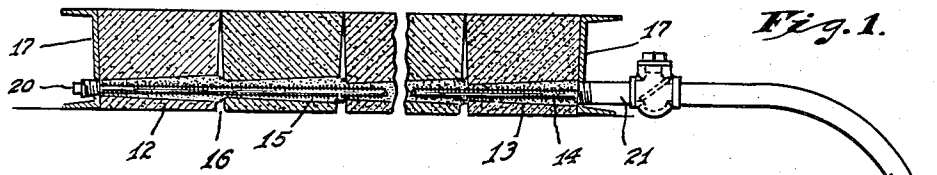
Aug. 23, 1960 H. R. CARPER 2,949,705

REINFORCED CONCRETE SLAB CONSTRUCTION

Filed June 5, 1953

2 Sheets-Sheet 1

Fig. 1.



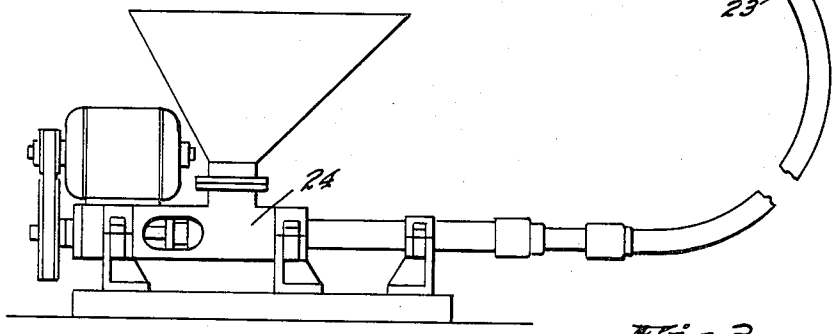
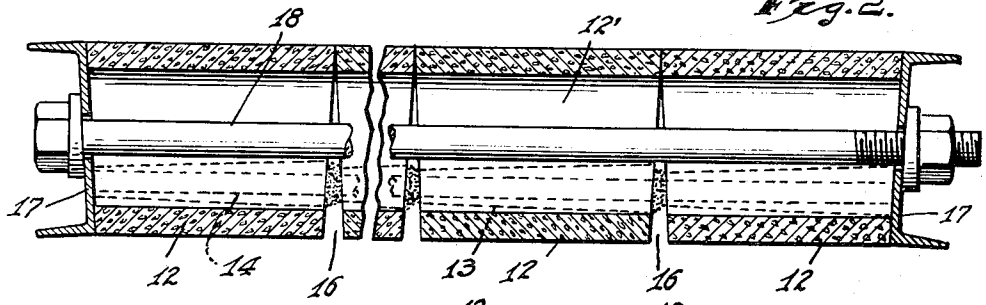


Fig. 2.



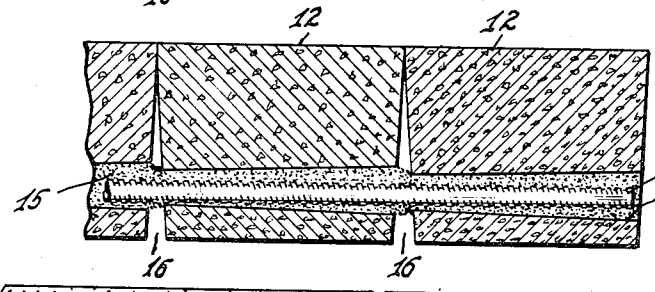
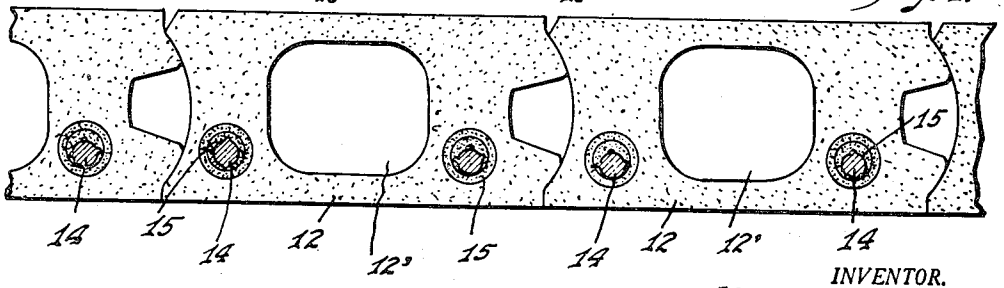


Fig. 3.

Fig. 4.



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REINFORCED CONCRETE SLAB CONSTRUCTION

Filed June 5, 1953 2 Sheets-Sheet 2

Fig. 5.

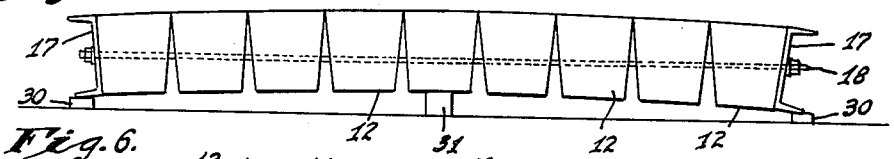


Fig. 6.

