This invention relates to connections between metal-reinforced, separately cast concrete structures, e.g., between a pre-cast superstructure that has one or more metal reinforcing rods and the support therefor, such as a foundation, column or girder having similar rods, and to a method of making such connections, viz., of erecting a superstructure on a support, etc. The structures, for example, be parts of a building, such as walls, columns, girders, beams or floor slabs, or may be poles or stanchions for supporting cables, pipes, power lines or the like, columns for elevated roadways or foundations.

Reinforced concrete structures of the type indicated above are frequently of such size or shape as to make it impracticable or uneconomical to cast two or more of them integrally. Thus, it is common to cast a supported structure separately from the support or foundation therefor and to erect or cast the latter as a separate structure at the site of erection and subsequently attach the pre-cast supported structure. This is usually accomplished by affixing mating brackets or bed plates to the pre-cast supported structure and to the supporting structure and connecting the brackets or plates of the two structures by bolting or the like. Such brackets or plates must be preciously leveled to the supporting structure or shims or the like must be employed to position the supported pre-cast structure in the desired, predetermined location and this necessitates some care in the installation of the support and/or the making of the connection. Moreover, to develop the desired tensile stress in the reinforcing rods of the structure entirely to the juxtaposed parts of the structures it is necessary to bond the rods to the brackets or bed plates, which further adds to the cost, especially when precise positioning is required.

It has not heretofore been feasible to join such separately cast structures by merely welding or otherwise connecting projecting reinforcing rods between two spaced structures and then filling the gap between the structures with fresh concrete or grout and permitting the latter to set for the reason that the latter shrinks during hardening, whereby the full strength in compression of the filling material is not developed over the full area of the juxtaposed parts of the structures. This causes non-uniform application of compressive stresses at the connection when the latter is subjected to loading. This is particularly objectionable and causes high localized compressive stresses when the connection is subjected to bending moments, e.g., when a column connected thereby is subjected to a horizontal force applied at some distance above the connection or when a beam having a cantilever connection is loaded. Moreover, in such a connection the metal reinforcing rods are not always adequately loaded to the juxtaposed ends of the structures, preventing early development of the full tensile strengths of the rods; further, this makes it impracticable to pre-stress the rods at the connection, such pre-stressing being desirable in certain installations.

It is an object of this invention to provide an improved connection between separately cast metal-reinforced structures and an improved method of making the same wherein the metal reinforcing rods are connected to develop tensile stress across the connection for anchoring the two parts together, and wherein the full compressive strength of the filling material is developed over the cross sectional area of the juxtaposed parts of the structures which does not require the use of bed plates, brackets, or the like. Ancillary thereto, it is an object to provide an improved connection and method of the type indicated wherein the reinforcing rods may, if desired, be pre-stressed at the connection.

A specific object is to connect a pre-cast, metal-reinforced concrete structure such as a column or the like on a support, such as a foundation, to achieve a secure anchoring of the structure to the support against tilting and afford substantially uniform distribution of compressive stresses over the cross sectional area of the connection without the use of bed plates or the like.

A further object is to provide an improved connection and method of erection of the type described that is more economical and is simply applied in practice to a variety of pre-cast structures.

Still another object is to provide a connection and method of erection whereby the exact location of the pre-cast structure in relation to the support can be adjusted, within limits, to fit the former into the desired conformation to other elements of a composite structure, such as a row of similar structures, a house having several pre-cast walls, or to an elevated roadway supported thereby, obviating the need for extremely precise location of the foundations.

Other objects of the invention will become apparent from the following description.

In summary, according to the invention separately cast concrete structures (for convenience sometimes referred to as the supporting and supported structures, respectively) have initially exposed surfaces adapted to lie in opposed and spaced relation in the completed, composite structure, and each structure has embedded therein one or more metal reinforcing rods that project from the non-exposed surfaces. The supported structure is positioned in relation to the supporting structure with the said surfaces thereof in opposed and spaced relation and brought to the precise desired relative position, e.g., by orientation and leveling, and held in such position. The reinforcing rods, which are preferably located in their respective structures in similar geometric patterns so as to be substantially in alignment when the structures have the desired relative positions, are then firmly connected together, preferably by welding or by clamps, so as to bond each of the rods of the supported structure to one or more rods of the supporting structure to insure the transmission of tensile stress between connected rods. The intervening space or gap between the exposed surfaces is then filled with a suitable load-sustaining filling material that includes a fresh hydraulic cementitious aggregate of the non-shrinking type which hardens to form a firm mass (expanding cementitious aggregates being included among non-shrinking aggregates) to enclose or embed the pre-stressed reinforcing rods and cover the exposed surfaces with the filling material. The hardened, non-shrinking aggregate may optionally be protected by a shroud or coated with a cement wash. The filling material and/or the shroud may be reinforced with metal rods.

