Jan. 26, 1954 N. J. CAMPBELL 2,667,060

REINFORCED BUILDING PANEL

Filed Feb. 12, 1948

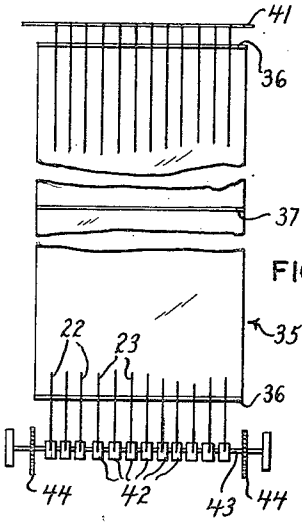

FIG. 1

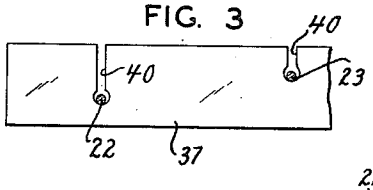

FIG. 3

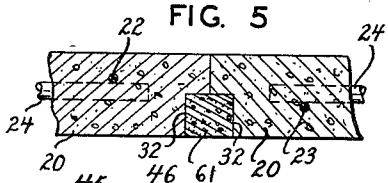

FIG. 5

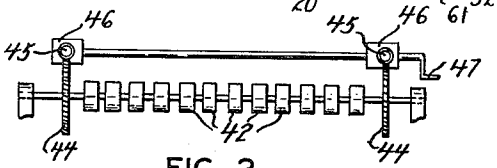

FIG. 2

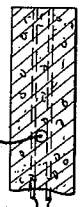

FIG. 9

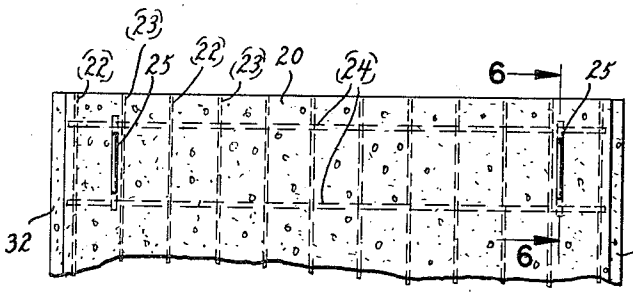

FIG. 4

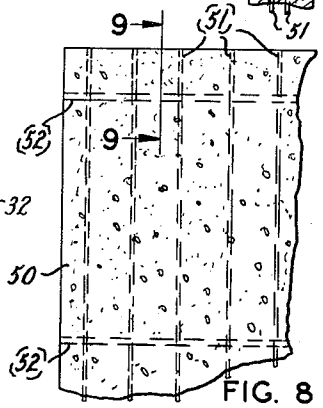

FIG. 8

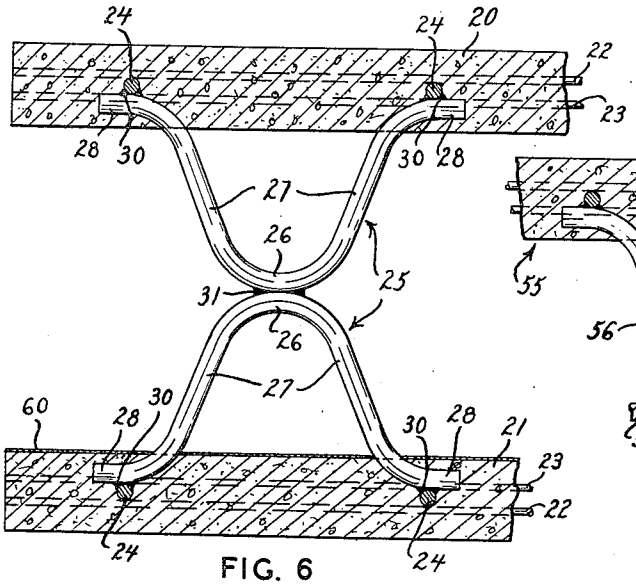

FIG. 6

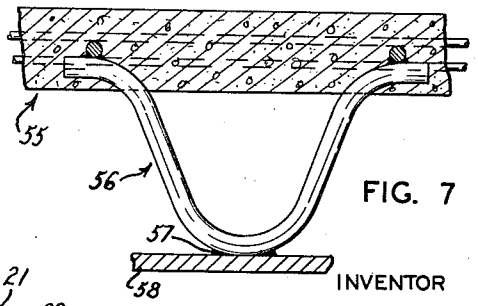

FIG. 7

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REINFORCED BUILDING PANEL

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6 Claims. (Cl. 72—44)

1

This invention relates to improvements in the construction of panel type buildings and panels therefor, and more particularly to an improved panel of low-cost, high-strength, light-weight type, and improved methods of forming and manufacturing such panels for use in a variety of building structures.

