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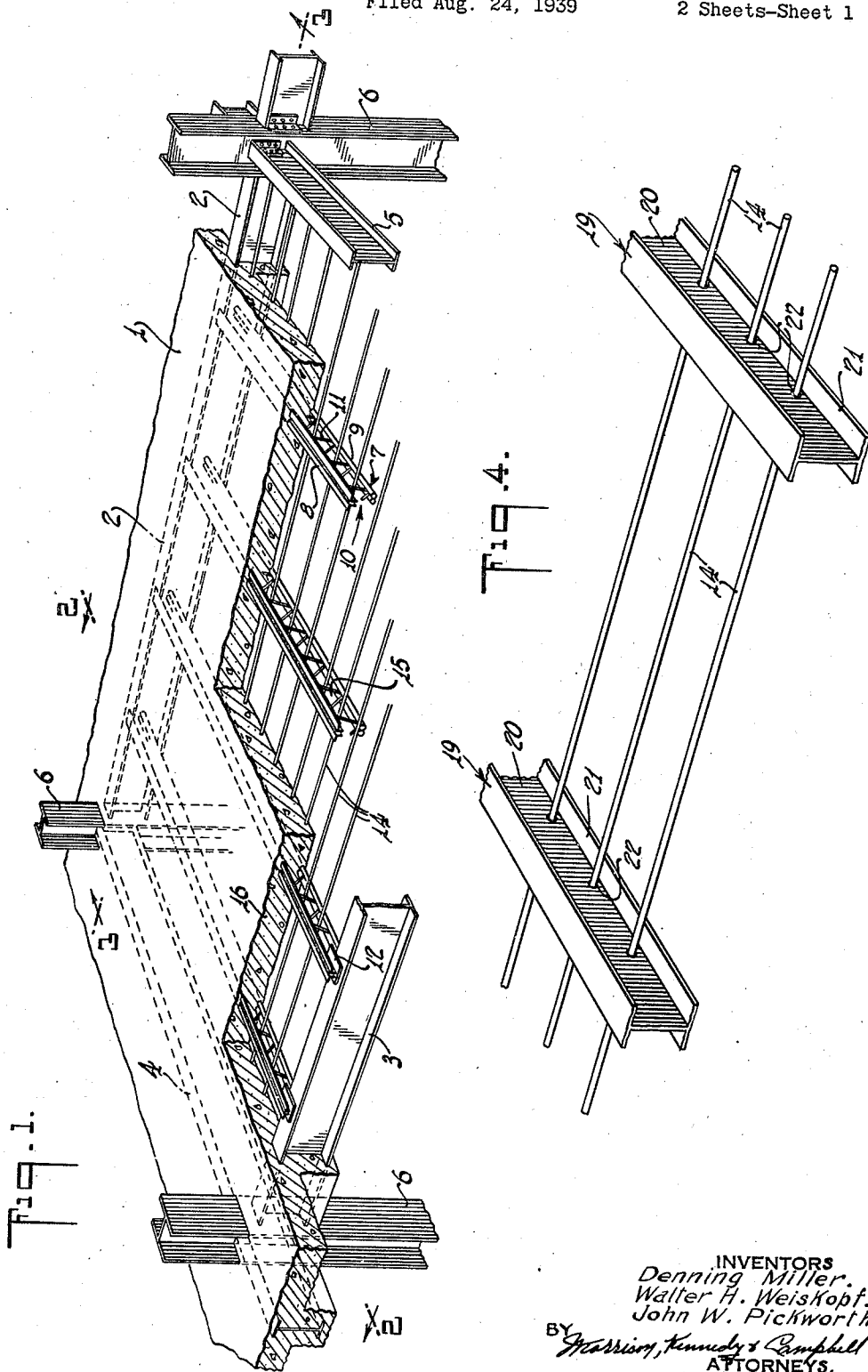
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2,296,863

REINFORCED CONCRETE FLOOR CONSTRUCTION

Filed Aug. 24, 1939

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 2.