The exposed surfaces considered above are advantageously substantially perpendicular to the reinforcing rods and substantially parallel to one another; in the case of a column or wall mounted above a foundation, or a girder supported above a column or wall, the rods are substantially vertical and these surfaces are horizontal; how-
ever, in some embodiments, e.g., when a beam is fixed to a column, girdle or wall, the surfaces may be horizontal, vertical or at some other inclination, and when two floor slabs are united the surfaces are usually vertical. The supported structure may be held in the desired position in relation to the supporting structure by any suitable means such as a derrick, crane, temporary tower, scaffolding or leveling jack that may support the structure during orientation and leveling, or the like, or a combination thereof. The connection between the rods that project from the several structures is advantageously such as to permit loading of the rods throughout their lengths to the full tensile strength thereof. For this reason it is preferred, when welding is employed, to make the rods long enough to overlap throughout the major part of the intervening space between the said exposed surfaces, and to weld the overlapping rods substantially along the full distance of the lap, e.g., for about 6–12 inches in the case of quarter-inch rods and proportional distance for rods of other diameters. Overlapping, though preferred, is not essential, and a separate tie member may be used to connect non-overlapping rods or to strengthen a connection wherein an insufficient overlap occurs.

Considering the filling material in greater detail, it is well known that mortars, grouts, and concrete aggregates, herein generally referred to as ordinary aggregates, when made from usual construction material shrink upon setting. Were such an aggregate employed alone to fill the intervening space between the exposed surfaces of the juxtaposed structures to be connected, the filling material would, after hardening, no longer fill the space completely and bear uniformly against the said surfaces; instead, only parts of the filling material would make contact and, in extreme cases, an actual small gap may result. This prevents a uniform distribution of compressive stresses over the cross sectional area of the surface, and may result in progressive failure, particularly when the connection is subjected to a bending moment. Since the reinforcing rods are in such case either slack or actually in compression (e.g., when the supported structure is resting on a supporting structure beneath it) they do not function to anchor the supported structure securely to the supporting structure, and an undesirably large relative motion between the structures may result from the application of a force of a given magnitude to the supported structure. For example, when the supported structure is a column resting on a foundation and a lifting force is applied to the column, a definite lifting movement would occur in the column before the rods at the side of the column from which the force acts are sufficiently stressed to counteract the resulting bending moment.

Now, according to the invention, this difficulty is overcome by using for at least a part of the load-sustaining filling material a special hydraulically cementitious aggregate, known per se, which is non-shrinking, i.e., which at least maintains its volume during setting and hardens to form a firm mass. Such an aggregate may have the property of maintaining its volume substantially unchanged during setting, but preferably is of the expanding type, whereby the reinforcing rods are placed under slight or considerable tension during the setting. The welded or otherwise connected rods may be optionally loaded slightly in tension prior to filling the intervening space by adjustment of the leveling device, or by other means exerting a force tending to separate the said surfaces. It is not necessary, particularly in the latter case. It is preferred to employ the non-shrinking cementitious aggregate only for a part of the load-sustaining material, as by filling up the greater part of the aforementioned intervening space with solids or ordinary concrete (which may be of the shrinkage type) leaving a smaller space into which the non-shrinking aggregate is tamped after the previously emplaced concrete has hardened. By this preferred method the expansion of the latter aggregate can cause only a small tensioning of the reinforcing rods, insufficient to destroy the bond of the latter to their respective structures or to the major part of the load-sustaining material. This feature is useful in that it permits the use of aggregate that is definitely of the expanding type without a very precise control of the amount of expansion, because mixtures that do not either expand or contract or those that expand to accurately specified limits are more difficult to control at the construction work. In certain instances, as where the said exposed surfaces are vertical, this preferred method involves the inconvenience of placing a vertical spacer board adjoining one of the exposed surfaces to fill part of the gap while the remaining, major part of the gap is filled with ordinary concrete and subsequently removing the spacer board and filling the resulting thin gap with expanding aggregate; in this case recourse may be had to an alternate method, wherein the entire gap is filled with an aggregate of the same composition, the content of the expanding cement or expanding aggregate thereof being more carefully controlled to avoid excessive expansion.

In the resulting structure the welded rods are preferably under tensile stress while the load-sustaining material between the surfaces of the support and the precast structure is under compressive stress. This load-sustaining material, being a body of cohesive aggregate, i.e., hardened cementitious aggregate, extending continuously between the said surfaces. In other words, the filling material is thus loaded without interposing a wedge, screw or the like.

The invention will be described in greater detail with reference to the accompanying drawings forming a part of this specification and illustrating certain preferred embodiments, wherein:

Figure 1 is an exploded elevation view showing the elements used for making the connection;
Figure 2 is a horizontal sectional view taken on line 2–2 of Figure 1;
Figure 3 is an isometric view of the completed structure;
Figures 4–7 are vertical sectional views through a foundation and lower part of a column showing successive stages of the method of erection;
Figure 8 is a vertical sectional view taken on line 8–8 of Figure 9 showing a modified connection applied for connecting a beam to a wall;
Figure 9 is an elevation of the connection according to Figure 8;
Figure 10 is a sectional view through a further modification showing a beam connected to a vertical surface of a wall or column;
Figure 11 is an elevation view showing an alternate connection between reinforcing rods;
Figure 12 is a sectional view taken on line 12–12 of Figure 13 showing a further application of the invention for joining concrete floor slabs that are cast separate from supporting columns;
Figure 13 is a sectional view taken on line 13–13 of Figure 12;
Figure 14 is a sectional view of a modified construction wherein the floor slabs are cast integrally with the beams and the invention is applied for joining adjacent slabs;
Figure 15 is a sectional view showing the invention applied to connecting a floor beam to a girder taken on line 15–15 of Figure 17;
Figure 16 is a sectional view taken on line 16–16 of Figure 15; and
Figure 17 is a fragmentary plan view, on a reduced scale, of the construction according to Figures 15 and 16.