Numerous attempts have heretofore been made to design panel elements suitable for use in and as parts of the walls, roofs and like parts of residential and other buildings. However, so far as is known to this applicant, all such panels which have heretofore appeared in trade are subject to many shortcomings, among which may be noted insufficient structural strength, particularly an inability to resist high bending and shear stresses; furthermore, most or all of the panels heretofore utilized in housing assembly are difficult and expensive to manufacture and insulate, and are not readily subject to adequate water proofing treatment. Accordingly, the present invention has as its major and general objective, the attainment of a panel for general building purposes which possesses the noted attributes.

A further and highly important objective realized in the present invention consists in a structural combination of initially separate spaced slabs of concrete or similar setting material through the use of metallically united structural web members intervening the slabs, so as to produce thereof a panel which is the equivalent of a truss, and in fact may be utilized in many situations calling for a truss-like structure.

A further object of the invention is attained in an improved multiple-slab building panel providing an internal space with inherent air insulation features, or suitable for the ready reception of insultation materials of fibrous or other types, and which provides by reason of its improved construction, only a minimum thermal path between the outside and inside of the panel thus minimizing heat transfer when the panel is utilized as an element of an outside building structurt.

More particularly stated in respect to the technique, steps, and method of producing panels of the noted type, there is objectively realized an economical, efficient and low-cost production of slabs ready for final assembly as a single operation.

Another and highly important object of the invention is realized in an improved technique for utilization of prestressed concrete in parts of the slabs constituting individually or in assembly, the building panels of the present invention.

2

The foregoing and numerous other objects will more clearly appear from the following detailed description of a presently preferred example embodying the present improvements, and of an advanced technique for their production, particularly when considered in connection with the accompanying drawing, in which:

Fig. 1 is a diagrammatic top or plan view of a mold or form suitable for casting a plurality of the slabs made in accordance with the present improvements, certain parts being omitted for clearness of illustration;

Fig. 2 is a side elevation of an assembly for tensioning certain of the reinforcing elements extending through the mold or form;

Fig. 3 is a fragmentary elevational view of a face of one of the vertical partitions utilized in the form, and showing a preferred arrangement of wire slots therein;

Fig. 4 is a plan or face view of one end portion of a two-slab panel, and in a form suitable for assembly in a wall or other element of a building;

Fig. 5 is a fragmentary edge view taken in the zone of a joint between two adjacent slabs in an erected wall, partition or the like;

Fig. 6 is a fragmentary sectional view, considerably enlarged, and being taken through a corner portion of a two-slab panel, particularly along line 6—6 of Fig. 4;

Fig. 7 is a view taken similarly to Fig. 6 but showing a modified form of a panel or sectional unit of double character;

Fig. 8 is a fragmentary face or plan view of a slightly modified form of concrete slab embodying present improvements, and as particularly adapted for use in a single thickness, and

Fig. 9 is a fragmentary sectional view as taken along line 9—9 of Fig. 8.

Proceeding first to describe a preferred form of the panel and elements thereof, it will be seen that the panel is comprised of a pair of spaced concrete slabs including an upper or outer such element generally indicated at 20, and an inner or lower such element designated at 21. These slabs are or may be uniform, each being of relatively thin or shallow dimension, in proportion to its width and length, and usually for convenience, but without restrictions, of rectangular form. One example of a slab of suitable and preferred dimensions is to construct the panels in a width of 3 ft., and a length of approximately 9 ft., with a depth or thickness of 1¼

inches. As will later better appear, the improved method of making the panels enables a reduction, yet with requisite strength, of the thickness in proportion to area, hence results in obvious economies in cost and weight of materials and in shipping, handling and storage expense.