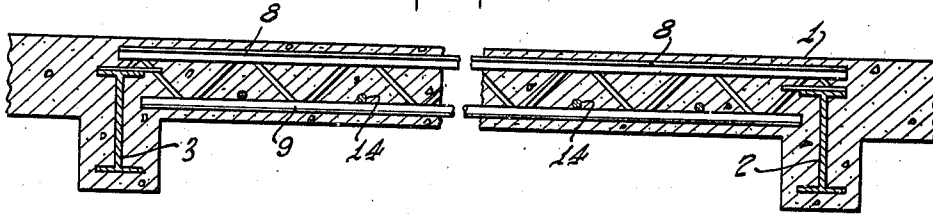


Fig. 3.

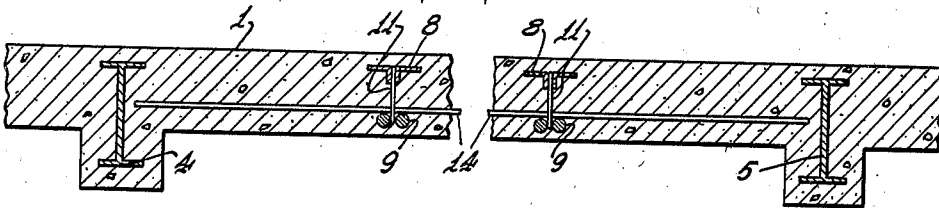


Fig. 5.

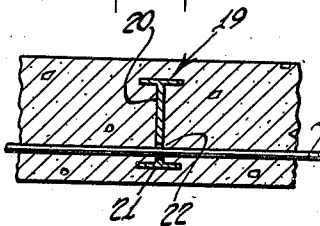


Fig. 6.

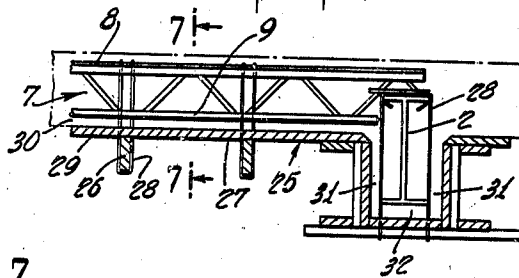
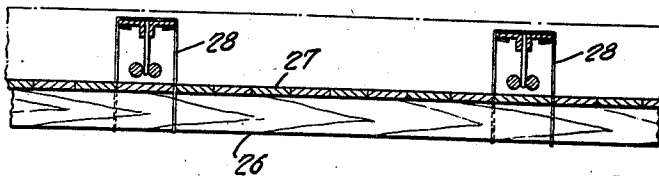


Fig. 7.



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UNITED STATES PATENT OFFICE

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REINFORCED CONCRETE FLOOR
CONSTRUCTION

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This invention relates to reinforced concrete floor construction, and more particularly to reinforced concrete floor panels for buildings and the like, wherein the floor panel constitutes a spanning slab between supports or abutments which bound the panel area.

A reinforced concrete floor construction of the character referred to usually comprises a plurality of rectangular panels, square or oblong, resting on marginal supports, such as girders, which form a part of the main structural framework, or such as bearing walls of suitable masonry materials, or on a combination of both. It has been a common practice heretofore to construct reinforced concrete floor panels in accordance with what is known in the art as a two-way floor system, and this system, generally speaking, consists in comprising in such a panel two sets of reinforced-concrete beam elements, usually arranged at right angles one to the other, so as to distribute the floor loads to both the side and end panel supports. In these beam elements the tension stresses are resisted by two sets of embedded steel reinforcing elements, each set of reinforcing elements corresponding to one of the sets of beam elements. The compression stresses for both sets of beam elements are resisted by the concrete; the concrete particles, being able to withstand compression along two horizontal axes at right angles to each other even better than along a single axis, thus serve in a double capacity. This property of so-called two-way systems is an important factor in their efficiency and economy.

A simple type of two-way reinforced concrete floor construction, and one which is widely used in buildings designed for human occupancy for spans, say, up to sixteen or eighteen feet, is that in which the two sets of steel reinforcing elements are embedded in a solid slab of concrete of uniform thickness. In order to reduce the dead load of solid stone or gravel concrete, two-way systems involving the use of weight saving inserts, such as hollow blocks or metal pans, have been successfully introduced into building construction in cases where it has been convenient or economical to space the supporting members at the opposite sides of the panels more widely apart than eighteen feet. In this latter type of floor system, each of the blocks or pans is surrounded on all four sides by reinforced-concrete portions constituting beams, and the blocks or pans are so aligned that each of the beams runs in a straight line between each opposite pair

of the two pairs of marginal supporting members.