The invention will be illustrated in Figures 1–7 by way of example as applied to the erection of a double stand-on for supporting pipes and the use of an internal leveling device will be shown; however, it will be under-
stood that other types of structures, as previously indicated, and other types of leveling devices, such as externally applied jacks or towers, fall within the scope of the invention.

Referring to the drawings, Figures 1–3, 10 and 11 are concrete foundations which may be bell-bottom footings located entirely beneath the ground level 12 having flat, upper exposed, horizontal surfaces 13. A double stanchion 14 has a pair of columns 15 and 16, each of which has a lower, exposed, horizontal terminal surface 17. The stanchion is prefabricated of concrete prior to erection and has suitable metal reinforcing rods of which only the rods 18 are shown. These rods are embedded in the concrete and project downwardly beneath the surface 17. Any suitable number, e.g., four, of such projecting rods arranged as a rectangle may be used on each column.

Each footing has a corresponding number of, viz., four, vertical reinforcing rods 19 firmly embedded therein and projecting upwardly beyond the surface 13 at locations to be substantially in alignment with corresponding rods 18, i.e., in juxtaposition thereto, when the corresponding column is placed in position above the footing as indicated in Figures 1 and 4–7. The proper relationship of the reinforcing rods 18 and 19 can be obtained by the use of wooden templates that position the rods prior to and during the casting of the concrete. A plurality of shorter vertical reinforcing rods 20 are optionally, although preferably, embedded in each footing so as to project upwardly above the upper ends of the rods 19 at positions outside of the rectangle defined by the rods 19 and laterally beyond the columns 15 and 16, as shown in Figure 2. A suitable leveling device may, if desired, be embedded in each footing; thus, a hollow tube 21 may be embedded at the central axis and project upwardly above the surface 13. The leveling device further includes an externally threaded tube 22 adapted to have a sliding fit within the tube 21 and having an enlarged bearing plate 23 at the top. A nut 24 is threaded on to the tube 22 and is wide enough to engage the upper edge of the tube 21; it may be provided with lugs 25 for receiving a spanner wrench.

To make the connection the stanchion 14 is erected to position the columns 15 and 16 over the footings 10 and 11 by means of a suitable derrick (not shown) with the surfaces 13 and 17 in opposition and in vertically spaced relation so as to leave an intervening space of convenient height, such as twelve inches. The subsequent operations will be described with reference to Figures 4–7 in which only one of the footings on columns is shown. It will be understood that both conditions are made simultaneously and in the same manner. As shown in Figure 4, the stanchion is first placed on the plate 23 so as to be supported thereby, and is leveled by adjusting the nut 24 to bring the surface 17 to the desired elevation; leveling of a stanchion in a direction transverse to the vertical plane joining the two footings is also effected, using an external support, not shown. When the stanchion is properly positioned each rod 18 is next to a corresponding rod 19; if necessary, these rods are bent slightly to bring them into contact.

The contacting rods are then welded continuously as indicated at 26. It will be noted that the reinforcing rods 20 extend above the surface 17. It is advantageous to make the cross sectional area of the weld equal to that of one reinforcing bar.

Referring to Figure 5, an annual reinforcing tie rod 27 is attached to the welded vertical rod and a second annular reinforcing tie rod 28 is attached to the lower portions of the rods 20. These annular reinforcing rods, although preferred, are optional.

A form 29 is then built around the rods and concrete 30 is poured into it to a level "A" slightly below the surface 17, thereby leaving a free space which may suitably have a height of one to several inches.

Referring to Figure 6, when the concrete 30 is dry and has completed substantially all of the shrinkage that accompanies setting, a hydraulic cementitious aggregate of the type that does not shrink upon setting, such as dry grout 31, is placed into the space immediately beneath the surface 17. It is preferable to roughen the upper surface of the concrete 30 and the surface 17 prior to introducing the grout. By dry grout is meant a fresh mixture of fine aggregate and hydraulic cement containing only enough water to permit setting but insufficient to form a plastic mix. The cement should consist of or contain ingredients that prevent shrinkage upon setting or which, preferably, cause a slight degree of expansion upon setting. Such ingredients are metallic aggregates having the quality of expanding in volume during the setting and curing stages, forming a void-filling staple ingredient that is insoluble in water. They may contain iron particles or iron in the ferrous form which oxidize during setting, and may include an alkali to cause oxidation. An example of such an ingredient is "Embeco" described in "The Action of Embeco in Concrete and Mortars," published by The Master Builders Company, Cleveland, Ohio, 1935. The grout should be tamped and hammered to pack it carefully and to fill all voids. The cementitious aggregate 31 is then permitted to set and expand to form a firm mass, thereby applying an slight tensile stress to the welded vertical rods 18 and 19. Although the preferred use of two bodies of filling material 30 and 31 was described it is evident that the expanding or non-shrinking aggregate 31 may in some instances be used to fill the entire space between the surfaces 13 and 17. If desired, the welded rods can be tensioned slightly prior to filling the space between the surfaces 13 and 17, e.g., by turning the nut 24 on the leveling jack. This is particularly advantageous when the grout is of the type that does not either shrink or contract appreciably during setting, and may be used to form a pre-stressed connection.