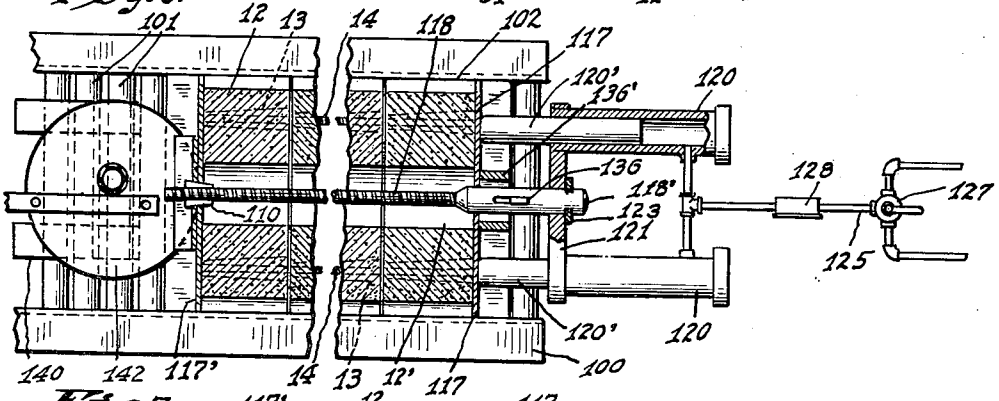


Fig. 7

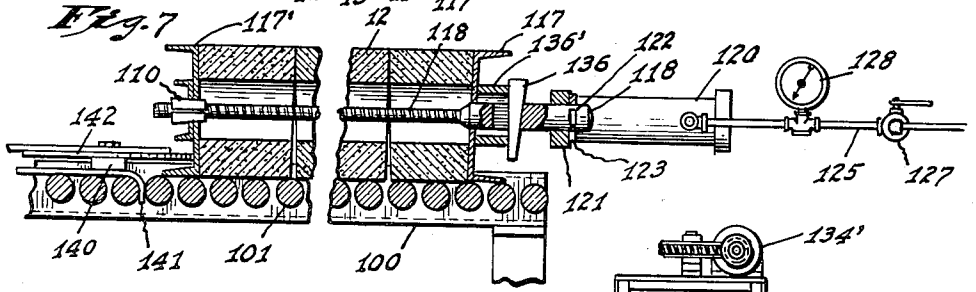


Fig. 8.

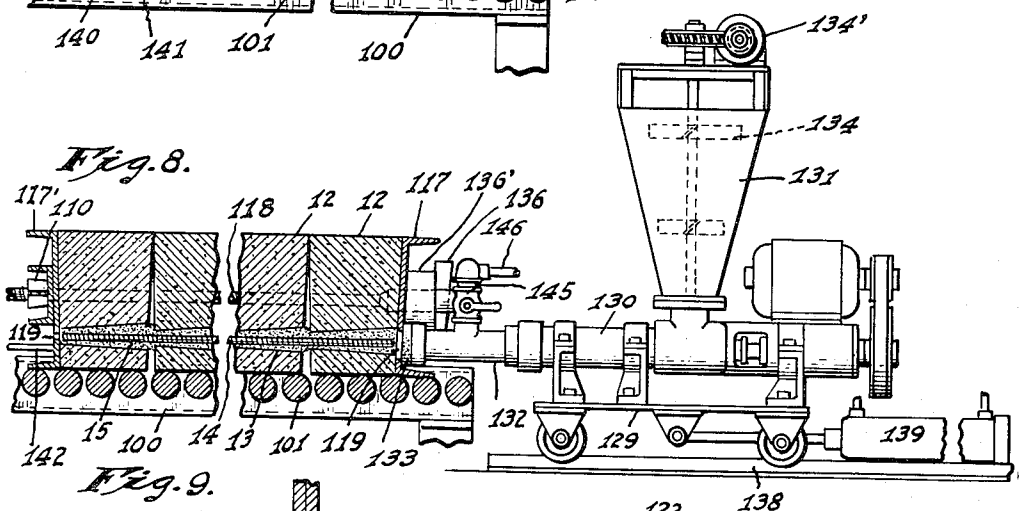


Fig. 9.

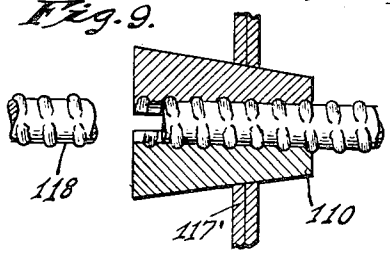
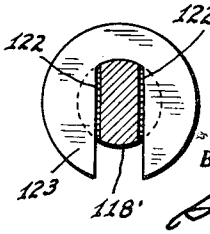


Fig. 10.