Since the two slab structures are or may be identical, a description of the structure of one, will suffice for both. Arranged lengthwise say of the slab **20** is a plurality of rod or wire elements, preferably wire of a high tensile strength and of the order of ⅛ inch diameter. These wires are arranged in approximate parallelism from end to end of the slab, and with an even center spacing, say of 3 inches, with the outermost such wires located somewhat inwardly of the lateral margins of the slab.

By further preference the wires are arranged in a plurality of depthwise spaced courses, alternate wires being near the outer surface and the intervening wires somewhat nearer the inner surface of the slab, those of the two courses being nevertheless mutually parallel, and the two courses disposed substantially equidistanctly on opposite sides of a median plane of the slab parallel to its face. By means and steps of the method hereinafter described, the wires are substantially tensioned and elongated, as by application of a high stretching effect prior to pouring the slab, whereby, incident to at least a partial release of wire tension in the course of setting, the concrete of the slab, due to the tension of the wires, is maintained under a degree of endwise compression.

The internal reinforcing structure of the slab includes as a further preference when the panel is used in external wall construction, a plurality of cross rods, these most economically being of circular section, formed of steel, and of a diameter such as to bridge and engage without dislocation the upper or lower courses of the stressed wire elements, the wire elements of the upper course being indicated at **22** and those of the lower course being indicated at **23**. A convenient size of the cross rods indicated at **24** is ¼ inch, in the example shown this being the space between the two courses of wires **22** and **23**, so that the wires make contact with the cross rods and tend to position them. In the example illustrated the rods are spaced on centers of 4¾ inches, these and other dimensions given being of course considered solely by way of example.

Assuming, as is preferred in panels for use in and as external wall elements of buildings, that such panels will be formed of two or more of the slabs **20** and **21**, it is desirable to provide suitable means for assembling the slabs securely, rigidly and permanently to each other, for which purpose there are provided a plurality of brackets, consisting of steel bars or plate elements generally indicated at **25**. These are located in the form in accordance with a pattern, fixed as by a template, locating jig or the like, so that the brackets project from the slab in a predetermined, preferably symmetrical pattern, such as will both facilitate and assure matching of those brackets of each slab with corresponding bracket elements of an adjacent slab. The members **25** will be formed of flat strip or plate, or of round stock as preferred, each member as shown, being bent into a general omega or U-shape, each bracket presenting in the completed slab, an apex or rounded bight **26**, together with divergent legs **27**, and more sharply divergent terminal projections **28**, the terminals being flared outwardly into substantial alignment and thus presenting a substantial area of anchorage within the slab.

As will appear from the drawing, the spacing of the cross rods **24** is such that they are engaged by the terminals of the U-shaped elements. This provides a firm and substantial relation between the ends of the metal brackets and the reinforcing structure within the slab. For fixation of location of the brackets **25** in the form or mold, and to secure the brackets to the rods, virtually integrally united thereto, fillet welds as shown at **30** may be employed to assemble the bracket terminals **28** to the adjacent cross rod **24**.

It should be noted that for many purposes, such as in internal partitions or the like, the individual slabs such as **20** and **21** may be employed each as a single thickness building panel of requisite strength with or without the rods **24**, and in many cases without the brackets **25**, although it is preferred for outside usage to construct a double wall panel of a pair of the slabs **20** and **21**. In the latter case the slabs are arranged in a pattern with the corresponding brackets **25** in substantial registry as shown. It will have been noted as a preference to locate the brackets so that each thereof lies in a longitudinal plane, in respect to the slab, and so that the brackets are disposed in pairs, somewhat inwardly of opposite lateral margins of the slab and with their terminals spaced from the adjacent tension wires.

For assembly of the slabs in a common panel, a pair thereof are disposed in a suitable holding device or jig, with the bights or apices **26** of the adjacent brackets securely welded or otherwise firmly secured together while maintaining the slabs **20** and **21**, in accurate parallelism, the welding zones being identified with the fillet welds indicated at **31**. After welding and following any finishing operation desired, the slab is ready for shipment and erection.