The formwork employed in the construction of the floor by generally prevailing systems is removably supported in position either by shores or posts resting on the floor below or by special construction-bridging, as the case may be, sustain the full load of the concrete until the latter has hardened sufficiently to sustain its own weight and the weight of any construction loads which may be placed upon it, including any shoring for the formwork of the floor next above it. The concrete which is employed is usually stone or gravel concrete, because cellular or light-weight concretes as a rule do not possess sufficient compressive strength for use with the conventional type of two-way system. In any case a considerable period of time must be allowed to elapse for the concrete to harden sufficiently before the formwork can be removed, this period being usually from one to two weeks depending mainly on the size and loading of the panel and also upon such factor as temperature and weather. Such method of construction is not only costly as far as labor is concerned, and uneconomical of materials, but is dangerous, cases being not uncommon where the shoring has been taken away before the concrete was sufficiently hardened to bear construction loads which had to be placed upon it, and, as a result, the floor panel has collapsed. In some cases where such collapses have occurred in multi-storied buildings, several panels, one below the other, have been broken down as a result of the failure of the topmost.

A further serious disadvantage of stone concrete is the difficulty attending the cutting of chases, holes, or other openings in floor slabs composed of this material. In spite of the great care exercised in modern design and construction, extensive cutting and trimming of the slabs and fireproofing must generally be resorted to in order to install the mechanical work, this work usually going forward from several days up to six months after the concrete work has been installed and the concrete thoroughly hardened. Further, after the building is occupied it may be necessary or desirable to cut openings between floors for the installation of chutes, ducts, stairways, dumbwaiters, pipes or conduits. In such circumstances, stone concrete requires slow, noisy and laborious cutting, with attendant discomfort to the neighboring occupants.

Other objectionable features and disadvantages of the prior art could be pointed out, but it is

thought that they will be obvious to those skilled in the art, and need not be set forth at this time.

The general object of the present invention is to obviate these various objectionable features of the prior art and, to this end, the present invention contemplates a new and improved reinforced concrete floor construction, as well as a new and improved system of reinforcing and method of constructing reinforced concrete floors.

The present invention, in one of its broader aspects, comprises a reinforced concrete floor construction of the two-way class which includes a system of two sets of elements for reinforcing the concrete of each floor panel or section one set of such elements serving the two-fold purpose of (a) sustaining and transmitting the weight of the mass of concrete to the marginal supports by which such elements are supported and (b) functioning cooperatively with the other set of elements to resist tensile stresses and with the concrete acting to distribute the loads which may be superimposed on the concrete to all or both pairs of the marginal supports of the panel. Usually, the new and improved reinforced concrete construction hereof is embodied in a floor comprising one or a plurality of substantially square or other rectangular panels, each of which is bounded or enclosed and defined by two pairs of spaced-apart marginal supports forming a part of a structural framework. A plurality of parallel, laterally spaced-apart joists such as shallow trusses or beams are arranged to span the space between one opposed pair of the marginal supports and to be supported thereby, and a plurality of steel reinforcing bars are arranged in spaced relation to one another to extend between the other opposed pair of marginal supports, such bar elements running crosswise, as at right angles, relatively to the joist elements. The trusses or beams are designed and formed of strength sufficient not only to adapt them to act alone to sustain and transmit to the marginal supports with which they are associated the entire weight of the floor construction of the panel, but also to act jointly with the steel bars and with the concrete for the function of distributing to both pairs of marginal supports the loads expected to be superimposed on the finally set and hardened concrete in the panel. The system of reinforcing permits the use of light-weight concretes having densities of less than 140 pounds per cubic foot, and having ultimate compressive strengths of less than 2,000 pounds per square inch.