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United States Patent Office

2,949,705

Patented Aug. 23, 1960

2,949,705

REINFORCED CONCRETE SLAB CONSTRUCTION

Harold R. Carper, Indianapolis, Ind., assignor, by direct and mesne assignments, of 35 20/36 percent to Carl F. Spickelmier, 32 8/36 percent to Edith S. Greer, and 32 8/36 percent to Betty S. Spickelmire, all of Indianapolis, Ind.

Filed June 5, 1953, Ser. No. 359,883

8 Claims. (Cl. 50—536)

This application, which is a continuation-in-part of my prior application, Serial No. 258,785, filed November 29, 1951, and now abandoned, relates to a building-construction unit which can be used individually as a beam or a plurality of which can be used in side-by-side relation to form a floor or roof. More particularly, the invention of this application is concerned with a building unit comprising a row of individual blocks and one or more tension members extending longitudinally of the row, the joints between adjacent blocks being mortarless. Units of this general type are not new with me, having been disclosed, for example, in U.S. Patents Nos. 818,884 to Grimm and 1,891,597 to Jagdmann.

Probably most units of the type described being manufactured today have been made by one or the other of two somewhat different methods. In one method, disclosed in U.S. Patent No. 2,102,447 to Whitacre, hollow clay tile blocks are clamped together with their abutting faces in full contact with each other by tension members in the form of bolts acting between end blocks of the unit. Usually, in this method, the blocks are provided with voids which, after the blocks are clamped together, are filled with grouting or concrete. In some instances, additional longitudinally extending reinforcing members are embodied in such filling; in which case the bolts may remain tightened and in place to serve as tension members in the finished beam.

In the second method of making a building unit of the general type with which my invention is concerned, the blocks of the unit are clamped together in full abutting face-to-face relationship independently of the permanent tension members. The blocks are provided with aligned grooves or channels in one face thereof for the reception of tension members; and with the blocks held together as aforesaid, the tension members are disposed in such grooves and the grooves filled with grouting to secure the tension members to the blocks. After the grouting has cured, the clamping effort is relieved. In this method, as heretofore practiced, the openings which receive the tension members open into the lower face of the unit, and the unit is manufactured in inverted position with the grooved faces of the blocks uppermost.

Any unit of the type described tends to sag under dead load when placed in its final position and supported only at its ends. In commercial practice, similar units made by either of the prior methods above set forth exhibit variations in effective rigidity in the sense that they sag to different extents under dead load; and when a plurality of units are assembled in side-by-side relation to form a floor or roof, undesirable vertical offsets will exist at the joints between adjacent units. To eliminate that undesirable condition in floors and roofs formed of units made by the first method above described, it is common to form the blocks with grooves at their sides, such grooves in juxtaposed units forming upwardly opening channels extending longitudinally of the units and between adjacent ones thereof. When the units are put in place in the building, the low units are jacked up

at intermediate points until all units are flush with each other, and the channels are then filled with grouting to hold the units in such flush or conformed relation. This operation imposes substantial shearing stresses in the grouting and also results in disuniformity of the tension in the tension members of the several units.

Units made by the second method above described are brought into conformity with each other on the job by jacking up the centers of the low units until the joints between adjacent blocks open at the upper face of the unit, and shims are then placed in the joints thus opened. As will be obvious, the thickness of the shims will determine the shape assumed by the unit when relieved of its center support; and by a proper selection of shims, the units can be made substantially flush with each other.

In either system, the necessity of adjusting each individual unit after it has been put into place on the job is obviously objectionable from the standpoint of cost if for no other reason.

It is an object of the present invention to produce multiple-block building units which will possess a controlled and substantially uniform shape and effective rigidity, so that alteration of the shape of individual units when installed will be rendered unnecessary. A further object of the invention is to provide units which when assembled in side-by-side relation to form an even floor or roof will be substantially uniformly stressed so as to permit effective distribution among the several units of stresses resulting from live loads. Another object of the invention is to reduce the cost of floors and roofs constructed of units of the type described. Still another object of the invention is to produce a unit which will result in a floor or roof of improved appearance.

In carrying out the invention I form the unit, hereinafter called a slab, of a plurality of individual blocks provided with aligned openings which receive tension members grouted in place. During the curing of the grouting which holds the tension members in place, I support the slab as a beam or arch in such a way that the vertical distribution of the pressure transmitted between abutting faces of adjacent blocks will be qualitatively the same as will exist when the slab is in use. Further, I support the slab during curing with a controlled degree of arching or camber, preferably such that when the slab is put in place after curing it will assume a substantially straight or very slightly arched condition under dead load. To make possible both the desired pressure-distribution and the preferred arch form of the curing beam, the blocks are given a slight keystone shape. The blocks employed are conveniently of concrete, and desirably have relatively large central voids for the purpose of reducing their weight.

In the preferred method of making a slab, blocks in the number required for the desired slab-length are supported in a row on a table between two clamping members disposed at the ends of the row. A clamp rod is then passed through the clamping members and the central voids of the blocks at an elevation about midway between the upper and lower block faces, and a controlled clamping effort is imposed on the row of blocks. The clamping effort tends, because of the keystone shape of the blocks, to cause the slab to arch; but such tendency is controlled, as hereinafter set forth, to prevent arching beyond that which is to exist during curing of the grouting. The tension members are put in place in the openings with which the blocks are provided, and the grouting is forced through the longitudinal passages formed by such openings until such passages are substantially filled. The slab is then ready for curing.