An added facility for sealing the joints between adjacent panels incident to erection, consists in a sealing channel **32** provided for in the form, so that such a groove is presented along the side margins of the front face, and if desired, also along the horizontal margins of the panel. This enables introduction of a suitable mortar or other sealing and securment material at the joint. It will have appeared from a consideration of the structure of the two slab panel, that the two surface members, such as slabs **20** and **21**, in the combination with the elements **25**, results in a truss structure of which the slabs constitute the inner or outer, or bottom and top chords, with the welded brackets collectively constituting a web structure between the chords.

Referring now to a preferred method comprising the steps in forming the slabs, and therefrom the panel units, there is indicated as a preference to provide an elongate form or mold, preferably of a length somewhat exceeding that of a plurality of the slabs. For example, in the case of a panel approximating 9 ft. in length, each slab having the same length, the inside length of the form for pouring six nine-foot panels, is of the order of 54 ft., plus some additional form length to compensate for actual length shrinkage incident to the prestressing technique hereinafter described. Such reduction in slab length may amount to several inches in a form sufficient to cast six finished slabs.

The mold generally indicated at **35**, is usually for convenience in proportions which lend themselves to building construction, the mold indicated at **35** being rectangular, and may be

formed of wood or other suitable material including a bottom, end closures 36 and removable cross partitions 37. Each of the elements 36 and 37 is preferably provided with a row of key-hole openings 40, so shaped to facilitate top insertion of the longitudinal tension wires, each such opening including a lowermost circular portion from which extends upwardly a slot to the top of the element, it being noted that the openings 40 are arranged in two depthwise staggered series corresponding to the location of the courses of the tension wires.

Located exteriorly of the mold or form and near one end thereof, is an anchor shaft or rod 41 to which the several tension wires 22 and 23 are secured. As may be desired, two of the rods 41 may be provided, one above another, each serving as an anchor element for one of the courses of wires 22 or 23. As will now be apparent, the parallel tension wires of the two courses are stranded along the top of the form and inserted in the several openings 40, which maintain the wire spacing depthwise in and laterally of the mold, and hence establish the predetermined positions of the wires in the finished slab 20 or 21.

The tension wires having been thus passed through the mold or form from end to end thereof, are extended beyond the form end opposite the anchor shaft 41, and each wire is securely fastened to a small-diameter winding reel 42, a requisite member of which are carried in spaced relation on, and fixed to a rotatable tensioning shaft 43, provided with one or more worm gears 44. Shaft 43 is obviously subjected to a very low rate of rotation, in fact its actuation will usually consist of only a partial rotation, conveniently imparted by a worm or plurality thereof, each carried by the output shaft 45 of a reduction gear unit 46, the latter being powered by any suitable, preferably rotatable means such as a hand crank 47.

The specific proportions of cement, aggregate, sand and water, to constitute the concrete mix of which the slabs 20 and 21 are formed, may be within any of the conventional proportions of materials, and their nature and exact proportion selected according to usage and stresses to which the slabs or panels are to be subject in service. Assuming now the wires 22 and 23 to have been arranged in position in the mold, and tension imparted thereto through the actuation of shaft 43. This loading is substantial in degree, and by way of reciting present preference as to practice, but without restriction, it may be of the order of 125,000 to 135,000 pounds p. s. i. cross section of each such wire. The prepared concrete mix is then poured to the requisite depth in the form or mold, and the latter subjected as may be desired and as preferred, to agitation, tamping action, or both, either of which is of itself conventional practice. Such consolidation may be accomplished by conventional means, and following which step the now poured slab is caused to set substantially completely, the extent or time of setting being determined by preliminary trials, but is in any case sufficient to create a definite, permanent bond between the wires and the mix. A strain gauge or the like may be employed at the time of tensioning so as accurately to control wire loading. Following release of tension of wires 22 and 23, the slab is permitted to age sufficiently to relieve it of any of its green character. Following this, the cross partitions or spacers 37 are removed, the slabs removed from the mold, and severance of the wires thereof effected in any suitable manner, as by a rotary saw, or gang thereof. The individual slabs such as 20 and 21 may now be stored, stacked or transported to a suitable station for their ultimate use in this form, or for assembly into the multiple-slab panels to be further described.

