Oct. 18, 1960 J. B. HENRY ET AL 2,956,375

PRE-CAST CONCRETE BEAM CONSTRUCTION

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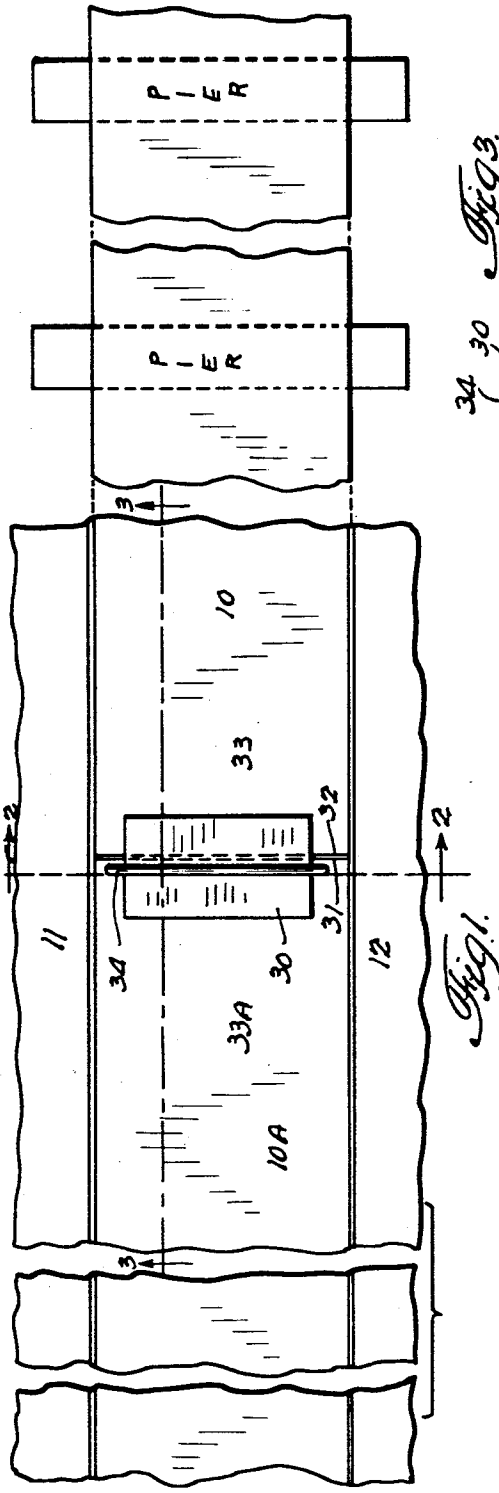


Fig. 1.

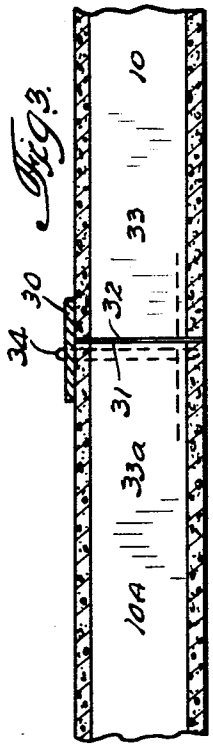


Fig. 3.

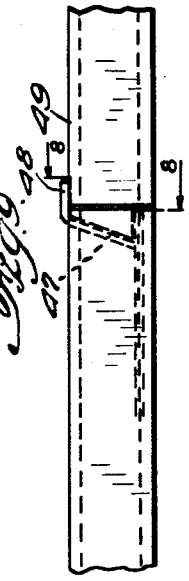


Fig. 4.

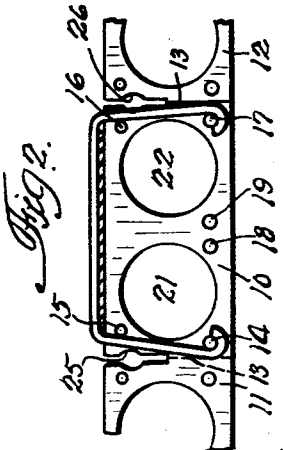


Fig. 2.

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Fig. 4.

