlocking engagement between the precast and the poured concrete section and to enlarge the contact surface therebetween over which bonding is to take place. The poured concrete also envelops the side plates 25 and penetrates the slots 27 thereof so that, once the layer 11 has hardened, relative movement between the row of blocks 24 and the steel shape 1 will no longer be possible. Accordingly, any further tensioning of the cables 7 (due, for example, to the application of live load to the structure) will be borne jointly by the metal and the concrete, the structure then functioning substantially as a monolithic whole.

If it is desirable to delay tensioning of the cables 7 not only for live load but also for dead load until after the slab has hardened, e. g. in order to prevent buckling of the row of blocks 24, then the imparting of any substantial compression to the steel shape 1 at the time of prestressing for dead load can be avoided by providing cavities 28 about the side plates 25, these cavities being filled with grout after completion of such prestressing.

Fig. 3 shows a steel beam 1*a* supporting a flat slab 11*a*. The upper flange of the beam has bolted thereto a plurality of brackets 35*a* slidably supporting a pipe 24*a* which represents the reaction member. In the finished structure the reaction member is imbedded in the concrete. Bearing endwise upon the pipe 24*a* are anchor plates 15*a* to which are secured the threaded terminals 16*a* of cables 7*a* by means of nuts 17*a*. The pipe 24*a* is shown recessed at 22*a* to insure intimate and interlocking contact with the concrete subsequently poured thereover.

The reaction member (pipe 24*a*) is again free to move relative to the shape 1*a* until the slab 11*a* is in place and has hardened around the brackets 35*a* and pipe 24*a*. The hardening of the slab thus immobilizes the pipe with respect to the concrete and the steel. As before, tensioning of the cables prior to and after application of the dead load (but before hardening of the concrete) places only the pipe in compression. Buckling of the pipe is prevented by the brackets 35*a*. After the concrete has hardened, the compressive strength of the pipe contributes only to a minor extent to the support of the load.

If the weight of the dead load is such that the combined steel section 1*a*, 24*a* is in danger of buckling before the hardening of the slab 11*a*, it may be necessary to employ temporary supports at intermediate points of the structure, to be removed after the concrete has set, and to delay until such time the tensioning of the cables 7*a*. In this event, too, the steel of the shape 1*a* should be subjected to little if any compression in the absence of live load, hence it will be necessary to allow for relative movement between the slab and the shape and to provide means for only thereafter solidifying the structure by rigidly coupling the two sections together. This may be done in simple manner by providing slots 27*a* in the upper flange of the beam 1*a* through which pass the bolts 26*a* holding the brackets 35*a* onto the flange. After the slab 11*a* has become strong enough to take compression, the cables 7*a* are tensioned with the nuts of bolts 26*a* loosened to enable longitudinal displacement of the brackets 35*a*, pipe 24*a* and slab 11*a* relative to the beam 1*a*. Subsequently, the nuts of the bolts 26*a* are tightened to produce a condition identical with that previously described. It may be desirable to defer tightening of these nuts until after shrinkage and plastic flow have reduced the layer or slab 11*a* to its ultimate size and after the cables 7*a* have been retensioned to compensate for this reduction in size. It will, of course, be necessary to provide suitable means for preventing the entrance of concrete into the slots 27*a* in order to maintain relative mobility between the slab 11*a* and the shape 1*a*; this can be done, for example, by the formation of cavities around these slots substantially in the manner described in connection with Figs. 1 and 2.

A variety of elongated metal reaction members may replace the pipe 24*a* shown in Fig. 3. Fig. 4 shows an I-beam 24*b* supported on and extending longitudinally of the main beam or girder 1*b*, the two shapes being joined together by means of bolts 26*b* which, however, permit longitudinal relative movement thereof by passing through longitudinal slots in the flange of either or both beams, in the manner illustrated at 27*a* in Fig. 3. By providing portions 6*b*′ of inverted U-shape in the pins 6*b*, lateral abutments are provided for the cables 7*b* which, as explained in my co-pending application Ser. No. 789,704, filed December 4, 1947, now Patent No. 2,590,685, issued March 25, 1952, prevents buckling of the shape 1*b* due to tensioning of the cables, the arrangement being similar to that shown in Fig. 2 of my co-pending application Ser. No. 57,179, filed October 29, 1948. By reason of the presence of the bolts 26*b* the buckling strength of the main beam 1*b* will be effectively added to that of the auxiliary shape 24*b*, so that the danger of buckling due to prestressing for dead load may be readily averted by suitably choosing the number and spacing of the pins 6*b*.