In further reference to the steps involved in casting the slabs, it will be understood as not necessary in all cases to include the cross rods 24, nor in all cases to utilize the brackets 25. However, if either or both of these elements are to be utilized, while the wires are yet under a low tension, the rods 24 may be inserted therebetween, and located preferably at a right angle thereto. It has been noted that the diameter of rods 24, if of round stock, is preferably such that the rods easily fill the vertical space between the inner and outer courses 22 and 23 of the wires, so as to avoid dislocation thereof. It is preferred, upon insertion of the web members or supports 25, to dispose each thereof in a vertical plane with its outturned terminals in a position to be embraced within the slab, and with each terminal metallically united, as by weld 30, to one of the rods 24.

It should be noted that for certain buildings or elements thereof, it may not be desirable to form a double slab with the slabs thereof in parallelism. However, when employed as elements of the wall of the building or the like, it will usually be desirable to dispose the slabs such as 20 and 21 in a suitable holding device or jig (not shown) close to parallelism as possible. In the location of the brackets 25 in the form, it has been noted as a preference to arrange these in a symmetrical pattern, and with the several brackets disposed in rows projecting outwardly of the adjacent faces of the web members, and each extending at substantially a right angle from the slab face. Such an arrangement assures that when the slabs carrying the brackets are disposed in an assembly jig, the extremities of the brackets will engage, preferably abutting each other, in which zone of contact they are welded together, as indicated by the fillet welds shown at 31. Upon completion of welding, and any further finishing operations desired, the two-slab panel is now in condition for shipment and erection.

A variant in structure and practice of producing a single-slab panel is shown by Figs. 8 and 9, wherein the slab is generally indicated at 50. In this form wires 51 may constitute the sole internal metal reinforcement, and are tensioned in accordance with the steps described in forming slabs 20 and 21, other steps of pouring, etc., being similar in the case of slab 50. This form of slab is desirably provided with cored passages or bores 52, extended transversely but fully within and through the slab, serving to receive tie elements such as metal rods or bolts (not shown) used in erection and assembly, for example in inside work such as partitions. The passages 52, with bolts or the like therethrough, enable assembly under conditions of edgewise compression.

A desirable variant for some purposes is a floor panel of a double character, generally indicated at 55, Fig. 7, in which a complete slab and bracket assembly 56, similar to 20—25 as described, is secured, say in parallel relation as by welding at 57, to a metal plate 58. Although the two-slab panel is admirably adapted for use as flooring sections, the panel or section 55 offers advantages for many other purposes. In this

structure, the outer slab is the counterpart of slab **20**, and the element **58**, the counterpart of slab **21**.

Certain added steps may sometimes be desirable, particularly when the panels are for use in residential buildings. One such example consists of the treatment of the outer face of the innermost slab of each panel to render it moistureproof and waterproof, for example by the addition of a layer or coating of a bitumastic material **60**. Further, it is sometimes desirable to form a seal between the adjacent panels following their erection in the wall or the like. For this purpose there is provided along the lateral margins of the front face of each of the adjacent panels, such as **20**, the rectangular undercut channel indicated at **32**, these mating in adjacent panels for the reception of any suitable sealing material or attachment compound **61**. Such channels are easily formed by insertion of filler strips (not shown) in the mold, and may be similarly formed at top and bottom of the outside slab when desired.

It will have been noted that the open end construction and the spacing between the brackets of the two-slab panel, also in panel **55**, provides for the ready introduction of fibrous or other insulation material as may be desired, and that by reason of the relatively restricted areas of union of the two spaced slabs, these consisting of the welding or securement zones, only a minimum path of conductive heat travel obtains between the inner and outer slabs of the panel, whereby the panel is inherently of a highly insulated character.

Although the invention has been described by making particularized references to a preferred structure and method, the detail of description is to be understood solely as instructive, rather than in any limiting sense, numerous variants being possible without departure from the full intended scope of the claims hereunto appended.