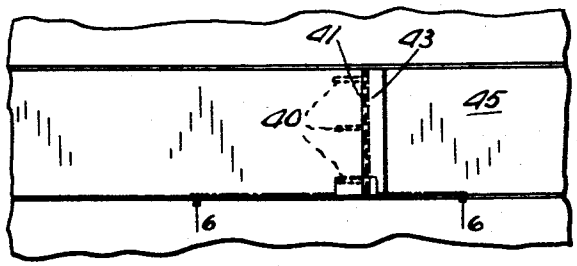


Fig. 5.

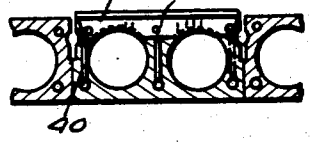


Fig. 6.

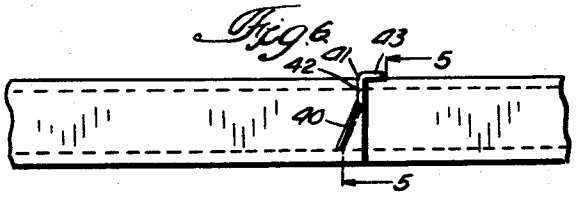


Fig. 8.

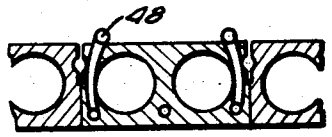
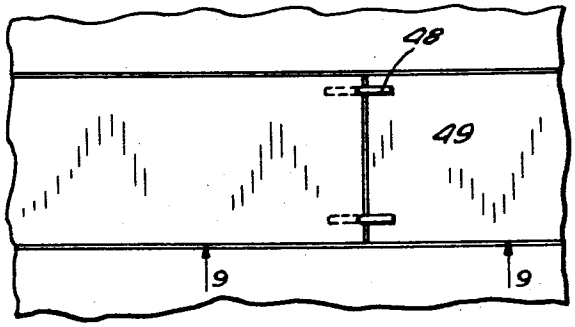


Fig. 7.



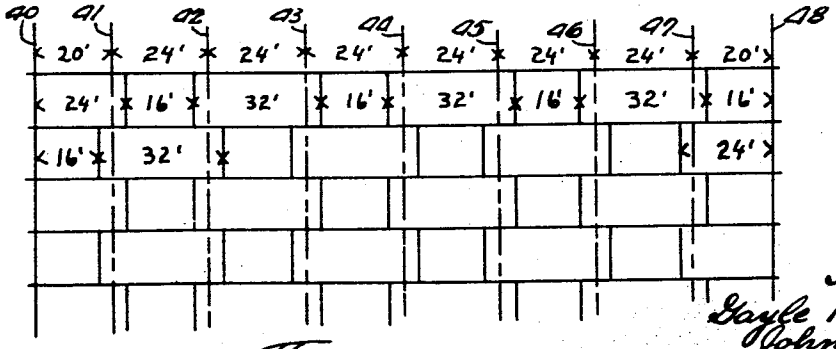


Fig. 10.

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PRE-CAST CONCRETE BEAM CONSTRUCTION