During the curing period, the slab is supported at three or more longitudinally spaced points, the relative elevation of the points of support controlling the degree

of camber. After the grouting is cured, the clamp members and clamp rod are removed and the unit is then in condition to be put in place in a building.

Preferably, the blocks forming the slab are of concrete embodying a light-weight aggregate such as haydite, pearlite, etc. A ceiling made of my slabs is of uniform, attractive appearance, may be left in natural color or painted, and possesses sound-absorbing properties.

The accompanying drawings illustrate the invention:

Fig. 1 is a view showing a slab in longitudinal section and illustrating one form of apparatus adapted for use in introducing grouting into the openings which receive the tension members;

Fig. 2 is a longitudinal vertical section, on an enlarged scale, taken on the median plane of the slab;

Fig. 3 is a fragmental vertical section showing a completed slab with the grouting in place;

Fig. 4 is an end elevation of a floor or roof made up of a plurality of the slabs;

Fig. 5 is a diagrammatic side elevation of a slab as supported during curing;

Fig. 6 is a fragmental plan view of a preferred apparatus for use in assembling the slab;

Fig. 7 is a vertical section through the apparatus of Fig. 6;

Fig. 8 is a view similar to Fig. 7 illustrating a preferred form of grouting apparatus; and

Figs. 9 and 10 are vertical sections illustrating on an enlarged scale details of the apparatus shown in Figs. 6 and 7.

As shown in Figs. 1 to 4, a slab embodying my invention comprises a row of blocks **12** placed in end-to-end relationship and provided with aligned openings **13** which receive tension members **14** extending from one end of the slab to the other. The openings **13** are larger than the tension members **14** in cross-section, thus providing a space for the reception of grouting **15** by means of which the tension members are held in place in each block. If the finished slab is to be substantially straight or is to have a slight camber, the individual blocks **12** are formed with a keystone shape providing between them wedge-shaped spaces such as are shown, greatly exaggerated, at **16** in Figs. 2 and 3.

In constructing the beam, the number of blocks necessary to form a slab of the desired length are supported on a suitable table and arranged in a row at the ends of which clamping members **17** are disposed, and a clamp rod, shown in Fig. 2 as a bolt **18**, is passed through the clamp members **17** and the central voids **12'** with which the blocks **12** are provided to lighten their weight. When the bolt **18** is tightened to draw the clamp members toward each other, the keystone-shaped blocks **12** will be brought into contact with each other adjacent the upper face of the slab, or at least above the bolt **18**; and any continued tightening of the bolt will tend to cause the slab to arch. Any such arching tendency, however, is so controlled that any resulting camber will be less than that which is to be maintained during curing of the subsequently introduced grouting.

After tightening of the bolt **18** the tension members **14**, unless already in place, are inserted into the passages formed by the aligned openings **13**, and grouting is forced into such passages. In the arrangement shown in Fig. 1, one of the clamp members **17** is provided in line with each of the passages **13** with a removable plug **20**, while the other clamp member is provided at similar locations with fittings **21** adapted to be supplied with grouting under pressure through a hose **23** communicating with the outlet of a grouting pump **24**. In utilizing the apparatus shown in Fig. 1 for supplying the grouting, the plug **20** is removed, grouting is pumped by the pump **24** through the hose **23** and fitting **21** until it flows from the remote end of the slab, whereupon the plug **20** is inserted and operation of the pump continued momentarily to apply pressure to the grouting in the passage **13**. After both passages **13** have been filled with grouting, the hose **23** is disconnected and the slab is ready for curing.

During curing, the slab, with clamp members **17** and clamp rod **18** still in place, is supported as indicated in Fig. 5. As there shown, the ends of the slab rest on end supports **30**, while the center of the slab rests on an intermediate support **31** slightly higher than the end supports so that the slab has a slight camber. After the grouting is cured, thereby securing the tension members to the blocks in the slab, the slab is ready for use. Freed from center support such as is provided by the support **31** and supported only at its ends, as on the supports **30**, the slab will sag under its own weight. If the clamping effort exerted by the bolt **18** is properly controlled, as in a manner hereinafter more fully set forth, all slabs supported during curing on the supports **30**, **31** will sag, when relieved of intermediate support, to substantially the same extent, so that the ultimate form of each slab in side elevation will depend upon the extent to which the intermediate support **31** lies above the end supports **30**.

To attain the full benefit of my invention, it is essential that a positive moment exist at all points throughout the length of the beam during the curing period. To insure this, it is necessary that the downward convergence of the end faces of each block be sufficient, and preferably somewhat more than sufficient, to permit the degree of arching provided by the elevated intermediate support without causing the joint between any pair of abutting blocks to open at the upper face of the slab. If a keystone shape of preferred degree is imparted to the blocks, spaces **16** may exist in the curing beam, especially at points remote from support where the internal moment is relatively large.