I claim as my invention:

1. A panel for use in multiple to constitute the walls, roof and like structure of a building, each said panel consisting of a pair of relatively thin concrete slabs of rectangular shape, a plurality of courses of steel wire of high tensile strength, the wires of each course being substantially parallel and spaced, and the courses thereof being depthwise spaced within the slab, a plurality of cross rods of a diameter to bridge the space between the courses of wire, the wire within the slab being permanently longitudinally stressed; a plurality of steel brackets each of approximately U-shape and each having its ends embedded within the slab, the free ends of the arms of the brackets diverging therefrom so as to form outstanding terminal portions, the brackets being disposed with their terminal portions within the slab and with the rods adjacent said terminal portions whereby firmly to anchor the brackets within the slab, tie means engaging certain of said terminal portions and the cross rods; a pair of said slabs forming the faces of each panel and being arranged in back-to-back relation, the spacing therebetween approximately twice the projecting dimension of the individual brackets; the brackets being arranged in predetermined corresponding patterns in and on each of the slabs, and the bight portions of the adjacent brackets being welded together to maintain the spacing and assembly of the slabs in the panel.

2. A building panel consisting of a pair of concrete slabs, each of said slabs including a series of laterally and depthwise spaced, substantially parallel elongate pre-tensioned elements within and bonded to the concrete matrix of the slab keeping the slab under permanent compression, metal elements extended across, and depthwise bridging certain of said elongate elements, a plurality of metal brackets projecting normal to the faces of and in predetermined pattern from each of the slabs, said brackets being secured to the metal bridging elements and forming a closed loop exteriorly of each slab, the loop portions of opposed brackets of said slabs being secured together to hold said slabs in spaced relationship.

3. A building panel consisting of a pair of concrete slabs, a series of laterally and depthwise spaced, elongate pre-tensioned elements within and bonded to the concrete matrix of the slab keeping the slab under permanent compression, rod elements extended across, and depthwise bridging certain of said pre-tensioned elements, a plurality of brackets projecting outwardly of the faces of said slabs, each of said brackets being secured to the rod elements and being of approximately U-shape to form a closed loop exteriorly of each slab, the bight portions of the loops of opposed brackets of said slabs being secured together to hold said slabs in spaced relationship.

4. A panel for use in multiple to constitute the walls, roof and like structure of a building, each said panel consisting of a pair of relatively thin concrete slabs of rectangular shape, a plurality of courses of steel wire of high tensile strength, the wires of each course being substantially parallel and spaced, within the slab, a plurality of cross rods of a diameter to bridge the space between the courses of wire, the wire within the slab being permanently longitudinally stressed, and being bonded to the concrete matrix of the slab keeping the slab under permanent compression; a plurality of steel brackets each of approximately U-shape and each having its ends embedded within the slab, the free ends of the arms of the brackets diverging therefrom so as to form outstanding terminal portions, the terminal portions of each bracket being disposed in mutual alignment, the brackets being disposed with their terminal portions within the slab and adjacent successive cross rods, tie means securing the terminal portions of each bracket to successive cross rods, whereby to anchor firmly the brackets within the slab; a pair of said slabs forming the faces of each panel and being arranged in back-to-back relation, the spacing therebetween being approximately twice the projecting dimension of the individual brackets; the brackets being arranged in predetermined corresponding patterns in and on each of the slabs, and the bight portions of the adjacent brackets being welded together to maintain the spacing and assembly of the slabs in the panel.

5. A building panel consisting of a concrete slab, a series of laterally and depthwise spaced, substantially parallel elongate pre-tensioned elements within and bonded to the concrete matrix of the slab keeping the slab under permanent compression, rod elements extended across, and depthwise bridging certain of said pre-tensioned elements, a plurality of bracket elements projecting normal to the face of and in predetermined pattern from the slab, said bracket elements being secured to the bridging rod elements and forming closed loops exteriorly of the slab, and means spaced from and in opposed relation to said slab, said means being secured to the ex-

terior loops of said bracket elements, whereby to hold the slab in spaced relation to said means.

6. A building panel consisting of a concrete slab, a series of laterally and depthwise spaced, substantially parallel elongate pre-tensioned elements within and bonded to the concrete matrix of the slab keeping the slab under permanent compression, rod elements extended across, and depthwise bridging certain of said pre-tensioned elements, a plurality of bracket elements projecting normal to the face of and in predetermined pattern from the slab, said bracket elements being secured to the bridging rod elements and forming closed loops exteriorly of the slab, and a metal plate spaced from and in opposed relation to said slab, said plate being secured to the exterior loops of said bracket elements, whereby to hold the slab in spaced relation to said plate.

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