Figs. 5 and 6 show how the slab itself, rather than a reaction member imbedded therein, may be made to absorb the stresses due to dead load without communicating any material portion of these stresses to the supporting shape or shapes, this method being applicable wherever the dead weight of the slab is so low as not unduly to deflect the beams before the cables are tensioned, or where it is convenient to provide temporary intermediate shoring means. Furthermore, the invention in such a case enables the slab to be composed, in its entirety or for its major part, of precast elements which by the action of the dead-load stresses themselves are constrained to act as a unit. These precast elements are shown at 11*c* and are of generally rectangular configuration, each such elements spanning a pair of adjacent longitudinal beams 1*c* only two of which are shown. The elements 11*c* abut one another in longitudinal direction while being spaced in transverse direction, thereby forming longitudinal channels above the webs of the beams 1*c* which channels are ultimately filled with grout as indicated at 28*c*. Thus the finished slab consists of the elements 11*c* and of the groutings 28*c*.

Projecting sideways from each of the elements 11*c* are the ends of reinforcing rods 29*c* which are bent around longitudinally extending rods 24*c*, each of the latter rods being thereby supported in one of the aforementioned channels in alignment with the web of the respective beam 1*c* and spaced from the upper flange thereof. Stirrups 35*c* straddle the rods 24*c* and their threaded extremities, engaged by nuts 26*c*, pass through longi-

tudinal slots 27c provided in the upper flange of beam 1c. Thus it will be seen that the slab, completed when the grouting 28c in the longitudinal channels has been hardened, will retain a certain mobility relative to the beams 1c until after the nuts 26c have been tightened, this operation being deferred until after the cables 7c have been stressed against the slab to balance the structure for dead load. The tension of these cables operates at the same time to stress the longitudinally adjacent elements 11c together for concerted action, an effect which may be enhanced by form-fitting the adjoining edges together, e. g. in the interlocking manner indicated at 11c'.

The arrangement shown in Fig. 7 differs from that of Figs. 5 and 6 by the use of hollow pre-cast elements 11d in lieu of the solid slab portions 11c. These hollow elements 11d have the shape of inverted pans, forming cavities bounded by side walls 11d' and end walls 11d'', which, by virtue of their reduced weight, may be higher than the slab portions 11c, this in turn enabling the anchor plates 15d to be raised above the level of their counterparts 15c, thereby increasing the upwardly acting component of the tension in the cables 7d.

Fig. 8 shows how, in a structure comprising two longitudinal beams 1e, each pre-cast slab portion 11e may laterally extend, cantilever fashion, beyond these beams while being of double T-beam configuration by virtue of having two longitudinally extending ribs 11e' respectively aligned with these beams, a central cavity and a pair of lateral recesses being defined by these ribs and by end walls 11e''. Stirrups 35e engage longitudinal reinforcing rods 24e extending within the ribs 11e', the entire arrangement being structurally similar and functionally equivalent to that of Figs. 5, 6 and 7 (after the hardening of the grouting separating laterally adjacent elements 11c or 11d).

It may be mentioned that some means is preferably provided for breaking the bond between the vertical legs of the stirrups 35c (Figs. 5, 6), 35d (Fig. 7) or 35e (Fig. 8) and the surrounding slabs, as by asphalting or otherwise coating these legs, so that tensioning thereof by the tightening of the associated nuts will be communicated to the rods 24c, 24d or 24e, respectively, and thereby to the entire slab, rather than just to the concrete in the immediate neighborhood of these stirrups. This will force the slab into frictional contact with the supporting flanges along practically the whole area of the latter, so that the stirrups will be relieved from bearing the entire shear due to the tendency of the slab to shift under live load relative to the steel shapes.

The embodiments specifically described hereinabove have been given merely by way of illustration and not as a limitation upon the scope of the invention. Thus it will be understood that a single elongated, precast member may be used in lieu of the aligned blocks 24, and that a large variety of means well known per se may be used for anchoring this or some other reaction member to the composite structure at the opportune moment. It may also be mentioned that relative mobility between the metal shape, on the one hand, and the reaction member and/or the concrete layer, on the other hand, may be enhanced through the interposition of an anti-friction layer, e. g. of the character set forth in my aforementioned Patent No. 2,590,685.

I claim:

1. A composite structure comprising an elongated metal shape having a substantially flat, horizontal bearing surface, a concrete layer resting on said surface, an elongated, compression-resistant element imbedded in said layer and extending along said surface, at least one flexible, elastic tie member anchored to the ends of said element and extending underneath said surface, tension means maintaining said tie member under stress, bracing means supporting at least one intermediate point of said shape on said tie member, connecting means securing said element to said shape, and means including said layer preventing relative displacement between said element and said shape.

2. A structure according to claim 1 wherein said element comprises a body of precast concrete.

3. A structure according to claim 1 wherein said element comprises a metallic shape.

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