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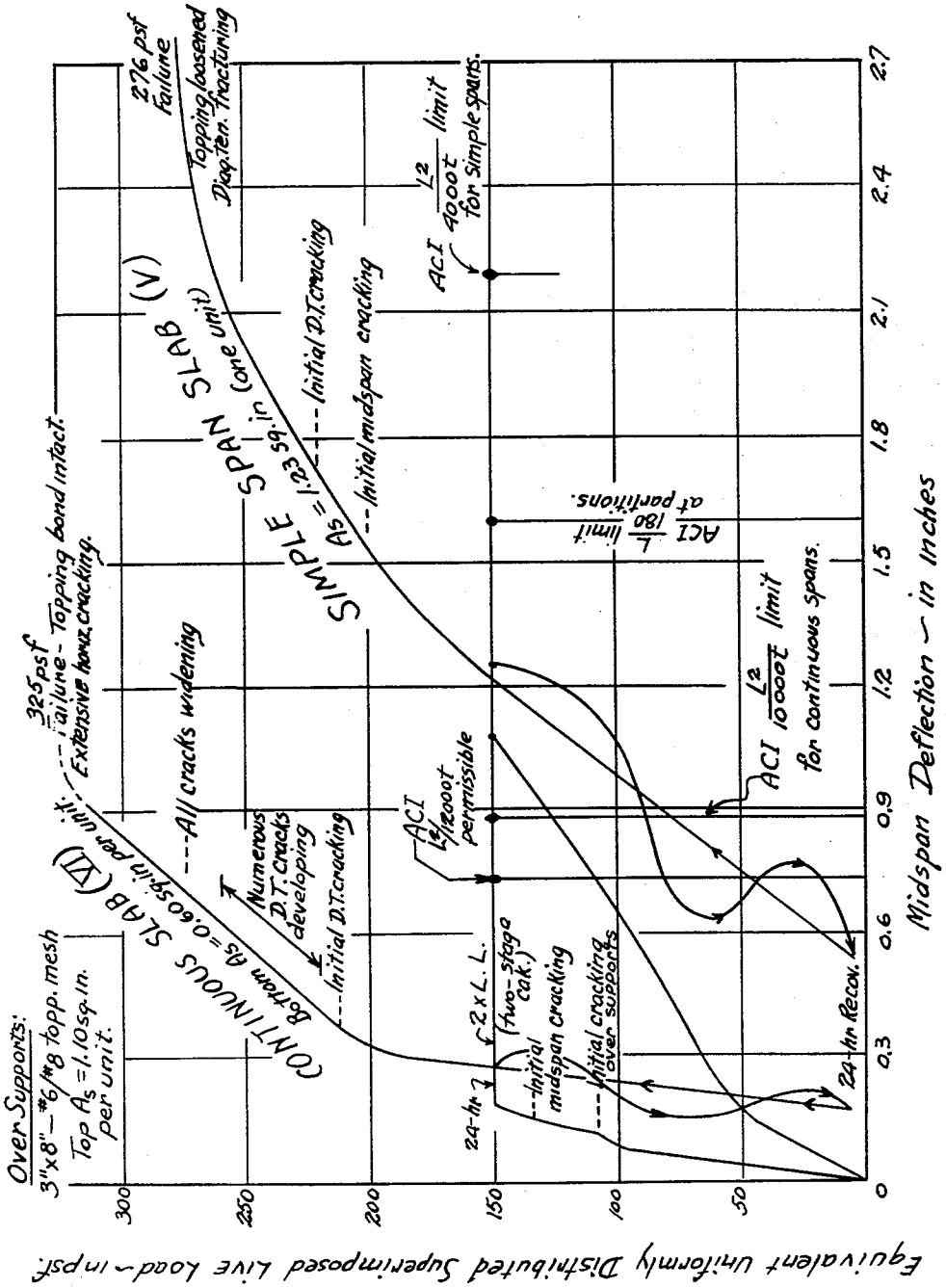


Fig. 11.

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2,956,375

PRE-CAST CONCRETE BEAM CONSTRUCTION

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Filed Aug. 6, 1957, Ser. No. 676,645

4 Claims. (Cl. 50—128)

This invention relates to a pre-cast concrete beam construction and aims to provide pre-cast concrete beams which may be combined in a construction having a smaller deflection for a given load than is true of simple spans.

In general this invention contemplates the use of reinforced pre-cast concrete beams, the beams having adjacent end portions joined together at predetermined portions of the structure to provide continuous beams. The joined ends of the beams are located so that the load transfer from one beam to another occurs at a region of low or zero moment.

An advantage resulting from the use of the invention resides in the saving of steel and the use of relatively short beams to provide a concrete construction which has less deflection or sag between spans than would be true with the use of simple spans extending between fixed supports.

A significant feature of the present invention resides in the manner and means by which load transfer is effected from one beam end to an adjacent beam end. As is well known, a concrete beam, like any other beam, when loaded has a neutral plane separating regions of compression and tension respectively. Since concrete has poor tension characteristics, a principal objective of steel reinforcement in a pre-cast beam is to so locate the neutral plane as to put most of the concrete in the beam in compression under beam load.

In effecting a load transfer from one beam end to another beam end, it is important to insure continuity of load between those portions of the beam ends which are in compression. As examples, the simple use of dowel bars or pins across the ends while perfectly satisfactory for steel and wood is totally unsatisfactory for pre-cast concrete. This is due to the fact that the load transfer results in tension upon the concrete and consequent failure.