Referring to Figure 7, after the concrete or grout 31 has set for about ten hours a third annular reinforcing tie rod 32 may be attached to the rods 29 near their upper ends. The form is then extended by adding a section 33 and concrete 34 is poured around the edges of the concrete 31 and the lower side portions of the column 15 to form a protective shroud for the grout. After setting, the forms are stripped resulting in a structure having the appearance indicated in Figure 3.

Any difference in color between the dry grout 31 and the surrounding concrete areas can be remedied by applying a suitable cement wash to the surfaces concerned after the grout is thoroughly dry; this makes the application of the protective shroud 34 unnecessary in many cases.

Referring to Figures 8 and 9, a reinforced concrete wall 40 has vertical reinforcing rods 41 embedded therein and suitably bonded thereto. The wall has a rectangular, upwardly open notch 42 having a width sufficient to receive a reinforced concrete beam 43 and a depth considerably greater than the depth of the beam so as to leave an interval between the bottom surface 44 of the notch, which constitutes the supporting surface of the wall and the lower exposed supporting surface 45 of the beam. The reinforcing rods 41 project upwardly from the surface 44 to a height slightly below that of the surface 45. The beam 43 has a plurality, e.g., four, reinforcing rods 46 embedded therein and projecting vertically downwardly from the surface 45, thereby being one rod 41. Some of these rods may, if desired, be integral with the lower longitudinal reinforcing rods 47 of the beam, while others may be inclined as shown at 46a to transmit shear, and extend horizontally to their ends, indicated at 46b. They may, if desired, be fixed to the upper reinforcing rods 47a.

In making the connection the pre-cast beam 43 is placed into the notch 42 and supported and leveled precisely, both longitudinally and transversely, with the surfaces 44.
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7 and 45 in spaced relation to leave an intervening space; the leveling device in this case may be an external jack, indicated diagrammatically at 48. Each rod 41 is then welded to a corresponding rod 46, as indicated at 49, and a layer of concrete 50 is cast to fill the major part of the intervening space. When this concrete has set and complete physical shrinkage, the upper and lower surfaces of the remaining space are roughened and a layer of non-shrink ing aggregate, such as dry grout 51, which is preferably of the expanding type, is tamped into this space and permitted to set to form a firm mass. It is evident that suitable forms, as previously described, as well as reinforcing rods may be used for the concrete 50 and aggregate 51. In this case, however, a cement wash would be preferred to the concrete shroud. The space between sides of the beam 43 within the notch 42 may be grouted, using grout similar to the grout 51 or ordinary grout.

Referring to Figure 10, there is shown a connection to a wall 69 that provides a vertical surface 61, and may extend above the top of the horizontal beam 63 to be supported thereby. This embodiment illustrates the application of the invention to the case wherein the exposed surfaces are vertical and the connected reinforcing bars are horizontal.

The wall 60 has embedded therein horizontally projecting metal rods 63 which are firmly bonded to the wall, e.g., welded to the upright metal reinforcing rods 64 of the wall and/or provided with large heads 65; the rods 63 may be made integral with the upright rods 64 and curved in the manner previously described for the bars 46 and 47 in Figure 8. The projecting rods 63 are arranged in a geometric pattern similar to that of the longitudinal reinforcing rods 66 of the beam, the latter rods projecting horizontally beyond the vertical, initially exposed terminal surface 67 of the beam; thus, four rods 63 and four rods 66, situated at the corners of a rectangle, may be used. The wall further has a shoulder or hatch 60 cast integrally therewith and provided with metal reinforcing rods 69 and 70. The beam 62 may have reinforcing rods 71 with inclined portions, as shown, to improve transmission of shear.

In making the connection the beam may be supported in various ways: according to one method it is supported and leveled precisely by means of a jack 48, independently of the hatch 68, leaving a small gap between the latter and the beam. The surfaces 61 and 67 of the wall and beam are thereby placed in perfectly spaced and horizontally spaced relation. Each horizontally projecting rod 63 is then welded to a corresponding horizontally projecting rod 66, as indicated at 72. The intervening space between the surfaces 61 and 67 and the space between the hatch and the bottom of the beam are then filled with fresh dry grout 73 of the non-shrinking type and, preferably, of the expanding type, which hardens into a firm mass, the grout being well tamped into position and retained by suitable forms, not shown. The grout, when of the expanding type, may cause a rise in the height of the beam but this is negligibly small because the layer of grout beneath the beam is quite thin. Expansion of the grout places the rods 63 and 66 under tension. Since the entire space between the surfaces 61 and 67 is, in this embodiment, filled with grout of the same composition, it is desirable to control the amount of the expanding ingredient of the grout to avoid excessive expansion such as would tension the rods sufficiently to destroy their bonds to the wall and beam. According to another method, the beam 62 may be placed directly on the hatch 68 without the leveling jack; the other operations are as described above, except that no grout is placed beneath the beam. With this method it is not possible to adjust the exact height of the beam independently of the hatch.