Referring to the drawings:

Fig. 1 is a perspective view, partly broken away, showing an illustrative embodiment of the improved reinforced concrete floor construction of this invention;

Fig. 2 is a vertical section, partly broken away, taken substantially on the line 2—2 of Fig. 1, looking in the direction of the arrows;

Fig. 3 is a vertical section, partly broken away, taken substantially on the line 3—3 of Fig. 1, looking in the direction of the arrows;

Fig. 4 is a fragmentary perspective view, showing a modification of the invention;

Fig. 5 is a fragmentary vertical section, showing a beam similar to that shown in Fig. 4;

Fig. 6 is a fragmentary vertical section, showing the formwork in place; and

Fig. 7 is a sectional view, taken substantially on the line 7—7 of Fig. 6, looking in the direction of the arrows.

As already stated, a two-way reinforced concrete floor system is usually formed of a plurality

of square or other rectangular shaped panels, defined by girders of the framework, or by other forms of supports, of the building or other structure of which the floor forms a part. Referring

particularly to Fig. 1, there is shown a floor panel 1, which is rectangular in shape and supported by two pairs of marginal supports or girders 2, 3 and 4, 5, horizontally disposed in parallel spaced apart relation to one another with the ends of one pair of girders 2, 3 adjacent the ends of the other pair of girders 4, 5. The ends of the two pairs of girders 2, 3 and 4, 5, as shown in the drawings, are secured in a customary manner to vertical columns 6, which thereby support the panel 1 at its four corners.

According to a preferred embodiment of the invention, and as shown in the drawings, the space between the two parts of girders 2, 3 and 4, 5, which define the panel 1, is spanned in one direction (in this case the short span between the pair of girders 2, 3) by a plurality of joists shown in the form of shallow trusses 7 arranged in parallel, laterally spaced-apart relation to one another, being substantially equally spaced apart one from another and from the pair of girders 4, 5. Ordinarily, the trusses 7 will be spaced apart from three to five feet, or a distance approximately equal to one-quarter the length of the trusses themselves, which in this case is the distance between the supports 2, 3, for reasons relating to the effective development of the compressive strength of the concrete, as is well-known in the art. The trusses 7 are in the form of shallow structural members comprising each an upper chord 8 and a lower chord 9, spaced apart vertically and connected by an open intermediate web 10. The open web 10 is formed of a continuous, bent bar 11, arranged to extend between the chords 8 and 9 at an inclination thereto and returning at recurrent intervals to the top and bottom chords, to which it is attached as by welding. At each end, each of the trusses 7 is formed with a supporting plate 12 connected to the intermediate web 10 and disposed between the upper and lower chords 8 and 9, respectively, the plate 12 being adapted to rest directly on the pair of girders 2, 3 and be secured thereto. Trusses of open character are well-known in the art and vary somewhat in structural details, so that the form shown and described is merely illustrative of a preferred type of truss.

A plurality of steel reinforcing bars 14 of suitable size and shape according to the engineering requirements are arranged to extend between the pair of girders 4, 5 substantially at right angles or other crosswise angle to the trusses 7, being spaced apart laterally approximately equal distances from one another. The form of the trusses 7 lends itself to the location of the bars 14 in position, since the bars rest on the top surfaces of the lower chords 9 of the trusses and can be arranged in open spaces 15 of the web 10.

Figs. 6 and 7 show the relation of the parts when the formwork is installed. According to the arrangement shown, the formwork 25 comprises a series of supports or stringers 26 extending in one direction below the trusses 7 and supporting a sheathing 27. The stringers 26 are arranged on edge and suspended from the trusses 7 by hangers of heavy wire 28, the wire 28 being bent over and thereby fastened to the upper chords 8 of the trusses 7. The supports 26 are located a sufficient distance below the trusses 7 so that when the sheathing of boards 29 is laid on top of the supports 28 it will be spaced from

the lower chords 9 of the trusses 7, as at 30, to permit the concrete to surround and fireproof the chords 9. In the region of the marginal supporting girders, the girder only being shown, the formwork 25 is suspended therefrom as from the trusses 7, being spaced at the sides and below the girders as at 31 and 32, respectively. When the formwork 25 is to be taken down, the wire 28 is cut to permit the removal of the stringers 26 and sheathing 27 and the ends of the wires then trimmed off at the under surface of the concrete.