It is also necessary that the distance between the clamping members **17** be so correlated with the elevation of the intermediate support **31** that no negative moment will exist in the beam above and adjacent such support. In this connection, it will be obvious that in the absence of the intermediate support **31** the degree of arching will depend upon the distance between the clamp members **17**, which distance can be controlled by adjustment of the bolt **18**. By decreasing the distance between the clamp members, the slab could be arched to such an extent that its center would clear the elevated intermediate support, creating a condition which would be undesirable because the intermediate support could then exert no control over the extent of arching. If, with the center of the slab clear of the intermediate support, the clamp members **17** are permitted to move apart, the slab sags until the intermediate support is engaged; and if separation of the clamp members continues, an increasing proportion of the weight of the slab is transferred from the end supports **30** to the intermediate support **31**. Should this process continue until the support **31** bore one-half the weight of the slab, the moment directly above that support would decrease to zero; and if separation of the clamp members progressed further, the moment above the support **31** would become negative.

The existence, during the curing period, of a negative moment at any point in the length of the beam is undesirable because it would cause gaps to open between adjacent blocks **12** at the upper face of the slab. If any such gaps are created during curing, control of the extent to which the slab will sag when in use is lost; for with the slab supported only at its ends, it will be incapable of supporting even its own weight until it has sagged sufficiently to close all gaps between adjacent blocks at the upper face of the slab.

One way to insure the existence of the desired positive internal moment throughout the extent of the slab is to place the slab on the supports **30** and **31**, tighten the bolt **18** until the center of the slab is clear of the intermediate support **31**, and then loosen the bolt until the slab just sags into load-transferring engagement with the support

31, a condition which can readily be determined by attempting to move such support. A different, and preferred method of insuring the desired positive moment, however, is described hereinafter.

Similar slabs cured under conditions insuring the absence of negative internal moments and the existence of equal extents of arching will all sag to substantially the same extent when supported at their ends. The positive moment obtaining during curing insures that all blocks will be in load-transmitting contact with each other above the neutral plane of the slab, where they must be in contact to sustain the beam-load imposed on the slab in use. Because of this contact of adjacent blocks above the neutral plane of the slab, any sagging of the slab after it is freed from intermediate support will immediately introduce tensile stresses into the tension members; and as the tension members are initially unstressed longitudinally they will all elongate to substantially the same extent under the stresses which they will sustain when the slab is in place and under dead-load.

Further consideration of the slab itself and its component parts will be deferred until after the preferred form of slab-making equipment shown in Figs. 6 to 10 has been described. In that equipment, the blocks **12** are assembled in a row of the desired length on a table **100** provided with a series of block-supporting, horizontal, parallel rollers **101**. The table has a length great enough to permit manufacture of the longest slab which may be desired, and is conveniently provided with an upwardly projecting flange or straight-edge **102** extending along one side.

The clamp members **117** and **117'** employed at the ends of the slab are conveniently of channel-iron having central openings for reception of the clamp bar **118** and also other openings **119** aligned with the holes **13** in the blocks **12**. In both clamp members, the central opening is considerably larger than the clamp rod **118**, which may conveniently be a length of reinforcing steel to one end of which is secured, as by welding, a head **118'** of larger diameter. Associated with one of the clamp members, shown as the member **117'**, is a two-part bushing **110** (Fig. 9) the two complementary parts of which are provided interiorly with axially extending grooves adapted to receive the clamp rod **118**. Exteriorly, the bushing **110** is frusto-conical, tapering from a diameter larger than that of the opening in the clamp member **117'** to a diameter smaller than such hole-diameter. If the exterior surface of the clamp bar **118** is roughened, as is commonly the case in reinforcing steel, the grooves in the two parts of the bushing may be complementarily roughened to prevent the rod from slipping longitudinally of itself in the bushing when the clamping effort is applied.

At what may be called the head end of the table, there is suspended thereabove a clamping mechanism shown as comprising two parallel hydraulic cylinders **120** secured to and interconnected by a cross member **121** to occupy spaced, parallel positions. The cross member is provided with a central opening large enough to receive the head **118'** of the clamp rod **118**. Near its end, the head **118'** has a pair of diametrically opposite transverse grooves **122** (Fig. 10) adapted to receive a split collar **123** through which thrusts may be transmitted between the clamp-rod head **118'** and the cross member **121**. The two pressure cylinders **120** are connected through a supply line **125**, including a flexible portion, to a source of fluid under pressure (not shown). In addition to the flexible section, the supply line may include a control valve **127** and a pressure gauge **128**.

Also mounted, as on a carriage **129** (Fig. 8), for positioning adjacent the clamp member **117** at the head end of the table is an appropriate grouting-supply apparatus preferably including two pumps **130** (only one of which appears in Fig. 8) and a grouting-supply hopper **131** arranged to supply grouting to the pump-inlets. Each pump **130** discharges through an outlet fitting **132** faced with a gasket or sealing member **133** of some compressible material, such as soft rubber. The supply hopper, which is desirably conical or provided with a conical bottom, has mounted within it a rotatable stirrer or agitator **134** which, during operation of the apparatus, is desirably continuously operated as by means of an electric motor **134'**. The carriage **129** is so positioned and the outlet fittings **130** so spaced that, after removal of the clamping mechanism **120**, **121**, the gaskets can be forced against the face of the clamp member **117** in respective alignment with the openings **119** therein.