In accordance with the present invention, means are provided for joining the various beams forming part of an entire structure in such a manner than an efficient and complete transfer of load from one beam to another is effected. In order that the invention may be understood, various embodiments will be disclosed, it being understood that these embodiments are examples to illustrate the invention and that variations may be made without departing from the scope of the invention as defined by the appended claims.

Referring now to the drawings, Figure 1 is a plan view of a portion of a concrete floor or roof embodying the present invention.

Figure 2 is a section upon line **2**—**2** of Figure 1.

Figure 3 is a section along line **3**—**3** of Figure 1.

Figure 4 is a top plan view of a portion of a structure using a modified form of the invention.

Figure 5 is a section along broken line **5**—**5** of Figure 6.

Figure 6 is a section along broken line **6**—**6** of Figure 4.

Figure 7 is a plan view of still another modified form of the invention.

Figure 8 is a section along broken line **8**—**8** of Figure 9.

Figure 9 is a section along broken line **9**—**9** of Figure 7.

Figure 10 is a diagrammatic plan view of slabs arranged to form a suitable floor construction in accordance with the present invention.

Figure 11 shows some curves illustrating the relative behavior of a simple reinforced concrete slab and a continuous slab construction embodying the present invention.

While various forms of concrete beams or slabs may be utilized in practicing the invention, it is preferred to use the cored reinforced concrete slabs disclosed and claimed in United States Patent No. 2,299,070 and the invention may be disclosed in connection with such reinforced beams.

Referring for example to Figure 2, there are illustrated in section one concrete beam or slab **10** and parts of adjoining slabs **11** and **12**. Inasmuch as the slabs are similar in construction, it is only necessary to describe slab **10** in detail. Slab **10** is of concrete and has longitudinal steel reinforcement at the four corners, these being indicated by numerals **14**, **15**, **16** and **17**. In addition, steel reinforcements **18** and **19** are provided, these being approximately in the center of the lower part of slab **10**.

Slab **10** has longitudinal bores or channels **21** and **22**. As is more fully disclosed in the above identified patent, it is preferred to have the total area of cored portions **21** and **22** bear a certain relation to the total area of the section of the slab. This area relationship is between about 40% and about 50%. For the purpose of the present invention however, this range of ratios may be varied within limits.

Longitudinal reinforcements **14** to **19** inclusive may consist of steel which is tensioned, the slab and reinforcement being so designed that the neutral plane is at or near the bottom face of the slab. The slabs are adapted to be disposed in side by side relation and in order to lock adjacent slabs together, grout keys **25** and **26** are provided along the top side portions of each slab for the full length thereof. As is illustrated in Figure 2, when slabs **10**, **11** and **12** are disposed in side by side relation, channels are provided by the grout keys for holding grout. The grout keys and the grout thus provide a suitable means for locking the slabs along the lengths thereof.

As is well known in continuous constructions, beams are disposed in side by side relation with the ends staggered so that the end of one beam is rigidly attached to an intermediate portion of an adjacent beam and the load transferred from the supported beam at that point to the suspended beam. In concrete slabs, it is necessary to effect this load transfer from one beam to the other without putting the concrete in tension.

As illustrated in Figure 1, beam **10** is a supported slab and beam **10A** is a suspended slab. Laterally disposed of beams **10** and **10A** are beams **11** and **12** which, at the regions illustrated in the drawing, may be considered as supported slabs. By supported slabs is meant that the slabs have at least two spaced points along the length thereof at which the slab is supported on piers or the like with the end extending cantilever style beyond a supporting region. The objective of this is to transfer the load from the end of beam **10** to an adjoining end of beam **10A**. In order to effect this, the opposed beam faces **31** and **32** of the two beams are disposed in prox-

imity to each other and have suitable means to join the beam ends.

Top faces 33 and 33A of the two beams have steel bridge plate 30 extending across the gap between faces 31 and 32. Bridge plate 30 extends over an extensive portion of the transverse dimension or width of beams 10 and 10A. The extent of overlap of bridge plate 30 beyond end faces 31 and 32 of the beams may vary within wide limits but it is preferred that bridge plate 30 extends for a distance of several inches beyond the free ends of the beams.