In the preferred mode of assembly of the parts, the trusses 7 are first located in position with the plates 12 resting on the pair of girders 2, 3 and secured thereto as by welding or wiring. Then the formwork 25 is installed, the formwork, as already stated, being suspended from the trusses 7 at an elevation with the upper surface thereof spaced below the bottom surfaces of the lower chords 9 of the trusses the proper distance according to the depth to which the chords 9 are to be embedded in surrounding concrete. Thereafter, the reinforcing bars 14 are laid across the top surfaces of the lower chords 9 and definitely located in their proper spaced apart positions, and the concrete 16 is next placed or poured over the structure to be received on the formwork between the girders and form the concrete panel slab, the concrete completely embedding the trusses 7, and the reinforcing bars 14, and at the same time covering and fireproofing the girders 2, 3 and 4, 5.

Since the formwork is hung from the trusses 7, it is clear that the weight of the concrete 16, from the time it is first poured and set, is carried by the series of joists or trusses, which thereby constitute a one-way system with respect to the dead weight of the floor panel. After the concrete has hardened, and hence for all loads other than the dead load of the slab, the construction acts as a two-way system, in which the lower chords 9 of the trusses 7 act as the tensile reinforcement for one set of concrete beam elements and the reinforcing bars 14, substantially at right angles thereto, act as the reinforcements for the other set of concrete beam elements.

In designing the trusses 7, the area or size of the top and bottom chords 8 and 9, respectively, will be governed by the following considerations: first, the top chord 8 must be of sufficient size and stiffness to resist the compressive stresses resulting from the dead weight of the slab; and, secondly, the bottom chord 9 must be of sufficient size to resist two successive tensile stresses, first those resulting from the dead load of the slab, as to which the trusses 7 are acting as simple beams or a one-way system, and secondly, those resulting from the superimposition of the live load and such added dead loading as fill, finish, partitions, and similar constructional items, when the lower chords 9 act as reinforcing for one set of concrete beam elements of a two-way system. It is to be understood that the numerical calculation of the stresses and of the related size of the truss elements, are in accordance with the established engineering formulae and requirements of structure of this character.

It is an important feature of the present invention that it comprises the use of shallow joists or trusses which become an integral part of a two-way reinforced concrete floor system. Because of the use of trusses, the formwork can be hung therefrom, effecting a great increase in the speed of construction, a reduction of hazards at-

tending concrete floor construction, and a saving of cost as compared to two-way systems of the prior art. Moreover, the formwork can be removed in a relatively short time (two to three days, in normal summer weather) after the concrete is poured, since it is necessary to wait only until the concrete has stiffened sufficiently to support its own weight across the span between the trusses with a reasonable margin of safety, this span being, of course, a fraction only of the entire span across the panel in either direction. Thus, the form material is rendered available for use over and again more frequently than heretofore, with an appreciable reduction in the cost of the construction being realized thereby, as well as greater convenience and smaller investment.

It is essential to the strength of floors of comparatively shallow depth, to which class two-way reinforced concrete floors may be said to belong, that substantially the full designed thickness of the floors be obtained. Therefore, a feature of the invention which is highly useful and convenient arises from the use of shallow trusses as part of the construction, since the trusses afford a rigid top chord close to the top lever of the finished floor construction. In accordance with the accepted requirements for fireproofing of such members, the top chords of the trusses will be located generally approximately from three-quarters to one inch below the top surface of the floor construction, and the trusses thereby provide an easy and convenient assistance or gage for the step of screeding the concrete to the proper thickness of the floor and of checking and inspecting its depth as it is poured.

Another feature of the invention is that the top chords or flanges of the trusses provide, without added expense or labor, suitable supports for the runways over which the concrete is wheeled into place. They serve in this capacity to maintain the runways at a vertical distance well above the position of the reinforcement and of the mechanical work, which elements of the construction cannot be damaged or disarranged as the runways are transferred from one location to another during the progress of the work.