In utilizing the equipment shown in Figs. 6 to 10, the number of blocks necessary to make a slab of the required length are placed on the table in a row, and the clamp members **117** and **117'** are arranged at opposite ends of the row, the member **117** being at the head end of the row. The clamp bar **118** is then inserted through the clamping members and the central voids in the blocks **12**. With the clamp bar positioned longitudinally of itself so that its head **118'** will project through the cross member **121** of the clamping apparatus, the two-part bushing **110** is applied to the rod at the cross member **117'** and driven inwardly until it seats in the central opening of such associated clamp member. The collar **123** is dropped into the slots **122**, and fluid under pressure is admitted to the cylinders **120** as by opening the valve **127** in the supply line. As a result of the pressure-fluid supply, the pistons **120'** of the cylinders **120** are forced outwardly into engagement with the outer face of the clamp member **117**, thus eventually drawing the blocks **10** together and applying tension to the clamp bar **118**. The magnitude of the tension applied to the clamp bar will be a function of the fluid pressure in the cylinders **120** and can therefore be measured by the gauge **128**; and when such pressure reaches the proper value, determined as hereinafter set forth, the valve in the supply line is closed.

The head **118'** of the clamp rod is provided inwardly of the cross member **121** with a diametrically extending slot, adapted to receive a wedge-like key **136**. Abutments **136'** secured to the clamp member **117** extend outwardly from the clamp member far enough to support the key **136** beyond the flanges of such clamp member where it will be accessible for the application of a key-driving effort. With pressure in the cylinders **120** maintained at the desired value, the key **136** is inserted in its slot in the head **118'** and driven downwardly until a drop in the pressure registered by the gauge **128** indicates that a substantial portion of the clamping effort initially exerted by the jacks **120** has been transferred to the clamp bar, whereupon the valve **127** is operated to relieve hydraulic pressure in the jacks **120**.

With the jacks freed of load, the collar **123** may be removed and the clamping mechanism swung aside to permit pumping of the grouting into the longitudinal passages formed by the holes **13** in the blocks **12**. In the application of the grouting, the gaskets **133** are placed over and in alignment with the holes **119** in the clamping member **117** and the pumps are operated to force grouting into the passages **13** around the tension members. I have found that with grouting of any ordinary consistency, the pressure required to force the grouting through the passage **13** until it emerges from the end thereof through the hole **119** in the clamping member **117'** is sufficient to insure that the passage will be effectively filled with the grouting. Accordingly, when grouting emerges at the remote end of the slab, the pumps are stopped.

For convenience of operation, the carriage **129** of the grouting-pump may be mounted on rails **138** and moved into and out of its operative position (Fig. 8) by a hydraulic cylinder-and-piston motor **139**. To prevent movement of the slab under the force exerted on it by the motor **139** when the carriage **129** is advanced to pumping position, I may employ an adjustable abutment at the

remote end of the slab. Such an abutment may comprise a base **140** provided with hooks **141** adapted to engage any of the rollers **101** of the assembly table. An eccentric cam **142** is pivotally mounted on the base **140** in position to be swung about its axis into engagement with the outer face of the clamping member **117'**, thus preventing movement of the slab when the carriage **129** is advanced and making possible a firm, sealing engagement between the gasket **133** and the face of the other clamping member.

If desired, the fittings **132** may be provided with valved branches **145** connected to a water supply line **146** to permit the walls of the holes **13** to be wetted before introduction of the grouting.

With completion of the pumping of grouting into both passages **13**, the slab is ready for curing in controlled, arched position as previously set forth. During curing, the key **136** remains in place maintaining the clamp bar **118** at the desired effective length.

Upon completion of the curing operation, the key **136** is driven out of the head **118'** and the clamp bar **118** and clamping members **117** and **117'** are removed for reuse in formation of additional slabs.

As a specific example of a slab made in accordance with my invention by use of the equipment shown in Figs. 6 to 10, I may cite a slab twenty feet in length, made up of thirty-two blocks each eight inches in height and of such cross-section and composition as to weigh fifty pounds per foot of slab length. The lower face of each block was about 0.006 inch shorter than the upper face. The slab embodied two tension members each ¾ inch in nominal diameter (0.44 square inch in cross-sectional area) located about two inches above the bottom of the slab, and the clamp rod **118** was of the same reinforcing steel. During curing, the beam was supported on an intermediate support **31** (Fig. 5) about three-eighths of an inch higher than the end supports **30**.