As was stated above, the projecting rods of the several juxtaposed structures may be connected by means other than welding. An alternative means suitable for use in areas wherein welding is not permissible, is disclosed in Figure 11, showing separately cast structures 75 and 76, having projecting reinforcing rods 77 and 78 respectively. When these structures are placed in the desired relative positions, the rods are secured by means of clamps 79 and 80, each comprising a U-bolt 81, a wire rope clip 82 and a pair of nuts, of which only the nut 83 is visible in the drawing. The connection may also be applied to connecting separately cast concrete slabs which may or may not have integral supporting beams.

Referring to Figures 12 and 13, which show the application of the invention to the joining of floor slabs that are separate from their supporting beams 43 that may be disposed in parallel relation and supported in any manner, e.g., in notches in walls such as the wall 40 as previously described for Figures 8 and 9, by welding the terminal, vertical parts of the horizontal reinforcing rods 47 and 47a of the beams at 49 to vertical rods of the wall and filling the interval with concrete 50 and expanding grout 51. In addition to the horizontal reinforcing rods 47 and 47a the beams have projecting right stirrups 84 that extend above the beams at the center line and have their upper, horizontal traverses spaced above the beam by a distance less than the thickness of the floor slab to be supported. The floor slabs 85, 85a and 85b, are cast separately from the beams and wall and have widths great enough to span the interval between adjacent beams 43 but less than the center-to-center distance between such beams, so as to leave horizontal intervals between the vertical marginal surfaces of each pair of juxtaposed slabs resting on the same beam. The floor slabs carry suitable horizontal metal reinforcing rods 86 at a suitable level, e.g., about a third of thickness above the bottom. Reinforcement may also be provided at a higher level as indicated at 87 by providing additional reinforcing rods or by bending some of the rods 86 up near the lateral margins. At least some of these rods project horizontally beyond the marginal surfaces of the slabs for distances sufficient to provide overlap between opposed rods on the juxtaposed slabs.

In assembling the slabs, the latter are first placed on the beams 43 with the margins in supporting engagement thereon and the stirrups 84 are connected to the reinforcing rods 86, preferably by welding. The opposed reinforcing rods 87 and 87a of the juxtaposed slabs are then connected, e.g., by welding as indicated at 88. Dry grout of the non-shrinking type, preferably the expanding type, is then tamped into the interval between the slabs as shown at 89 and allowed to set to form a firm mass thereby effectively loading the bars 86 and 87. The completed connection is able to transmit bending moment, i.e., the upper rods 87 are loaded in tension and the lower part of the grout 89 is loaded in compression; for this reason the connection between the lower reinforcing rods 86 could be omitted under certain design loading conditions. At the center of the span between beams the slabs are subjected to a bending moment in the opposite sense, and inflection points occur between the center and the margins of the slab. It may be stated, however, that the invention is not strictly limited to cases wherein the reinforcing rods 86 and 87 are provided at different levels; in some floor slabs, rods are provided only at one level, sometimes near the mid-level, and the connection according to the invention is also applicable to joining such slabs.

Referring to Figure 14, showing the invention applied to the joining of separate floor slabs that are cast integral to the beams, the floor slabs 90 project laterally to both sides of their beam portions 91, the latter being supported in any manner, e.g., in the wall 40 as described above for the beams 43. The combined beams and floor slabs carry suitable longitudinal reinforcing bars 95 of which only the rods 92 are shown, and transverse reinforcing bars 93 that are preferably below the mid-level of the
slab and may extend downwardly into the beam portions and anchored therein, as shown. The structures may be further reinforced with reinforcing bars 94 at a higher level above the beam portions for transmitting shear and to strengthen the structure for carriageway loading. The bars 93 project beyond the vertical marginal surfaces 95 of the slabs and the beam portions are mounted in spaced relation so that the vertical surfaces 95 of juxtaposed slabs are spaced apart, with the bars 93 of the respective slabs overlapping.

For connecting the floor slabs the projecting opposed bars 93 of the juxtaposed slabs are first firmly connected, e.g., by welding as shown at 96. The gap between the surfaces 95 is then filled with non-shrinking, preferably expanding, grout as indicated at 97, a suitable form (not shown) being provided. When the grout hardens to form a firm mass the interval between the surfaces 95 is filled completely and, when expanding grout is used, the rods 93 may be loaded slightly in tension. The conjoined slabs are thereby adapted to be subjected to a bending moment such that the upper part of the slab is in compression.

Referring to Figures 15–17, a reinforced concrete girder 100 is used to support the intermediate parts of a series of parallel, separately cast, reinforced concrete beams 101, 102, it being understood that the beams are additionally supported by walls or by other girders, not shown, extending parallel to the girder 100. The girder 100 may be supported in any suitable manner on columns or the like, e.g., on haunches 103 projecting from a wall 104. Separately pre-cast reinforced concrete floor slabs 105, 107, extend between adjacent beams or between the wall 104 and a floor beam.