A further feature of the invention is the greatly improved ease with which the reinforcement can be detailed, erected and inspected. Heretofore, extreme care has been required in the detailing, bending, placing and inspecting the reinforcing. Detailed plans of the position, size and spacing of the reinforcement must be prepared and carefully followed, to be sure that the appropriate members are correctly placed in the proper panels. In the new and improved system of two-way floor construction of this invention, these difficulties are greatly simplified with regard to both sets of reinforcing elements. The use of shallow joists or trusses to form one set of reinforcing elements insures that the correct amount of reinforcement is used and that it is correctly situated, both as to its horizontal position and its lateral spacing. With regard to the relatively transverse reinforcing bars, they are placed across the lower chords of the trusses and are positioned automatically at the designed distance above the formwork. With respect to their horizontal spacing, the fact that the web forming bar of each of the trusses returns to the lower chord at recurring equal distances makes it easy to select sizes of reinforcing bars such that they can be placed in a regular and recurring relation to the spaces between the points at which the web bar returns to the bottom chord. Figs. 1 and 2, for

example, show one bar 14 in each such space 15. Therefore, the correct placing and spacing of the reinforcing bars become easy and, once in place, the correctness of their location is subject to easy visual check and inspection. And it follows that the amount of labor required to place the reinforcing elements is correspondingly reduced over the labor needed for two-way floors which have been used extensively heretofore.

As pointed out previously, it is a highly important aspect and feature of the present invention, and one that is believed to be completely novel in the art, that it permits the successful adoption of light-weight concretes for practical use in the improved two-way floor construction hereof. This becomes possible because the so lightened weight of the floor structure itself is carried by its stressed joists or trusses and the concrete is required to act in the supporting of the later superimposed load only. Owing to the reduced total amount of load which, therefore, is stressing the concrete, the stresses involved in typical loadings occurring for example in buildings designed for human occupancy are well within the permissible values for light-weight structural concrete. The economy and usefulness of such light-weight concretes are due, first, to the economy of the quantity and costs of the materials themselves, and, secondly, to the reduction in the gage of the framework and foundation members permitted by the reduced dead load involved.

Other features and advantages of the present invention could be set forth, but it is thought that they will occur to those skilled in the art and need not be recited herein.

A modification of the invention is shown in Fig. 4, wherein joists in the form of beams 19 having a solid web section 20 are utilized instead of trusses. In this instance, the web 20 is formed or punched immediately above its lower flange 21 with openings 22 to accommodate the reinforcing bars 14, the openings 22 in all the beams 19 in each panel being formed to align so that the bars 14 can be threaded therethrough to extend continuously through the beams 19 between one pair of girders or supports. Except for the solid webs 20 of the beams 19, the structure and arrangement of the parts, and the advantages arising therefrom, will be the same as already described in connection with the preferred embodiment of the invention.

The beam form of joist is shown in Fig. 5 with the beam 19 and reinforcing bar 14 embedded in concrete 16. It will be noted that the openings 22 are punched in the web 20 as close to the bottom flange 21 as is practically possible and that the concrete completely embeds the beam 19 and bar 14, there being a sufficient thickness of concrete above and below the beam 19 to render it fireproof.

In the accompanying drawings, the invention has been shown merely by way of example and in preferred form, and obviously many variations and modifications thereof and in its mode of application may be made without departing from its spirit. For example, and as already stated, there are many different forms of steel joists comprising trusses and beams which are well known and in use in general construction, and which can be employed in the same manner as the trusses and beams shown in the drawings. Also, while the reinforcing bars 14 have been shown as arranged in the spaces 15 in the webs 10 of the trusses 7 regularly one in each space, 75

obviously their order of placement relatively to the trusses can be varied in accordance with the engineering requirements in each instance. There may be occasions too when it will be desirable or convenient to arrange the reinforcing bars below the bottom edges of the joists and tie them thereto. It is also within the spirit of the invention to arrange reinforcing bars between the joists and extending in the same direction as the joists so as to supplement the joists in resisting tensile stresses resulting from loadings superimposed on the panel. Moreover, although the floor panel has been shown and described as defined or bounded by the two pairs of girders, there may be instances where some other form of marginal support, such as a wall, will be provided instead of one or more of the girder members and upon which the end or ends of the trusses will rest. It is to be understood, therefore, that the invention is not limited to any specific form or embodiment, except insofar as such limitations are specified in the appended claims.