To determine the relative elevation of the center support **31** for any particular beam, I first calculate by ordinary procedure the extent to which that beam will sag at its midpoint under dead load when supported only at its ends. The relative elevation of the support **31** is then made equal to the sum of such calculated sag and the amount of any rise which the beam is to possess under dead load. The specific beam mentioned above would sag about one-quarter inch when relieved of center support, and would therefore have a rise of about one-eighth inch under dead load.

The downward convergence of the end block-faces is somewhat greater than a base value equal to the calculated downward convergence which would be possessed by the end faces of similar blocks constituting a uniformly curved arch having a span equal to the length of the slab and a rise equal to the relative elevation of the center support **31** determined as previously set forth. To prevent unduly high unit pressures between the abutting faces of adjacent blocks, as well as for other reasons, it is desirable that the excess of downward convergence over the base value should not be too great. Expressed in the terms of block-length (b), slab thickness (t), slab-length (1), and relative elevation (h) of the center support **31**, the difference (d) between the lengths of the upper and lower block faces may be calculated from the following equation:

$$d=k\frac{bht}{l^2}$$

where k desirably has a value between 10 and 30 and all dimensions are expressed in the same unit. The length-differential corresponding to the aforesaid base value may be obtained by assigning the value 8 to the coefficient k in the above equation and equals about 0.0031 for the specific slab above mentioned. The actual length-differential (0.006") employed in that slab corresponds to a value of 15.5 for k.

Control of the downward convergence of the end block-faces to the values just indicated requires accurate finishing of those faces; but such accurate finishing is indicated for other reasons. Control of slab length with any degree of accuracy requires accurate control of the length of each individual block; for any error in block length is multiplied by the number of blocks in the slab. Further, in order to obtain straightness of the slab in horizontal plan and straightness or smoothness of curvature in side elevation, finishing of the blocks with greater accuracy than that ordinarily obtained in the common type of block-making machine would be required. Taking such considerations into account, grinding is perhaps the best method of finishing the end faces of the blocks. To finish the blocks with the accuracy necessary to provide proper length, satisfactory end-face finish, and the required relative angular disposition of the end faces, the blocks may be drawn on a conveyor between the opposed, axially presented faces of two accurately located grinding wheels; and to provide the downward convergence of end faces which I desire, the axes of those wheels may be set at a slight angle to each other in a plane perpendicular to the path of block travel.

The clamping effort applied to the blocks in the assembly operation should be so controlled that any arching it produces will be less than that which is to exist in the curing slab. Preferably, the effort applied by the jacks **120** is somewhat below the minimum effort required to produce any material arching at any point in the length of the slab. That minimum slab-arching effort will depend upon a number of factors, including the length, weight, and thickness of the slab, the downward convergence of the end faces of the blocks, and the modulus of elasticity of the material from which the blocks are formed. For slabs having thicknesses of six or eight inches, weights between 35 and 50 pounds per foot, and lengths between 20 and 32 feet, I have used clamping efforts between 8,000 and 12,000 pounds, the lower clamping efforts being used on the shorter, thicker slabs. To insure adequate transfer of the clamping effort from the jacks **120** to the key **136**, the latter may be driven downwardly until the pressure indicated by the gage **128** undergoes a drop of about ten percent.

Desirably, the voids **12'** through which the clamp rod extends have a height sufficient to permit the clamp rod to extend chordally when the slab is supported in arched condition during curing. As a result, the clamp rod will undergo a decrease in length when the slab is arched for curing. In practice, however, that decrease in length will be a small fraction of the elastic elongation which the clamp rod sustains as an incident to its transmission of the initial clamping effort.

It may be noted that under conditions existing during curing the slab of my invention differs from the ordinary beam in that all tension resides in the clamp bar and is uniform throughout the effective length of that bar. Because the tension is uniform throughout the length of the beam the force transmitted between engaging block faces will be uniform throughout the length of the beam. The external moment will vary along the beam, and the internal moment will vary with it. Since the forces creating the internal moment are uniform at all points in the length of the beam, variations in the internal moment can arise only by virtue of variations in the distance between the clamp bar and the center of pressure between abutting block faces. Abutting block faces will therefore be more nearly parallel at points where the moment is small than at points where the moment is large. At and adjacent points of support, where the moment will be relatively low, abutting block faces may be in contact for the full depth of the slab, although unit pressure between them will increase toward the top of the beam. Remote from points of support, however, where internal moments are high, the area

of contact between adjacent block faces may not, and in most cases will not, extend to the bottom of the slab.

The support provided between the ends of the slab during curing need not be confined to the midpoint, and it may be desirable in the case of relatively long beams to provide supports of appropriate heights at the third or quarter points. In general, I find it well to provide a midpoint support even if other intermediate supports are provided. In making a slab of six-inch depth and thirty feet length, employing 48 blocks, I have supported the slab during curing at the midpoint and third points, the midpoint support having an elevation of one and one-quarter inches and the third-point supports an elevation of one inch.