The beams have central tongues or ridges 101a, 102a, extending the full lengths of the beams and shoulders 101b, 102b, on both sides of the ridges for supporting the slabs. Similarly, the wall 104 has a tongue or ridge 104a at the outer side thereof, leaving a supporting shoulder 104b. The slabs rest on these shoulders and are positioned by the ridges; they have suitable metal reinforcing rods 106, 109, extending across the span and passing through the beam and wall, respectively. The point of novelty in this construction resides in the connection between the girder and beams.

The girder 100 has the upper part thereof notched as indicated at 110, Figure 15, at each crossing of a beam while each beam 101, 102, etc., has the lower part thereof notched as indicated at 111, Figure 16, at each girder. Vertical thrust is transmitted through the plane of contact 112 between the bases of the notches. As seen in Figure 15, the notches 110 need not be made substantially longer (along the length of the girder) than the width of the beam, and they are usually made only large enough to permit the beams to be inserted without binding into aligned notches on a number of girders. The notches 111 on the beams are, however, longer (along the length of the beam) than the width of the girder. The depths of these notches are such that the shoulder 101b of each beam is at about the level of the top of the girder. The girder carries suitable metal reinforcing rods, such as longitudinal rods 113 and 114. Beneath each notch the girder has transverse metal reinforcing rods 115 embedded therein and projecting laterally beyond the beams of the girder, the overall lengths of the rods 115 being slightly less than the total width of the notches 111 in the beams. These rods 115 may be fixed, e.g., welded, to the rods 113. The beams carry longitudinal reinforcing rods 116 and 117, the latter being at the level of the notches 111 and almost in alignment with the rods 115 so as to be in touching, side-by-side relation. As shown in Figure 16, the rods 117 project into the notch 111 so as to overlap the rods 115. Some of the rods 117 may be bent up over the notch, as indicated at 117a. The rods 116 and 117 may be connected by looped rods 118.

In assembling the structure, the girders 100 are first placed and the beams 101, 102, are fitted with the notches in interlocking relation and the projecting rods 115 in overlapping relation to the projecting rods 117. The overlapping rods are then firmly connected, e.g., by welding as shown at 119. Dry grout 100 is then deposited over the projecting ends, or preferably, of the connecting type is then tamped into the space between the beam and girder surrounding the connected rods to fill the notch 111 and allowed to set to form a firm mass. A suitable form, not shown, may be provided for this operation. The notch 110 may be similarly filled with grout while maintaining slabs 105–107 are then placed on the beams and wall, secured by any conventional or suitable means, such as hold-down bolts (not shown), and the spaces between the slabs and the ridges are filled with grout, as indicated at 121. The slabs may, of course, be attached by the arrangement shown in Figures 12 and 13, in which case the beams would have flat upper surfaces. The grout 120, when hardened, effectively loads the lower portions of the beams in compression, thereby better adapting the beams for sustaining loads that subject it to bending moments at the girders in which the lower parts of the beams are loaded in compression.

I claim as my invention:

1. Method of making a connection between two separately cast concrete structures each of which has embedded therein metal reinforcing rods projecting outwardly from a surface thereof, comprising the steps of: positioning the said pre-cast structures with the said surfaces thereof in opposite and spaced relation so as to leave a free intervening space; firmly securing each rod projecting from one of the structures to a rod projecting from the other structure to form for each rod a connection adapted to transmit tensile stress thereafter maintaining the interval between said surfaces so as to hold the connected rods tautly and filling the said intervening space completely between the said surfaces with a load-sustaining material that consists essentially of a hydraulic cementitious aggregate of the type that contains expanding cement in amount at least to maintain its volume against the setting and hardens to form a firm, essentially non-elastic mass; and allowing the said hydraulic cementitious aggregate to set, whereby the portions of said connected rods between said surfaces are secured tautly after setting.

2. Method according to claim 1 wherein said surfaces are positioned to effect an overlap between the oppositely projecting rods over the major part of the distance between said surfaces and the rods are secured by welding along substantially the full length of the overlap.

3. Method according to claim 1 wherein the step of filling the intervening space includes the following operations: filling the major part of said space with concrete that hardens to form a firm, essentially non-elastic mass and leaving a small clearance immediately adjacent one of said surfaces; allowing said concrete to set; and thereafter tamping a dry grout into said small clearance, said dry grout consisting essentially of the hydraulic cementitious aggregate defined in the said claim.

4. In combination with the steps of the method according to claim 3, the step of placing a concrete shroud about the grout.

5. In combination with the steps of the method according to claim 1, the step of moving said pre-cast structures slightly apart after securing the rods and prior to filling the intervening space with the load-sustaining material to apply tension to the connected rods, and maintaining said tension until after the said hydraulic cementitious aggregate has set.