Having thus described our invention, what we claim is:

1. A two-way reinforced-concrete flat-ceiling floor construction having one or more generally quadrilateral floor panels, and embodying in each such panel, in combination with a first pair and a second pair of opposite structural supports arranged at the four margins of the panel; a set of laterally spaced apart joists having a substantial resistance to downward deflection and being supported at their opposite ends by said first pair of marginal supports; a set of concrete-reinforcing bars of low vertical dimension relative to that of the joists extending crosswise of all the joists continuously between said second pair of marginal supports and being arranged within the vertical limits of the joists near the lower or tensional side of the panel; and a monolithic slab of hydraulic-cement concrete embedding and bonding with the joists and bars and being co-extensive with the panel and edge-supported by both said pairs of marginal supports; the joists providing the support for the panel and being embedded in the slab of set concrete in the stressed condition to which they are subjected in supporting the load of the panel before the concrete has set, and being adapted also in cooperation with the embedding concrete to sustain and distribute to said first pair of marginal supports a share of a load superimposed on the panel; and the bars being adapted in cooperation with the embedding concrete to sustain and distribute to said second pair of marginal supports the remainder of such superimposed load; whereby the weight of the panel per se is at all times borne by the stressed joists and the concrete is thus relieved of sustaining its own weight, while the load superimposed on the panel is carried by the entire reinforced panel structure acting as a two-way support therefor with the full strength of the concrete available for that purpose.

2. A two-way reinforced-concrete flat-ceiling floor construction as in claim 1, wherein the joists are in the form of steel trusses having each a top chord and a bottom chord connected together by an open web; and wherein the concrete reinforcing bars are arranged above the bottom chords of the trusses in the open spaces of the web.

3. A two-way reinforced-concrete flat-ceiling floor construction as in claim 1, wherein the joists

are in the form of steel trusses having each a top chord and a bottom chord connected together by an open web; and wherein the concrete reinforcing bars are arranged above the bottom chords of the trusses in the open spaces of the web and are wholly supported thereby.

4. A two-way reinforced-concrete flat-ceiling floor construction as in claim 1, wherein the joists are in the form of steel I-beams having each a top flange and a bottom flange connected together by a solid steel web, the webs of all the joists being formed closely above the bottom flanges thereof with apertures located for lateral alignment at correspondingly spaced intervals lengthwise of the webs; and wherein the concrete-reinforcing bars extend through the aligned apertures in the webs.

5. A two-way reinforced-concrete flat-ceiling floor construction as in claim 1, wherein the joists are in the form of steel trusses having each a top chord and a bottom chord connected by an open web, the top chord being of sufficient cross-sectional area to resist the compressive stresses resulting from the weight of the panel slab, and the bottom chord being of sufficient cross-sectional area to resist both the tensile stresses resulting from the weight of the panel slab and the additional tensile stresses resulting from the expected super-imposed load.

6. A two-way reinforced-concrete flat-ceiling floor panel as in claim 1, wherein the joists are in the form of shallow light-weight steel trusses having top and bottom chords connected by an open web which is wholly embedded in and fire-proofed by a shallow concrete slab, and wherein the hydraulic-cement concrete is a light-weight concrete having a density of less than 140 lbs. per cubic foot and an ultimate compressive strength of less than 2000 lbs. per square inch.

7. The method of applying in situ a two-way reinforced-concrete flat-ceiling floor panel of

generally quadrilateral shape between two spaced apart pairs of supports forming a part of a framework and defining the margins of the panel; which method comprises arranging a series of laterally spaced apart and unbridged steel joists of substantial resistance to downward deflection to span the space between one pair of said marginal supports and be supported thereby, said joists constituting one set of concrete reinforcing elements of the two-way panel; providing formwork suspended from the joists and spaced therebelow, arranging concrete-reinforcing steel bars of low vertical dimension relative to that of the joists to extend continuously crosswise of all the joists and at least substantially the entire distance between the other pair of marginal supports, with the reinforcing bars located wholly within the vertical limits of the joists near the lower or tensional side of the panel, and placing on said formwork hydraulic-cement concrete to cover the structure thus assembled and completely fill the area between the two pairs of marginal supports and embed and bond with the joists and reinforcing bars therein, whereby the weight of the panel structure per se and the framework is sustained and distributed through the joists to the one pair of marginal supports by which the joists are supported, the joists becoming embedded in the concrete when the latter has hardened in the stressed condition to which they are subjected in supporting the structure before the concrete has hardened, while the weight of a load superimposed on the finished panel acting as a two-way supporting system is sustained and distributed in part by the joists and in part by the reinforcing bars, both in cooperation with the embedding concrete, to both pairs of marginal supports.

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