In describing the invention above I have usually referred to the curing slab and to the forces and bending moment within it as if the slab were a beam. In use, with the grouting cured and the tension members 14 stressed, the slab is a beam; but in the curing stage, with the grouting still unset and the tension members free from stress, the slab is really a very flat arch and the clamp rod 18 or 118 serves merely to prevent separation of the clamping members 17 or 117 under the horizontal thrust which is characteristic of any arch. The clamping members could be replaced by any two properly spaced abutments without affecting the slab. While the clamp bar is useful in assembling the slab and in transferring it to the curing site, once the slab is deposited on the supports 30, 31 the clamp bar is nothing but a convenient expedient for maintaining the arch-abutments (the clamping members) at a proper spacing against the horizontal thrust exerted at the ends of the arch. The pressure transmitted from block to block within the slab is merely an incident to the arch action, and is exerted nearer hpotetahn t etoani etaoin shrdlu and is exerted nearer the top than the bottom of the slab because the downward convergence of the end faces of the blocks is greater than that which would correspond to the curvature of the arch as determined by the elevation of the intermediate supports.

I claim as my invention:

1. A method of making a composite slab from a plurality of blocks each having end faces which converge downwardly and one or more horizontal holes extending between said end faces, said holes being located in corresponding position in the several blocks and opening in said end faces at points spaced from the edges thereof whereby, when the blocks are aligned in a row with their end faces abutting, the holes will provide, extending from one end of the row to the other, a passage for the reception of a tension member and for the longitudinal flow of grouting from block to block, said method comprising the steps of so aligning said blocks with the end faces of adjacent blocks interengaging, disposing a tension member in said passage to extend into and between the end blocks of the row, forcing the end blocks toward each other with a predetermined effort to bring all the blocks into contact with each other adjacent their upper faces, forcing grouting into said passage, supporting the slab, while said effort is maintained, at longitudinally spaced points including two points at the ends of the slab and one or more intermediate points, and maintaining the slab so supported and under beam loading by virtue of its own weight until the grouting has set, the intermediate point or points at which the slab is supported being above the end points to impart a predetermined rise to the slab, and the downward convergence of the end faces of the blocks being sufficient to insure that in the supported slab the center of pressure at each joint between adjacent blocks will be above the line along which said effort is exerted.

2. The method set forth in claim 1 with the addition that the holes in the blocks lie between the upper and lower faces of the slab and cooperate to form a laterally confined passage for each tension member, the grouting being forced into each such passage from an end thereof.

3. A method as set forth in claim 1 with the addition that the line along which said effort is applied lies between the tension member or members and the upper face of the slab.

4. A method as set forth in claim 1 with the additional step of relieving said effort after the grouting has set.

5. In a method of making a composite slab comprising a row of rigid blocks adjacent ones of which directly interengage, one or more tension members extending longitudinally of said slab through aligned openings located in and below the middle of the blocks, and grouting surrounding the tension members and securing them to the blocks, the steps of forcing the end blocks of the row toward each other with a predetermined effort applied along a line between the top and bottom faces of the slab, supplying grouting to said aligned openings to fill the space therein surrounding the tension members, then, before the grouting has set and while said effort is still maintained, subjecting the slab to beam loading to create at each joint between adjacent blocks an internal bending moment of a sense such that the center of pressure at the joint will be displaced upwardly from such line, and maintaining such beam loading until the grouting has set.

6. A method according to claim 5 wherein the blocks of which the slab is made have downwardly converging, interengaging end faces and the beam loading to which the slab is subjected during curing of the grouting is created by supporting the slab in right-side-up position and only at points spaced along the length of the slab, such points of support including the ends of the slab and at least one intermediate point whose elevation is such that the slab has the form of an arch the rise of which is less than that corresponding to the downward convergence of the end faces of the blocks.

7. A method according to claim 6 wherein the points at which the slab is supported are so relatively disposed vertically as to maintain the slab in an arched condition satisfying the following equation:

$$d=k\frac{bht}{l^2}$$

in which d equals the difference between the respective lengths of the upper and lower faces of each block, b equals the length of the block, h equals the rise of the arch, t equals the thickness of the block, l equals the length of the slab, and k has a value between 10 and 30.

8. A method according to claim 5 with the addition that the beam loading to which the slab is subjected during curing of the grouting is created by supporting the slab in right-side-up position and only at points spaced apart longitudinally of the slab, such points of support including the ends of the slab and at least one intermediate point of predetermined elevation.

References Cited in the file of this patent

UNITED STATES PATENTS

818,884	Grimm	Apr. 24, 1906
1,891,597	Jagdmann	Dec. 20, 1932
2,044,382	Dunagan	June 16, 1936
2,075,633	Anderegg	Mar. 30, 1937
2,102,447	Whitacre	Dec. 14, 1937
2,413,990	Muntz	Jan. 7, 1947
2,644,497	Wilmer et al.	July 7, 1953
2,696,729	Vander Hayden	Dec. 14, 1954

FOREIGN PATENTS

122,798	Great Britain	Feb. 6, 1919
126,100	Great Britain	Apr. 28, 1919
273,004	Great Britain	June 27, 1927
330,983	Great Britain	June 23, 1930
608,150	Great Britain	Sept. 10, 1948
812,716	Germany	Sept. 3, 1951