6. Method of making a connection between two separately cast concrete structures each of which has embedded therein metal reinforcing rods projecting outwardly.
from a surface thereof, comprising the steps of: positioning the said pre-cast structures with the said surfaces thereof in opposite and spaced relation so as to leave a free intervening space; firmly securing each rod projecting from one of the structures to a rod projecting from the other structure to form for each rod a connection adapted to transmit tensile stress; and thereafter filling the said intervening space completely between the said surfaces thereof with a load-sustaining material that includes a hydraulic cementitious aggregate of the type that expands during setting and thereby applies a tension to the connected rods and maintains said tension after setting.

7. Method of erecting a pre-cast concrete structure on a concrete support, said structure having embedded therein metal reinforcing rods projecting from a surface thereof and the support having embedded therein metal reinforcing rods projecting beyond an opposed supporting surface thereof, comprising the steps of: positioning the pre-cast structure in relation to the support with the said surfaces thereof in opposite and spaced relation so as to leave a free intervening space; firmly securing each rod projecting from the structure to a rod projecting from the support to form for each rod a connection adapted to transmit tensile stress; thereafter maintaining the interval between said surfaces so as to hold the connected rods tautly and filling the said intervening space completely between the said surfaces thereof with a load-sustaining material that includes a hydraulic cementitious aggregate of the type that contains expanding cement in amount at least to maintain its volume against shrinkage during setting and hardens to form a hard, essentially non-plastic mass; and allowing the said hydraulic cementitious aggregate to set, whereby the portions of said connected rods between said surfaces are secured tautly after setting.

8. Method of erecting a pre-cast concrete structure on a concrete supporting base, said structure having embedded therein metal reinforcing rods projecting downwardly beneath a downwardly directed surface thereof and the base having embedded therein metal reinforcing rods projecting upwardly beyond an upwardly directed supporting surface thereof, comprising the steps of: positioning the pre-cast structure above the base with the said surfaces thereof in opposite and vertically spaced relation so as to leave a free intervening space; firmly securing each rod projecting from the structure to a rod projecting from the base to form for each rod a connection adapted to transmit tensile stress; and thereafter filling the said intervening space completely between the said surfaces with a load-sustaining material that includes a hydraulic cementitious aggregate of the type that expands during setting and thereby applies a tension to the connected rods and maintains said tension after setting.

9. Method of connecting a horizontal pre-cast concrete beam having a substantially vertical surface to an upright concrete support having a substantially vertical surface, said beam having embedded therein metal rods projecting horizontally beyond said surface thereof and said support having embedded therein metal reinforcing rods projecting horizontally beyond said surface thereof, comprising the steps of: positioning the beam in relation to the support with the said surfaces thereof in opposite and horizontally spaced relation so as to leave a free intervening space; firmly securing each rod projecting from the beam to a rod projecting from the support to form for each rod a connection adapted to transmit tensile stress; and thereafter filling the said intervening space completely between the said surfaces with a load-sustaining material that includes a hydraulic cementitious aggregate of the type that expands during setting and hardens to form a firm, essentially non-plastic mass; and allowing the said hydraulic cementitious aggregate to set, whereby the portions of said connected rods between said surfaces are secured tautly after setting.

10. Method of connecting in juxtaposition separately cast concrete floor slabs that have embedded therein metal reinforcing rods projecting horizontally beyond the adjacent marginal surfaces of the slabs, comprising the steps of: positioning the pre-cast structures in relation to one another to place said marginal surfaces in opposed and horizontally spaced relation so as to leave a free intervening space; firmly securing each rod projecting from one of the floor slabs to a rod projecting from the other floor slab to form for each rod a connection adapted to transmit tensile stress; and thereafter filling the said intervening space between said surfaces so as to hold the connected rods tautly and filling the said intervening space between the said surfaces with a load-sustaining material that includes a hydraulic cementitious aggregate of the type that contains expanding cement in amount at least to maintain its volume against shrinkage during setting and hardens to form a hard, essentially non-plastic mass; and allowing the said hydraulic cementitious aggregate to set, whereby the portions of said connected rods between said marginal surfaces are secured tautly after setting.

11. Method of connecting a pre-cast concrete beam to a separately cast supporting girder member extending transversely thereto at the intermediate parts of said members, at least one of said members having a notch that is materially longer than the width of the other member, said one member having reinforcing rods embedded therein horizontally and longitudinally into said notch from opposite ends thereof and said other member having a transverse reinforcing rod projecting laterally from the sides thereof, comprising the steps of: positioning said beam member on and transversely to said girder member for support thereby with said other member at least partly within said notch so as to leave an intervening space within the notch on each side of the said other member; firmly connecting each longitudinally projecting rod to a laterally projecting rod to form for each rod a connection adapted to transmit tensile stress; maintaining the intervals between the sides of said other member and the ends of the notch so as to hold the connected rods tautly and filling the said intervening spaces about the connected rods completely between the end of the notch and the side of said other member with a load-sustaining material that includes a hydratable and expansive cementitious aggregate of the type that contains expanding cement in amount at least to maintain its volume against shrinkage during setting and hardens to form a firm, essentially non-plastic mass; and allowing the said hydraulic cementitious aggregate to set, whereby the portions of said connected rods within said load-sustaining material are secured tautly after setting.