End 31 of the suspended slab, in this case 10A, has steel stirrup 34 rigidly atttached to steel reinforcing rods 14 and 17. As is indicated in Figure 2, stirrup 34 is of rod or wire and has its ends hooked around and welded or rigidly attached to corner reinforcing rods 14 and 17. Stirrup 34 extends upwardly from the lower corners along the side of the beam within the concrete and across the top of face 33A of the beam outside of the concrete. It will be noted from Figure 3, that stirrup 34 extends enough above top face 33A of beam 10A to provide a clearance region into which bridge plate 30 may project.

It is clear that the end of supported beam 10 does not require any stirrup although this may be provided if necessary. Since beam 10 is supported, there will be a tendency to rock bridge plate 30 upwardly in such a way as to tend to pull stirrup 34 up from beam 10A. A broad area of bridge plate 30 engages the top surface of face 33A of beam 10A and the concrete in beam 10A under plate 30 will be compressed by plate 30. The only part of beam 10A which will be in tension will be stirrup 34 and this will be sufficiently heavy to withstand the loading.

In addition to the above construction, it has been found that grout keys 25 and 26, locking beams 10 and 10A on the one hand to side beams 11 and 12, also tends to impart load transfer characteristics. Bridge plate 30 should be wide enough—this is the dimension along the length of the beam—so that the bridge plate has a large area upon the top face of each end portion of beams 10 and 10A. The concrete will therefore not be subjected to excessive compression.

It is preferred to design the entire structure so that the regions of support for supported slab 10 are so selected along the length of the slab that substantially at the end faces of the beams 10 and 10A the moments will be substantially zero. This may be obtained by properly proportioning the ratio of the portion of the beam extending between fixed supports as piers to the cantilever portion in the supported end of the beam.

As an example, beams having a length of thirty-two feet and sixteen feet respectively may provide a continuous floor supported on piers with twenty-four foot spans. A thirty-two foot beam would be supported at points spaced twenty-four feet apart to leave four feet of cantilever lengths at each end. The sixteen foot beam would be located at a four foot cantilever end so that a sixteen foot beam would be suspended and would not in itself have any pier support.

Referring now to Figure 10, there is illustrated a view of a floor or roof construction embodying the principles of the invention. Piers, walls or other rigid supports have their center lines at 40 to 48 inclusive. Except for end piers 40 and 48, the spans are twenty-four feet between centers. For convenience in using beam lengths, the end spans are twenty feet each. Except for end beams or slabs, slabs alternating in length sixteen and thirty-two feet are used. It will be clear that for intermediate piers, the junction lines between abutting slab ends are four feet beyond the pier center lines. It is only certain of the end spans which have to be twenty-four feet long. The slab lengths in feet are shown in the figure.

The above construction uses less steel than one using simple twenty-four foot spans throughout, except for the end twenty foot spans. As an example, a construction as illustrated in Figure 1 will require five pounds of steel per square foot of floor area for a load of 122 pounds per square foot.

The comparable simple span construction (all slabs are supported) will require 6.65 pounds of steel per square foot for the same loading. In the above comparison, the extra steel required at slab ends for the continuous construction (the bridge plates and steel loops) are disregarded.

A further advantage of the continuous construction is the greatly reduced deflection or sag as compared to simple slab construction where the slabs are all supported. The continuous construction in this example has about 40% of the sag or deflection of the corresponding simple slab construction.

In the above example of continuous construction, the thirty-two foot slabs had prestressed steel in both top and bottom parts of a slab. The sixteen foot suspended slabs had the prestressed steel only in the bottom of the slab, the steel in the top layer being unstressed in the free slab.

Referring now to Figures 4, 5 and 6, a modified construction is illustrated wherein stirrup 40 is rigidly attached to angle irons 41 having portions 42 and 43. Portion 42 of the angle iron is disposed at the end face of the suspended slab and when the slab is cored as shown, it may be necessary or desirable to shape the angle iron portion to conform to the curvature of the concrete. Portion 43 of the angle iron extends over the top face 45 of the supported slab.

Referring to Figures 7 to 9 inclusive, a still further modification is illustrated wherein stirrups 47 are rigidly attached to the bottom reinforcing rods as in the previous modifications. Stirrup 47 however has end portion 48 which extends over the top surface 49 of the supported slab. End portions 48 of the stirrups may be provided with metal plates below them for distributing the compression force over the top surface 49 of the slab.

In the practical application of the invention, the supported slab ends will be suitably anchored to the steel, masonry or other support structure. In the case of steel beams or supports for the slab ends, the end of the concrete slab may overlie a steel web or tie plate and the steel slab reinforcement may be welded to the steel web or tie plate.

It is understood that the slab end constructions illustrated in the various figures may be applied to one or both ends of a slab.

Referring now to Figure 11, some curves illustrating the behavior under test of a simple slab and a continuous slab construction embodying the present invention are shown. The slabs under test are Flexicore slabs generally available on the market and made in accordance with the disclosure of United States Patent No. 2,299,070 insofar as the core passages are concerned.

Both the simple and continuous slabs were tested under increasing loads. The various points on the curve where significant changes occured under load are marked in the figure. Important test points as defined by the A.C.I (American Concrete Institute) are marked. In the figure, L and t must be measured in the same units and refer respectively to the length of the span and thickness of the slab. A_s refers to the area of steel. The failure of the beam under diagonal tensioning (abbreviated to DT) is clearly shown as the loading on the beam increases. The curves illustrate the greater efficiency in the use of steel in a continuous slab construction embodying the present invention.

A continuous slab construction embodying the present invention has far less deflection (sag) than a simple span using the same amount of steel and thus would meet engineering specifications under conditions of cost and deflection where a simple span might fail.

In addition to the above test curves, a greater safety factor is introdced in a slab embodying the present in-

vention by virtue of the grout keys along the slab sides. It has been found that the grout connections between adjacent slab sides tend to distribute the load between supported and suspended slabs to an even greater degree than indicated by the above curves.

What is claimed is:

1. A pre-cast concrete slab construction comprising parallel, laterally spaced rigid supports providing supporting regions lying in a generally horizontal plane, a plurality of pre-cast reinforced concrete slabs supported by said rigid supports, each slab having a length great in comparison to the width or thickness thereof, the slabs being disposed in the finished construction so that all have their lengths transversely across said rigid supports, certain of said slabs being supporting slabs and each having a length greater than the distance between adjacent rigid supports, each supporting slab being disposed to overlie adjacent rigid supports and the end portions thereof extending in cantilever fashion beyond the rigid supports, other slabs being suspended slabs and each having a length too short to reach between adjacent rigid supports, said supporting and suspended slabs being arranged in a pattern to provide a continuous slab construction wherein a suspended slab lies between the ends of longitudinally aligned supporting slabs and between the sides of laterally spaced adjacent supporting slabs, all suspended slabs lying between rigid supporting regions and deriving the entire support from the ends and sides of adjacent supporting slabs, every slab having a generally rectangular cross-section and having flat ends and having the sides thereof adjacent the top face shaped so that adjacent sides of any two slabs are grouted to provide a rigid joint, every slab having hollow longitudinal passages extending the full length thereof, the area of the passages in a slab section constituting between about 40% and about 50% of the total sectional area of the slab, every slab having straight longitudinal steel reinforcement members adjacent the bottom and top corners of the slab and extending straight for the full length of the slab and steel stirrup means for the suspended slabs only rigidly secured to the bottom corner reinforcing members and extending upwardly toward the top face of the slab, each steel stirrup means having support portions just clearing the top slab face and extending longitudinally beyond the end of the suspended slab and overlying the top of the adjacent end of a supporting slab, said entire construction using steel reinforcement so efficiently that, with the same amount of steel reinforcement in an entire construction, slab deflection between rigid support regions is reduced by about 30% compared to a simple span construction having similarly spaced rigid supporting regions whereby said continuous slab construction can use less steel for the same deflection or can reduce deflection with the same amount of steel as compared to a simple span construction.

2. The construction according to claim 1 wherein all the steel reinforcement in the supporting slabs are prestressed and wherein the reinforcing members in the bottom only of the suspended slabs are prestressed.

3. The construction according to claim 1 wherein each slab has an additional longitudinal steel reinforcement adjacent the bottom face but disposed between longitudinal passages and wherein stirrup means are rigidly attached to all of the bottom longitudinal reinforcing members.

4. The construction according to claim 1 wherein an angle iron is rigidly attached to said stirrup means, said angle iron having one part extending across the end face of the suspended slab and having the other part extending away from the end face and overlying the top face at the end portion of the adjacent supporting slab.

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