12. Method of connecting a pre-cast concrete beam to a separately cast supporting girder at the intermediate parts of the beam and girder, said girder having an upwardly open notch of a length materially in excess of the width of the girder, said beam having a longitudinal reinforcing rod embedded therein and projecting longitudinally into the lateral notch from at least one end thereof and said girder having a transverse reinforcing rod projecting beyond a side of the girder beneath the said notch therein, comprising the steps of: positioning said beam on the girder transversely thereto with the said notches in interlocking relation for support of the beam between bases of the notches with the said reinforcing rods in juxtaposition so as to leave an intervening space within said notch of the beam on each side of the girder whereas a reinforcing rod projects; welding each longitudinally projecting rod of the beam to a laterally projecting rod of the girder; and thereafter filling the said intervening space completely between the end of the notch and the side of the girder with a load-sustaining material that includes a hydraulic cementitious aggregate of the type that expands during setting and hardens to form a firm, essentially non-
plastic means and thereby applies a tension to the connected rods and maintains said tension after setting.

13. The combination uniting separately cast, metal-reinforced concrete structures which comprises: a first and a second pre-cast concrete structure, each said structure having a bounding surface and the said bounding surfaces of the structures being situated in opposed and spaced relation, each of said structures having a plurality of metal reinforcing rods embedded therein and projecting beyond said surface thereof towards the other structure; a firm connection between each of the said reinforcing rods projecting from one structure and a reinforcing rod projecting from the other structure adapted to transmit tensile stress; and a firm, essentially non-plastic and cohesive, load-sustaining material consisting essentially of hardened hydraulic cementitious aggregate which contains hardened expanding cement extending continuously between said surfaces and surrounding the said projecting rods and the said connections thereon, said material being under compressive stress and said connected projecting reinforcing rods being under tensile stress.

14. A combination according to claim 13 wherein said pre-cast concrete structures are concrete floor slabs, said terminal surfaces thereof are adjacent lateral marginal surfaces thereof, and said reinforcing rods project horizontally from said marginal surfaces.

15. In combination with the elements recited in claim 14, a support beam having an upwardly projecting metal reinforcing rod embedded therein, the said lateral margins of the two floor slabs being in supported engagement on the said beam on opposite sides of said upwardly projecting rod, the last-mentioned rod being firmly secured to said horizontally projecting rods of the floor slabs, and the said rods of the floor slabs and the said load-sustaining material being all situated above the said support beam.

16. In combination with the elements recited in claim 14, a pair of spaced support beams, each said floor slab being supported at the intermediate part on one of the said beams and projecting laterally beyond said beams, the said adjacent marginal surfaces of the floor slabs are situated between the said support beams.

17. A combination according to claim 13 wherein one of said concrete structures is a girder member and the other is a beam member extending transversely thereto, at least one of said members having a notch that is materially longer than the width of the other member and said other member being situated at least partially within the notch with the sides thereof in spaced relation to the ends of the notch, each end of said notch constituting a bounding surface of the member containing the notch and each side of said other member constituting a bounding surface thereof.

18. The combination uniting a pre-cast concrete girder and a separately pre-cast concrete beam which comprises: a girder having an upwardly open notch at an intermediate part thereof, said notch having a length at least equal to the width of the beam; a beam extending transversely to the girder having a downwardly open notch at an intermediate part thereof and supported from said beam through the bases of the said notches, said notch in the beam having a length which is materially in excess of the width of the girder and extends to each side of the girder; a longitudinal metal reinforcing rod embedded in the beam on each end of the notch and projecting longitudinally into said notch toward the girder; a transverse metal reinforcing rod embedded in the girder beneath the notch and projecting laterally beyond the sides of the girder into the notch in the beam; a firm connection between each said longitudinally projecting rod and said transverse metal rod; and a firm, essentially non-plastic and cohesive, load-sustaining material consisting essentially of hardened hydraulic cementitious aggregate which contains hardened expanding cement extending continuously between each side of the girder and the ends of the notch in the beam and surrounding the said projecting rods and the said connections thereon, said material being under compressive stress.

19. The combination uniting a concrete base and a structure comprising: a pre-cast concrete base having an upwardly directed supporting surface and a plurality of metal reinforcing rods embedded therein and projecting upwardly above said surface; a pre-cast concrete structure supported by said base and having a downwardly directed surface situated in vertically spaced relation above said supporting surface, said pre-cast structure having metal reinforcing rods embedded therein and projecting downwardly below said surface thereof; a firm connection between each said reinforcing rod projecting from the structure to a corresponding reinforcing rod projecting from the base adapted to transmit tensile stress between the rods; and a firm, essentially non-plastic and cohesive, load-sustaining material consisting essentially of hardened hydraulic cementitious aggregate which contains hardened expanding cement extending continuously between said surfaces and surrounding the said projecting rods and the said connections thereon, said material being under compressive stress and said welded rods being under tensile stress.

20. A combination according to claim 19 wherein said downwardly projecting rods are arranged in a pattern corresponding to the pattern of the upwardly projecting rods and each rod is substantially in alignment with the downwardly projecting rod connected thereto, both groups of rods extending sufficiently beyond their respective surfaces to overlap over a major part of the vertical distance between the said surfaces, and said firm connections are weldments extending substantially over the full lengths of the overlapping portions of the rods.

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